THE BENEFITS OF MODERN AGRICULTURE

A Reassessment Following Recent Controversies

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Introduction[1]

The global food and agricultural sector faces a tremendous challenge: the FAO has projected that food production must increase 70% by 2050 in order to keep abreast with global population growth and changing diets. At the same time, the sector is confronted with a growing scarcity of arable land and water, and a number of serious environmental problems, ranging from pollution, decreased biodiversity to climate change, to which it has itself contributed. In the face of daunting challenges such as this one, it is perhaps only natural that people are tempted to seek refuge in what they perceive to be straightforward solutions. Some have been drawn to the argument that the solution lies purely in modern advances to continue productivity growth, since food security, after all, is humankind's greatest objective. Others put their faith in a simpler, less modern agriculture, which they feel is more sustainable. In the words of Bill Gates, "on one side is a technological approach that increases productivity. On the other side is an environmental approach that promotes sustainability." Of course these are simplistic caricatures, but the fact is that views about modern agriculture are indeed quite divided.

This paper reviews the impressive global agricultural growth of the past decades. The paper also examines the daunting resource constraints facing the sector, to which the sector has certainly contributed. We see the solution to the challenge facing the sector today neither in a blind pursuit of agricultural productivity, nor in a return to pre-modern agriculture, and argue instead that modern agricultural technology must become more sustainable. Like Bill Gates, we believe that viewing the world exclusively through the productivity or the sustainability lens "is a false choice," one that "blocks important advances" and "breeds hostility among people who need to work together."

The paper also addresses a number of other controversies surrounding modern agriculture. Controversies cannot be resolved as long as some prefer to downplay or ignore them, while others – equally unhelpfully - tend to exaggerate them and fixate on them.

In order to do greater justice to the tremendous variety of agricultural areas and practices, and to highlight some particularly impressive productivity growth rates, the paper provides a number of case studies about specific regions and countries in Annex I. Such case studies also allow us to take a closer look at more location specific controversies engendered by modern agriculture.

For purposes of this paper, we define "modern agriculture" as being directly and explicitly characterized by the adoption of production processes, technologies and tools derived from scientific advances, and results of the research and development process. Modern agriculture is not restricted to large-scale, capital intensive agricultural production. In line with a rich intellectual tradition, we believe that science and technology have much to contribute to the transformation and modernization of traditional agriculture, particularly in developing countries, where literally billions of people depend, totally or largely, on agriculture to ensure their livelihoods. Thus, the economic and social stakes of the modernization of agriculture in many parts of the world are huge.

[1] The assistance and professional contributions of Pascal Tillé in the preparation of this paper is gratefully acknowledged. In addition, heartfelt thanks are given to Charlotte Hebebrand and Christine St. Pierre for their highly professional editorial contribution.

PRODUCTIVITY GAINS

The successes of world agriculture over recent decades, in both developed and developing countries, have been tremendous if one puts them in the context of human history. Only thirty or forty years ago, serious doubts emerged about the ability of mankind to feed itself. Yet in the subsequent decades, world food production increased faster than population growth. This is also the case for developing countries as a whole. Of course, the food riots of 2008 and FAO's reported increase in the number of hungry people from a little over 800 million a few years ago to more than one billion today, suffice to remind us that global production trends are not sufficient to capture the complexity of the issues involved. Food security, which must be assessed at the household or even at the individual level, cannot be ensured only by a sufficient total quantity of food available in the world. Geographic, economic and social distributional issues are equally important for achieving food security. Yet, the total availability of food matters. In times of scarcity, the weakest and the poorest are the most vulnerable.

No one global productivity indicator is entirely appropriate for all purposes. Often, it is useful to consider several indicators.

Looking at past trends of agricultural production entails several intellectual difficulties which must be well understood to avoid common mistakes and to overcome unnecessary controversies. Agricultural production is a concept that includes the production of diverse products - crops and livestock – of varying relative importance across regions of the globe. Even for a common product such as wheat, which is cultivated on all continents, there are many differences, beginning with the distinction between durum wheat, used for semolina, pasta and couscous, and soft wheat mainly used to produce bread. Economists typically aggregate those multiple products into one figure for total agricultural production, measured in dollars or some other monetary unit. This indicator is reached by multiplying a physical volume (tons, liters, gallons, etc.) by price. Such a calculation requires, however, choosing a common set of prices, which is not straightforward.

Another measure, commonly used for homogeneous categories of products, such as cereals for instance, is a unit of physical quantities. This implicitly assumes that one ton of durum wheat is equivalent to one ton of soft wheat, to one ton of barley and one ton of corn/maize. Obviously, this assumption is not strictly exact, but allows an acceptable approximation. The same approximation would not be appropriate, however, for products of different natures. One ton of wheat, for example, is only equivalent to one ton of apples or to one ton of beef in terms of weight, not in terms of its value or other attributes.

Finally, a common aggregation procedure is the use of the calorie equivalent, which weighs each agricultural product according to its contribution to the energy requirements of the human diet. This approach has the advantage of allowing the aggregation of all food products into a single figure without having to resort to a set of common prices of unknown relevance. The main limitation, however, is that a healthy human diet includes a range of nutrients as well as calories. Generally speaking, such calorie equivalent analyses downplay the dietary roles of livestock products, fruits and vegetables.

No one global productivity indicator is entirely appropriate for all purposes. Often, it is useful to consider several indicators. Here, we will examine growth in cereal production by using physical amounts – tonnage – as an aggregator. This approach highlights the important cereal productivity increases that began in the 1950s. It also points to recent controversy surrounding declining rates of yield growth. We then will attempt to overcome the limitations of dealing with cereals

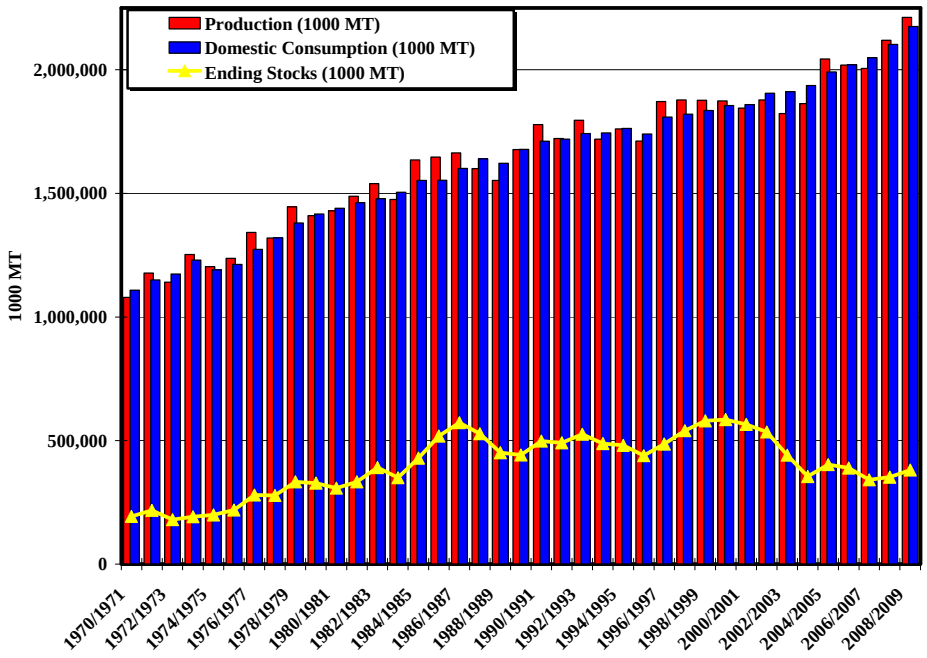
only by capturing all agricultural products, using calories as common units of measurement, paving the way for a discussion of trends in total factor productivity.

Total Cereal Production

Cereal production has doubled in the last 38 years, at an annual growth rate of approximately 2.5%.

Cereals play a key role in the diets of most poor people. Rising incomes shift dietary trends, with increasing livestock products – milk, eggs and meat – typically incorporated into the diet. Since livestock consume ever-larger quantities of cereals, total cereal consumption increases as a result, even though direct human consumption of cereal products (bread, couscous, pasta, rice) per capita diminishes. Figure 1 gives the evolution of total annual world cereal production and consumption between 1970/71 and 2008/09, as well as that of ending stocks at the end of each crop year.

Figure 1: Global Grain Production, Consumption and Stocks, 1970-2008



The general trend is one of steady growth in spite of understandable year-to-year variations, due most significantly to the weather. Production doubled over the course of this 38-year period, which translates into an average annual growth rate of 2.5% – a rate well above total population growth (about 2%).

Productivity Increases: A Key Driver

Productivity improvements, or production per unit of land, is the key engine of production growth.

This doubling of production growth stems primarily from increased yields, since the total area devoted to cereals only increased by roughly 10% during this 38-year period. Productivity increases are therefore the key engine of production growth. Yield per hectare is, strictly speaking, the average productivity of land. This is often called "partial productivity" to reflect the fact that land is only one of several factors of production, or inputs, used to obtain a final product. Other important inputs include chemical fertilizers and pesticides, although the intensity of use of those inputs has generally declined in developed countries over the last two decades; better weed and pest control; more productive crop varieties; and improved agronomic practices, notably tillage practices. The spread of these farm practices has been facilitated by more widespread use of better and bigger farm machines (tractors, plows, drills, combines, etc.) in many countries. Those machinery improvements have reduced the need for labor and led to large increases in average labor productivity (tons of cereals produced per worker) and changes in the land/labor ratio (decreases in the number of workers per hectare), but contributed less to increased land productivity (yields).

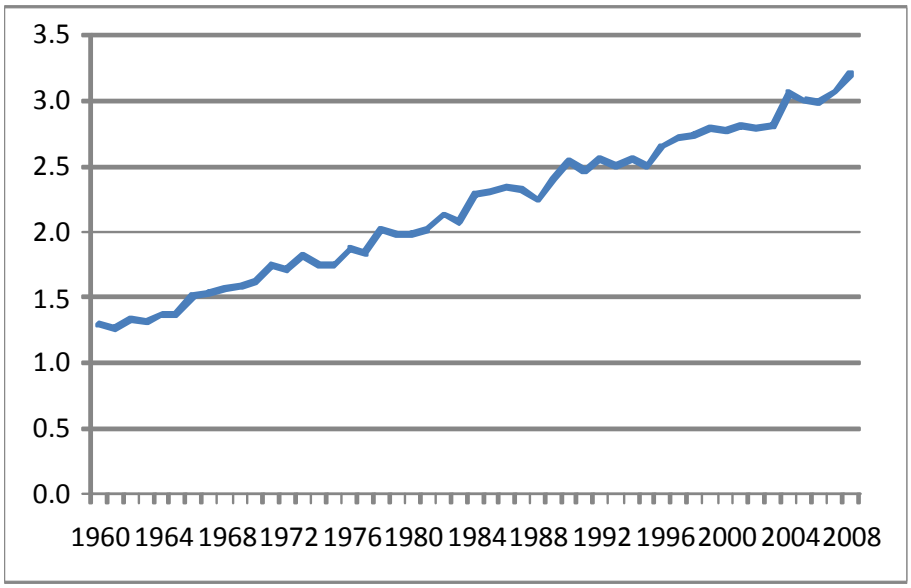
Trends in Cereal Yields

Although there have been some differences of opinion about whether cereal yields of the last two decades have increased at the same rate as during the previous two, supplies have kept up with growing demand.

In recent years, concerns have been raised about declining yield trends. This section briefly addresses the main points in contention. Alston and colleagues[2] recently presented data supporting the view that, "Global yields for maize, rice, wheat, and soybeans (in metric tons per harvested hectare) grew rapidly from 1961 to 2007: Maize and wheat yields each grew by a factor of 2.6, while rice and soybean yields increased by a factor of 2.2 and 2.0, respectively. However, for all four crops, in both developed and developing countries, rates of yield growth were slower during 1990 to 2007 than during 1961 to 1990." Based on their analysis, rates of yield growth for wheat declined from 3% annual growth to 0.5%; for rice, from 2 to 1%; for maize, from 2.3 to 1.9%, and for soybeans from 1.0 to 1.2%. The authors note that a slowdown in crop yield growth was seen in more than half of the countries that grew these four crops. Fuglie,[3] using essentially the same FAO data, made similar observations. Westhoff,[4] using USDA data, which are actually very similar to those of FAO, however, points out that the slowdown is much less obvious when one plots the evolution of yields through time (See figure 2). In absolute quantities, the trend is very close to a straight line, which would indicate a continued growth in absolute terms, which admittedly implies a slowdown in percentage terms (annual rates of growth), but presented in this fashion, the slow down appears much less dramatic than in the other studies.

[2] Julian M. Alston, Jason M. Beddow, Philip G. Pardey, "Agricultural Research, Productivity, and Food Prices in the Long Run" *Science,* September 4, 2009.
[3] Fuglie, K. 2008. "Is a Slowdown in Agricultural Productivity Growth Contributing to the Rise in Commodity Prices?" *Agricultural Economics,* 39 supplement: 431-441.
[4] *The Economics of Food*, Pearson Education, to be published, 2010

Figure 2. World Average Cereal Yields (metric tons/hectare): 1961-2008



Source: Author calculations based on data in USDA's PSD Online dataset, June 2009. Includes wheat, corn, rice, sorghum, barley, oats, millet, rye and mixed grains.

Regardless of whether one sees grounds for pessimism in recent trends, one must bear in mind that cereal yield growth has been the major cause of past success given the mere fact that supplies have kept up with growing demand. To more fully analyze the issue, however, requires going beyond the concept of partial productivity of a single production factor – land – to consideration of total productivity. This requires looking beyond cereal growth rates and at total food production trends.

Total Food Production

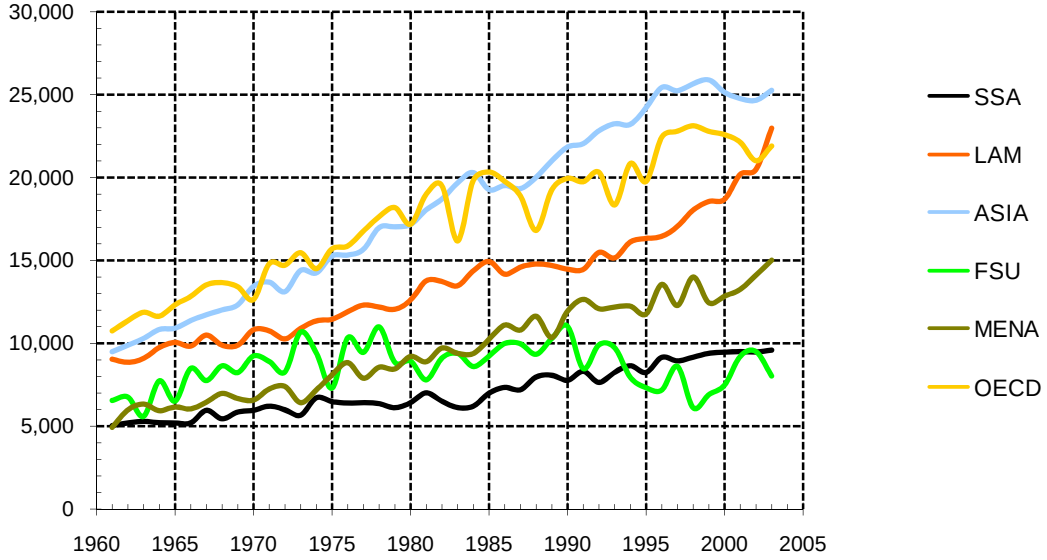
Total world food production increased by a factor of 2.5 between 1961 and 2003, i.e. an average annual growth rate of 2.2%, surpassing that of population growth (1.7%) during the period. Increases in yields were responsible for 89% of the food production growth.

Using FAO data, notably those of the food supply/use balances, authors of the French foresight exercise, called Agrimonde, have used Giga Kilocalories per day, to aggregate all products contributing to human food.[5]
These products have been classified in five categories corresponding to very different production conditions: 1) crops, 2) ruminant livestock products, such as milk, beef and mutton meat, 3) products of mono-gastric animals, such as pork, eggs and poultry, 4) aquaculture products, and 5) sea foods. This indicator shows that crop production provides the bulk of food requirements in all regions of the world, even in the richer OECD countries.[6] A significant growth of food production is also evident: it increased by a factor of 2.5 over the 42-year period between 1961 and 2003, corresponding to a 2.2% annual rate of growth, whereas population increased during the same period at a 1.7% rate. Also significant is that food production grew faster in developing countries than in developed ones. (The average rate of growth for the OECD countries was slightly less than 2%, with no growth for the Former Soviet Union.) For the sake of comparison, the average rates of growth were 2.4% for Africa, 3.4% for Latin America, and 3% for Asia and the Middle East and North Africa (MENA).

At this global, aggregated level, the main source of growth also stems from productivity increases, since total crop area increased by only 13% during this 42-year period and total pasture area by 11%. In other words, yield increases were responsible for 89% of the total growth in world food production.

[5] INRA, CIRAD. Agrimonde, Agricultures et alimentations du monde en 2050 : scénarios et défis pour un développement durable, Rapport. Institut National de la Recherche Agronomique, Centre de Coopération Internationale en Recherche Agronomique, Paris, Février, 2009.
[6] Most of the data come from FAO sources, notably the food supply/utilization balance sheets. Admittedly, these data have well-known limitations but there is really no alternative source available. As a result these data inform all policy debates at the world level. One may reasonably hope that the consistency checks conducted by FAO and the CIRAD authors quoted here have been such that the orders of magnitude are reasonably robust. And it is orders of magnitude that matter for our purpose.

Figure 3: Food Production by Hectare by Region (Kcal/day/ha)



Comparisons across regions are also instructive. Figure 3, charting the evolution of total food production per hectare by region during this 42-year period, shows that Asia experienced the fastest average aggregate yield increases: yields multiplied by a factor of about 2.5, starting from a respectable level of 10,000 kcal/day/hectare in 1961.[7] The curve suggests a plateauing of this indicator after 1995. Latin America experienced the second highest level of food production: aggregate yields increased by a factor of 2.3 over the four decades until 2003, and at an even higher rate in the last few years of the period under study. By contrast, OECD countries, which had the highest average aggregate yield in 1961, performed less well than Asia and Latin America since their yield only doubled during the same 42-year period, with a slow down beginning around 1980. In spite of difficult natural conditions, the MENA region performed well: yields multiplied by a factor of 2.5 over this period, admittedly starting from a fairly low level. Then there is the specific case of the Former Soviet Union, the countries of which underwent deep structural transformations: yields increased until about 1975, fluctuated around a quasi-stagnant trend afterwards, declined in the late 90's, and rebounded somewhat at the end of the period.

This indicator also throws a new and surprising light on the African situation. Figure 3 confirms that African yields are low compared to other developing areas. But Africa's average aggregate yield practically doubled during this 42-year period, growing at a rate of growth equal to that of the OECD countries. As is the case for all indicators, there are uncertainties about the data upon which this indicator is based. Given the importance of intercropping and multiple cropping in many African fields, individual crop yields are difficult to measure and interpret. An aggregate indicator, which includes all crops grown in a field, may well be a better indicator of land productivity than individual crop yields, and lead to the conclusion that African agriculture has not performed as dismally as commonly perceived.

[7] Expressed in terms of wheat yield, this figure corresponds to about 2.2 t/ha.

Regardless of the type of indicator used, it is evident that all regions of the world witnessed significant yield increases in recent decades, confirming that yield increases are the main contributor to the remarkable growth in agricultural production. As previously discussed, multiple factors contribute to yield increases. Economists generally classify these factors into two broad categories: increased use of other inputs per unit of land and increased efficiency resulting from technical or organizational progress.

Total Factor Productivity

Estimates of total factor productivity suggest overall productivity growing at about 2% per year since the 1960's, although regional differences in TFP are pronounced.

Economists use the concept of total factor productivity (TFP) to capture the impact of this second set of factors related to technical or organizational progress. TPF is defined as total output divided by total inputs. This definition is deceptively simple, given the difficulties involved in aggregating multiple and different products into a single output value as discussed previously. This aggregation challenge is even greater when it comes to inputs; land, labor and all capital items must be combined into one single value. The only feasible method for doing so is to use prices as weights, but in many places, an input market to assess the prices of inputs is missing or irrelevant, as for example, land and labor in the case of subsistence agriculture.

Fuglie effectively characterizes the difficulties involved in this process and addresses how such inherent challenges can be overcome.[8] He notes that previous research on global agricultural TFP growth gives a mixed picture, which is not surprising given the methodological difficulties just mentioned. Despite the many complexities, Fuglie's conclusion is important: "Contrary to widely held perceptions, I find no evidence of a general slowdown in sector-wide agricultural TFP, at least through 2006. If anything, the growth rate in agricultural TFP accelerated in recent decades. However, the results do show a slowdown in the growth of agricultural investment. Accelerating TFP growth largely offset decelerating input growth to keep the real output of global agriculture growing at about 2% per year since the 1960's. Regionally, however, agricultural productivity performance has been uneven." TFP growth continued at a steady pace in developed countries, while in those areas, total inputs were reduced. Countries that have invested solidly in public agricultural research, notably Brazil and China, also have performed very well. Poorer countries, notably in sub-Saharan Africa, however, remain at a very low level of productivity.

What lessons regarding modern agriculture can we draw from these global indicators? As discussed, modern agriculture involves both the introduction of inputs, such as chemicals, new seeds and machinery, and the promotion of technical change based on scientific advances. In reality, the distinction between more inputs and greater efficiency tends to be blurred, in as much as technical change is often embodied in new inputs. But a large share of the increases in average yields can nevertheless be attributed to technical change, as suggested by the discussion on total factor productivity. We emphasize that modern agriculture is not equated solely with large commercialized farms. It was shown, for instance, that progress in Asia had been rapid; yet we know that large commercial farms do not play a major role in countries such as China, India, Vietnam, and even Indonesia, in spite of a significant plantation sector in that

[8] Fuglie, 2008.

country. Science and technology, however, as well as 'modern' inputs, played a great role in the Asian successes.

By contrast, the somewhat disappointing performance of African agriculture can be attributed in large part to the modest development of modern agriculture in that region. And this laggard development is due, we know, to a multitude of causes which cannot be analyzed here, but which include inappropriate public policies, insufficient public and private investments, dysfunctional institutions in many sectors and subsectors, inadequate education, lacking infrastructure, and multiple failures of past development projects. Although the "Green Revolution" did not take hold of the continent, there are also some success stories in African agriculture, particularly in recent years. It would be wrong to view the continent as doomed to fail forever, and it is clear that modern agriculture can make an important contribution to its future development.

Whereas the use of global indicators usefully allows us to track productivity growth, they do not fully account for the multiple factors and processes involved in agricultural development. To gain a deeper understanding of those factors and processes, as well as of the unintended consequences of specific actions and, as a result, of the controversies clouding the choice of future actions, assessments must be undertaken at a regional or national level. Towards this end, the paper includes five regional case studies in Annex I.

ENVIRONMENTAL CONCERNS

We now turn our focus from productivity gains to examine a range of environmental problems, caused in part by modern agriculture. In so doing, we pose the question whether the undeniable productivity growth achievements of the past are sustainable. Evidence of massive soil erosion and degradation, loss of biodiversity and of growing water scarcity suggests that past trends may not be sustainable in the future, as argued by some authors for many years. Because an in-depth analysis is beyond the scope of this paper, we briefly touch on four aspects: soils, biodiversity, water, and agricultural greenhouse gas emissions. We refer to a small number of quantitative indicators to support qualitative statements, in order to describe the main environmental challenges confronting modern agriculture. In each of these four areas, we suggest that modern agriculture – despite having contributed to these problems – can also play an important role in addressing them.

Soils[9]

Over the last four or five decades, more than one hundred million hectares of natural land have been converted to farmland, increasing the rate of land erosion, since cultivated land erodes at a much faster rate. It is estimated, for instance, that an undisturbed forest loses between 0.004 and 0.05 metric tons of soil/ha/year, whereas a cultivated US field can lose up to 12 to 15 metric tons of topsoil/ha in one single heavy rainfall. In tropical climates, erosion rates reaching 30 to 40 metric tons/ha/year have been observed. By comparison, the rate of soil formation is about 1 to 2.5 metric tons/ha/year.[10] Soil erosion also has cost consequences for waterways (e.g., addressing flooding, dredging). For the United States, Hawken et al. estimate the cost of topsoil

[9] Much of this section is borrowed from Clay J. (*World Agriculture and the Environment. Island Press: Washington DC. 2004*)
[10] Pimentel et al. 1995.

losses at $44 billion over the next 20 years,[11] and global damages may reach $400 billion per year.[12]

Some global estimates imply that about 80 % of agricultural land is moderately to severely eroded. Cropland is most susceptible to erosion, but pastureland can also be severely degraded if overgrazed. In total, some estimates suggest that about 1.2 billion hectares have been moderately, severely or extremely degraded by agriculture since 1945, with four-fifths of this degradation occurring in developing countries. According to Clay, these figures underestimate the extent of degradation, because farmers tend to abandon degraded land and move on to new lands. According to Clay, "globally, the land used and abandoned in the last fifty years may be equal to the amount of land used today." Even if this may be overstating the issue, there is no doubt that the expansion of agriculture has led to serious soil losses.
Despite this fact, without modern agriculture, the losses would be even higher. *Constant yield increases in the face of increasing demand, helped to limit the expansion of area devoted to crops. Literally, hundreds of millions of hectares of additional land would have been necessary to feed the world population if yields had remained stagnant, leading to huge increases in soil erosion.* Given an ever shrinking availability of arable land, further increases in yield will also have important environmental benefits.

Biodiversity

Concerns raised about biodiversity loss have been forcefully expressed in recent years by the authors of the Millennium Ecosystem Assessment (MEA), a major undertaking which brought together more than 1,300 experts from some 50-odd countries to reach consensus on the threats to ecosystems around the world and on how to respond to them. Whatever one may think about the strength of the consensus and the validity of the diagnosis, the MEA represents an important body of opinion that should not be ignored.[13] The MEA finds that "changes in biodiversity due to human activities were more rapid in the past 50 years than at any time in human history, and the drivers of change that cause biodiversity loss and lead to changes in ecosystem services are either steady, show no evidence of declining over time, or are increasing in intensity." The assessment refers to the most important direct drivers of biodiversity loss and ecosystem service changes as habitat change (such as land use changes, physical modification of rivers or water withdrawal from rivers, loss of coral reefs, and damage to sea floors due to trawling), climate change, invasive alien species, overexploitation, and pollution. Agriculture is not the main culprit in these changes, although in certain instances it may be either directly or indirectly related. More directly relevant to modern agriculture, however, are the authors' findings that "since 1960 there has been a fundamental shift in the pattern of intra-species diversity in farmers' fields and farming systems as a result of the 'Green Revolution," and that the "intensification of agricultural systems, coupled with specialization by plant breeders and the harmonizing effects of globalization, has led to a substantial reduction in the genetic diversity of domesticated plants and animals in agricultural systems."

In addition to its impressive productivity increases, modern agriculture has clearly had a more negative impact on biodiversity, which needs to be recognized. *Negative side effects of modern agriculture include reduced genetic diversity among domesticated species, habitat deterioration*

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[11] Hawken et al. 1999.
[12] Pimentel et al. 1995.
[13] Ecosystems and Human Well-Being, MEA, Biodiversity Synthesis, 2005. Source: http://www.millenniumassessment.org/documents/document.354.aspx.pdf

or destruction due to pollution, and an extension of invasive species. Modern agriculture, however, can importantly contribute to the solution of some of these problems, mainly through the development of knowledge-intensive, scientific solutions. These include intelligent management of gene pools, expansion of seed banks, aggressive animal breed conservation, development of more environmentally benign inputs, and the implementation of sophisticated landscape management.

Water

Modern agriculture has relied heavily on water, which is of course a key input into agricultural production. Agriculture now accounts for about 69% of all fresh water withdrawals globally, and water demand for industrial and other uses is expanding rapidly in urban areas, raising valid concerns about whether water may be running out. Total demand for fresh water increased dramatically during the last century (from 579 to 3750 cubic kilometers per year) and will continue to do so. Shiklomanov, the authoritative source on the subject, estimated that total withdrawals would reach 5100 cubic kilometers by 2025.[14]

The area of land under irrigation increased from 47.3 million hectares in 1930 to 254 million hectares in 1995.[15] Agricultural production greatly benefited from this increase: half of the growth of food production from the mid-1960's to the mid-1980's has been attributed to irrigation (Hawken et al., 1999). Three out of every four irrigated hectares are located in developed countries, where about 73% of fresh water is used for irrigation. In Asia, this rate reaches 86%, and in Africa, 88%.

A number of inefficient irrigation practices, past and present, lead to wasteful water use: unchecked withdrawals in the upper parts of irrigation basins, poor maintenance of irrigation facilities, and limited use of water-saving irrigation techniques, such as drip irrigation. In addition, many farming practices, that can help preserve water, are not widely used, i.e. leaving soils bare after harvest cause evaporation, reduce soil organic matter, in turn decreasing soil water holding capacity.

In many places around the world, water is pumped from aquifers faster than it can be replenished, leading to rapidly falling water tables and a depletion of water stocks. Kimbrell estimated the annual rate of depletion at 163.6 cubic kilometers.[16] In many countries, most of the water withdrawals are used for agricultural irrigation, including the United States, North Africa, the Middle East, China and India.

There is an urgent need to address what some see as a looming water crisis. Modern agriculture's contribution can be significant. *Whereas modern agriculture has been reliant on a dramatic expansion of irrigation in the last decades, it must now become reliant on improved technologies in irrigation and crops.* Work on developing water-saving technologies and equipment and drought-resistant or tolerant crop varieties must be accelerated. Focus must also

[14] Shiklomanov, 1998.
[15] Kirda, 1999 cited in Soth, 1999.
[16] Kimbrell, 2002.

be placed on the development of better information systems for improved irrigation facility management.

In many dry or drought-prone areas, the impacts of new irrigation developments can be spectacular. For long term success, however, these new systems often require the adoption of new management practices fostered by institutional changes. Serious consideration should also be given to new policy approaches, in particular those related to water pricing.

Green House Gases (GHG)

Agriculture is estimated to contribute about one-third of anthropogenic emissions of greenhouse gases, either directly (mainly methane from rice paddies and ruminant livestock, and nitrous oxide (N_2O) from fertilizer and animal waste management) or indirectly through land use, deforestation or forest degradation.

Modern agriculture has admittedly contributed to the problem, mainly through increased use of chemical nitrogen fertilizer and livestock concentrations making waste management more difficult. And yet, as discussed in the section on soils, increased yields have limited and importantly must continue to limit, the expansion of cultivated land. Similarly, in the case of livestock, increased productivity per head has contributed to limiting the number of ruminant animals, thereby limiting the emissions of methane.

Agriculture's greatest mitigation potential lies in better forest management (avoiding deforestation, promoting afforestation/reforestation, enhancing agro-forestry), and improved methane and N_2O management. Targeted research and development, and improved water management, is also recommended. Carbon sequestration is achieved by increasing soil organic matter and this enhances soil fertility. It is worth noting that many of these measures are knowledge-intensive and congruent with the modernization of agriculture.

Three quarters of all agricultural GHG emissions are generated in developing countries, and the greatest mitigation potential in the agriculture, forestry and land-use categories, also lies in developing countries. Moreover, such mitigation actions in developing countries may cost about one-fourth to one-third of total mitigation in all sectors and regions, while generating one-half to two-thirds of all estimated emission reductions. These estimates serve to reinforce the desirability of modernizing agriculture in developing countries, as there are clear benefits to be gained not only in terms of food security, poverty alleviation but also climate change mitigation.

PENDING CONTROVERSIES

The two previous sections of this paper have shown that modern agriculture has significantly contributed to enhanced productivity, a key necessary condition to ensure global food security. At the same time, modern agriculture has led to negative environmental impacts. But, through intensification of land use, it has reduced the pressure on many natural habitats and, as such, it has also contributed to the protection of the environment. In addition, modern agriculture has the capacity to contribute to the amelioration of the negative environmental consequences discussed above. Innovations often trigger robust and vocal debates about benefits versus risks. Thus, it is not surprising that several important issues remain controversial. Three of them are discussed now: those regarding the development of genetically modified organisms (GMOs), the safe use of pesticides, and the risk of social marginalization of peasant farmers in developing countries. These three have been chosen for discussion here because they are pivotal to the ability to fully

acknowledge the actual and potential future benefits of modern agriculture, while recognizing possible limitations and ways that those limitations may be effectively overcome.

GMOs

Applications of agricultural biotechnology and the development and marketing of genetically modified seed (GMO's) represent a true scientific revolution in biological science during recent decades. Empirical evidence, based on farmers' surveys, indicate that farmers adopt GMO's for three main reasons: increased average yields, reduced pesticide use and simplification of farm practices. The fact that hundreds of millions of hectares have been planted to GMO crops over the last ten years or so is sufficient proof of the value of that technology for millions of farmers, who easily could have chosen to forego the option. In addition, a number of new biotech traits are in the pipeline, notably ones that can enhance product and nutritional quality and ones that introduce drought tolerance and more efficient use of fertilizers.

GMO's, however, remain controversial. Food safety concerns are waning, but it is critical that technology providers and regulators remain vigilant to maximize the likelihood that the record remains unblemished. On the environmental side, concerns range from an inadvertent transfer of genetic traits to non-GM crops or wild relatives. It should be noted that concerns about cross-fertilization are not unique to GMO's; it is a part of agriculture that has been and continues to be handled by farmers quite well. While this risk cannot be eliminated altogether,[17] the problem becomes one of risk management: balancing risks of potential damages against benefits and requiring proper protections to minimize any reasonable risks. Regulatory bodies often, as conditions of approval, specify management plans to ensure product stewardship, and care needs to be taken that such management plans are also carried out on the ground.

What we classify as a more societal concern pertains to issues related to intellectual property rights. There is a difference of views about whether living plant varieties should be subject to private ownership, with some arguing that it is at odds with common property rights for traditional communities, and defenders arguing that innovation, and the significant investment required for innovation, can only occur if property rights can be assigned and enforced. We refer the reader in particular to the case study presented in Annex I on GM cotton in India, which demonstrates concerns that poor farmers have about becoming reliant on multinational seed companies.

Despite these controversies, genetic modification has become an extremely important tool in modern agriculture. *While for many, GMO's remain a polarizing issue, the technology's demonstrated and future potential value toward addressing world food security is undeniable. It behooves the industry and governments to continue being vigilant about the rigorousness of approval systems and stewardship plans, while also engaging in an ongoing dialogue in order to reach consensus on outstanding questions and differences of opinion.*

Pesticides

Many controversies have developed around the proper use of pesticides. Yet nobody questions the fact that chemical pesticides are effective tools to control pests. The negative unintended consequences of pesticides are just as much undeniable. These consequences have included tragedies–when farmers and farm workers were poisoned by pesticides, major health hazards – when large amounts of pesticide residues were found in food, particularly fresh fruits and

[17] A few years ago, a violent controversy arose on whether or not transgenic material had contaminated wild relatives of maize in Mexico. Obviously, the evidence at that time was questionable. But most experts, including those in support of GMO maize, agreed that the real question should not be whether such transfer had happened or not, but rather when it would happen, because 'contamination' could not be ultimately avoided.

vegetables, and environmental damages. The fact that pesticides are at the same time effective and potentially dangerous has led to controversies where one can identify two camps: those who are basically for and those who are against pesticides.

Paradoxically, however, an international consensus was developed in recent decades on the proper use of pesticides. The first expression of that consensus is that the most dangerous pesticides were banned altogether. Another component of the consensus is the support to biological control, whenever feasible. The beautiful story of the control of the cassava mealy bug in Africa, based on the identification and collection of a natural enemy of the mealy bug in Brazil (the "area of origin" of cassava) by a CIAT scientist based in Cali, Colombia working then with colleagues at IITA (another CGIAR center based in Ibadan, Nigeria) for the multiplication and dissemination, through aerial sprays of the mealy bug pest, illustrates the power and the potential effectiveness of biological control. This example also illustrates that the development of such a procedure is extremely knowledge intensive and often limited by insufficient information about the pests of the pests. It is this limit which has led to the development and popularity of what is known as integrated pest management (IPM), which is defined by FAO as "the careful consideration of a number of pest control techniques that discourage the development of pest populations and keep pesticides and other interventions to levels that are economically justified and safe for human health and the environment. IPM (encourages) . . . natural pest control mechanisms."[18] Finally, the existence of an international consensus is illustrated by several policy documents of large international organizations on the topic.[19]

What are then the controversies beyond this general consensus? To understand the current debate and the controversies, it is important to come back to the two camps, for and against pesticides, as identified above. Those who defend pesticides, and that includes the pesticide industry and many farm organizations, tend to focus on the benefits and to minimize the risks. They point out for instance that losses of crops due to pests before and after harvest are huge; they stress that the desire of consumers to have food with no pesticide residue at all is really not based on solid scientific evidence: it may be that low levels of toxic chemicals can have positive effects, a plausible outcome supported by some empirical evidence (e.g. Trewawas 2004). They view themselves as part of the solution to the nocivity of pesticides through the development of new pesticides, which are much less dangerous for human health and the environment. And they emphasize that large (multinational) companies are ethically responsible and respect international guidelines, such as those of FAO, whereas local companies marketing generic products, i.e. chemical compounds for which the patent has expired, are much less socially responsible. They stress that they can not be held responsible for farmers' mistakes when these farmers apply pesticides in ways which are dangerous, putting their own health at risk for instance, since they (the agrochemical companies) give instructions on the proper use of pesticides.

Their critics, the specialized NGO's in particular, convinced that the profit motivation of the multinational corporations always trumps whatever they may say about their ethical

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[18] FAO, 2002.

[19] FAO issued an "International Code of Conduct on the distribution and use of pesticides, which was elaborated in close consultation with all stakeholders, notably representatives of the pesticides industry, and was adopted by member governments in a formal session of the FAO Council (November 2002). Similarly, the World Bank has edited specific instructions on pest management for several decades, the last revision having been adopted in 1998. Many other policy instruments have been adopted by various international bodies and organizations. (For a list, see IAASTD Global report, p. 105). They all reflect the same general consensus briefly sketched out in the previous paragraphs.

commitments, emphasize the instances when MNC's have lobbied against more stringent controls by public authorities, have undermined research on IPM, have turned a blind eye when governments in developing countries have been lax in enforcing regulations on the safe use of pesticides. In addition, the fact that small local private firms manufacturing and selling generic products may be less socially responsible than large MNC's does illustrate the inherent tensions between the search for profits and social responsibilities which all private firms are subjected to. This is a classical case of a situation justifying public intervention, as market forces may not lead to the greater public good.
The implications of these controversies for modern agriculture are straightforward, even if they are often difficult to implement: use pesticides intelligently, i.e. develop less aggressive products, formulate and implement safe use practices, and conduct research on pests so as to be able to elaborate effective IPM programs in which farmers have an important voice.

Marginalization of Poor Peasants

The key question here is whether or not modern agriculture necessarily entails the social and economic marginalization of poor peasant farmers in developing countries. It must first be recognized that debates on the compatibility of modern agriculture with small farms go back a long time in history. Useful lessons from these old controversies should be remembered. They have led to a broad consensus in the agricultural economics profession that family farms are superior to large corporate farms when labor is plentiful, when priority is given in public policies to poverty alleviation and when the modernization of small farms is supported by strong public policies. This belief may, however, have become itself an ideological position, neglecting the three conditions just listed.
A robust lesson can, however, be drawn from that consensus; modern agriculture does not necessarily require large scale farms. Actually, Nobel Laureate T.W. Schultz showed almost fifty years ago that the "transformation of traditional agriculture," as practiced today by large numbers of smallholders in developing countries, was possible; technological change, based largely on scientific advances, playing an important role in the process. The examples from China and India, discussed in the Appendix to this chapter, vindicate that view. The large number of small farmers in developing countries, numbered in hundreds of millions, supporting more than 2 billion family members, according to FAO, makes the modernization of the sector a development imperative of the highest priority. The necessary modernization must entail a progressive structural transformation: from subsistence to commercial, from very small to more medium-sized farms, including the growing use of capital substituted for labor, at a speed depending on how quickly new employment opportunities are created in other sectors of the economy. Note that such a structural transformation is similar to what happened in industrialized countries, as illustrated in the appendix on the case of France.
The recent, so-called "land grab" movement illustrates the risks which an alternative, more radical transformation of agriculture, relying mainly on large scale production units, would entail, as expressed several times in recent years by the DG of FAO himself. Press reports[20] indicate that 25 to 30 millions hectares of farm land have been sold or leased on a long term basis by governments of developing countries, particularly in Africa, to agencies of foreign governments from land scarce countries, seeking to ensure the long term security of their food supplies. Undoubtedly, the foreign operators will use modern agricultural techniques, leading thus to an expansion of modern agriculture. But the obvious danger is the economic and social

[20] Admittedly, these reports are exaggerated. There is no doubt however that the phenomenon is significant.

marginalization of those who have been using the land, admittedly very extensively, until now. Indeed there are very few tracts of cultivable land for which there is no user at all today, with sometimes formal but often only traditional land use rights. When a government "gives" land to a foreign agency, it takes that land away from a former user.
The challenge for modern agriculture is to be supportive of the transformation process of agriculture in countries and regions where small scale farmers are predominant, in other words, to support the general economic development process, recognizing that in very poor countries, notably in Africa, the numbers of people working now in agriculture are so high that the transition period necessary for the diversification of economic activities will be very long. In the meantime, farming conditions must improve. Undoubtedly, modern agriculture has much to offer in this process, as illustrated by the cases of China and India.

Conclusion

This paper has attempted to provide an overview of the productivity gains made through modern agriculture in the last decades, while also briefly outlining a number of environmental and societal controversies it has engendered. Undoubtedly, the benefits of modern agriculture have been crucial to human progress. Agricultural production grew faster than population in the world as a whole, as well as in developing countries themselves. On that score, even the performance of sub-Saharan Africa is better than often perceived. And much of that performance is due to modern agriculture as reflected in development and widespread use of new and better tools, techniques and technologies.

While significant hunger and malnutrition still persist in many parts of the world, its incidence and extent would have been much greater without the increased food availability resulting from agricultural modernization. (Much of the current problem is owed to poverty and inadequate distribution, rather than a physical lack of food.) This additional food supply has enabled literally hundreds of millions of people to realize more of their potential and to have better lives.

Modern agriculture has led to increased quality of life and living standards: as agriculture has modernized, the proportion of income spent on food has decreased, leaving more purchasing power for other consumer goods, education, health care and leisure. When consumers spend as much as 2/3 of their income and virtually all of their daily endeavors in pursuit of food for the family, little money or time is left for "human flourishing." This characteristic typifies most of the smallholder farmers seeking a meager subsistence from their agricultural activities. This suggests that foregoing the potential benefits of the modernization of traditional agriculture would not be an appropriate development strategy.

Although modern agriculture has negatively impacted the environment, less recognized are the ways in which crop and livestock yield increases have directly or indirectly contributed to many environmental benefits. In many cases, modern agriculture prevented deforestation and extension of farming onto increasingly fragile lands, and thereby the destruction of wildlife habitat, loss of biodiversity, and increased water and air pollution from soil erosion and degradation. In many places where traditional agriculture did not go through a modernization process, demographic pressure has led to major environmental degradation through encroachment of poor peasants in forests, on hillsides and, more generally, in marginal lands with results that include soil erosion, destruction of natural habitats and flooding. Agricultural biotechnology has played a major role here, enabling both higher yields and a reduced environmental footprint through reduced land, fertilizer and pesticide use per unit of output, as compellingly illustrated by the

reduction in pesticide use with biotech cotton varieties in the Indian Bt cotton case study in Annex I.

The modernization process has not been restricted to field production alone. Better post-production processing and handling practices have contributed enormously to improved food safety through pathogen reduction, as well as greatly reduced post-harvest losses which thereby increase the available food supply.

Considering the need to further increase production by 70% by 2050, there is in our mind do doubt, that it is vital to continue increased productivity, and indeed, to overcome what may be a recent slowing down of productivity. Being mindful about the realities we face in terms of declining water and arable land availability, pollution and climate change, and the need to do a better job safeguarding biodiversity, means however, that increased productivity cannot be the only objective.

Modern practices entail risks that need to be managed. We have seen throughout this paper that those risks are often linked to unintended negative consequences of the modernization process. Clearly, mistakes have been made in the past, and some of these negative consequences could have been anticipated and their impact minimized. The challenge for the future is to do better on that score.

There are no easy solutions to resolving environmental and societal controversies surrounding modern agriculture. Every societal action, including those in the agricultural realm, entails risks which must be weighed against potential benefits, paying attention to the distribution of both costs and advantages. In fact, risk management is becoming a major task and challenge for public policy development everywhere in the world and requires ongoing dialogue with the society at large.

Modern agriculture must be enlisted if we are to overcome this false choice between productivity and sustainability. Modern agriculture – like all technological and scientific applications – is not static. It has and must continue to adapt to changing demands and challenges. Failure to continue advancements on the farm and across the food system will only exacerbate many of the problems that the critics highlight. These advancements will not occur automatically, however. They require the steady pursuit of
a clearly articulated goal, namely one of feeding a growing population while holding steady, or even better, minimizing, the environmental footprint.

ANNEX I -REGIONAL CASE STUDIES

To better understand the various factors and processes involved in agricultural development that are discussed in the main body of the paper, and to highlight more specific controversies surrounding modern agriculture, we examine five specific cases related to modernization and growth in agricultural production. The cases have been chosen to represent a wide range of situations; all of them highlight achievements of and point to some controversies surrounding modern agriculture.

The Outstanding Performance of Chinese Agriculture After 1979

Over a period of several decades, China has been able to feed nearly 20% of the world's population on only 5% of the world's arable land. In addition, over the last thirty years, it has been able to increase production very rapidly to keep pace with the large increases in domestic

demand associated with its extraordinary general economic growth. This performance is remarkable and stands in sharp contrast with the concerns expressed by many outside China some fifteen or twenty years ago, notably Lester Brown, who feared that economic growth in China would lead to massive imports of agricultural products, which could literally starve vast segments of the population in developing countries.[21]

Scope and Magnitude of the Successes: In terms of agricultural growth, Chinese authorities proudly point out that agricultural production has nearly quadrupled since 1979, which corresponds to an annual growth rate of approximately 5%, a significant achievement for the agricultural sector over a 30-year period. The year 1979 is chosen as a reference because this is when major institutional reform, the abolition of production communes and establishment of the so-called household responsibility system, was initiated. The change meant eliminating collectivized agriculture and returning to a family farm structure, made up of small—often very small—production units, effectively restoring the role of economic incentives.

Another dimension of the success of Chinese agriculture is how well it has adapted to the rapidly changing needs and demands of the population between 1970 and 2005. The share of crops in the total value of agricultural production declined from 82 to 51%, while that of livestock increased from 14 to 35%, and of fisheries from 2 to 10%.[22]

What is particularly striking in this case study is that the Chinese agricultural sector was able to adjust so nimbly both to changes in level of demand and to the types of product being demanded. Contrary to the fears expressed by Brown and others, China has remained practically self-sufficient not only for such major staple foods as rice and wheat, but also for pork, beef and poultry. The only major exception is oilseeds; China has become the largest importer of soybeans, soya oil and oilcakes to feed its livestock. It has also become a significant importer of coarse grains. Note that these two imported products are land intensive, whereas China has developed its production around horticultural products, which are labor intensive, and has become a net exporter in that sub-sector. These developments highlight the fact that the search for comparative advantage and international trade flows play a critical role in the recent performance of Chinese agriculture. Self-sufficiency concerns, which were high in the past, particularly for staple foods, now have only limited relevance.

Primary Success Factors: Multiple factors are responsible for the strong performance of the Chinese agricultural sector:

- **Large investments in infrastructure, particularly for irrigation and flood control**. It is reported that China spent more than $150 billion over a sixty-year period in water management investments, and today there are 86,000 dams[23]. The proportion of crop area under irrigation increased from 18% in 1952 to about 50% in the early 90's.
- **Investments in transportation and market infrastructure** have also been important, to the point that domestic markets now are well integrated. Huang and Rozelle (2006) point to evidence that the efficiency of markets in China is comparable to that in the United States.

[21] Brown, L. Who Will Feed China: Wake-Up Call for a Small Planet, Worldwatch Institute, Washington, 1995.
[22] Huang & Rozelle, 2009.
[23] Zhongoguo Qingniand Bao, reproduced in *Courrier International* , 987 (October 2009).

- **Improvement in the economic policy environment**. In addition to healthy macroeconomic policies, notably through measures to avoid a rapid appreciation of the Yuan, the process of reform since the period of central planning has been both deliberate and prudent. Domestic market liberalization has taken a long time, particularly for cereals, but finally culminated with China's admission to World Trade Organization a few years ago. More recently, following a pattern well established by Japan and South Korea, the Chinese government has even begun providing subsidies to agriculture.
- **Technological change.** A significant body of literature demonstrates that this has been the single most important factor of success since the establishment of the household markets responsibility system., Detailed analyses by province of TFP trends, combined with data on R&D expenditures and on number of varieties released, show a significant improvement in TFP between 1979 and 1995, at a rate of around 3% per annum.[24] Less detailed but more recent evidence suggests that this growth has continued through the present. The detailed earlier data indicate that variations in TFP growth by province and through time have been important, and these variations are closely related to past public investments in agricultural research. China more than tripled its agricultural R&D investments between 1990 and 2005 and is one of the few developing countries where research intensity (i.e. the share of research expenditures in agricultural GDP) is rising. The positive impact of hybrid rice on yield and productivity is just one example of the return on research. Also of note, a significant share of these investments is in biotechnology, and China has become a leader in the production and use of GMO seeds.

Criticisms and Controversies: Such rapid agricultural growth leads to an immediate question: to what extent is such a success sustainable? Indeed, serious environmental and social concerns have legitimately been raised. Population densities are very high in the most prosperous and fastest growing provinces in the East and Southeast of the country. Evidence of air and water pollution in these regions is truly worrisome. Water scarcity is a serious and growing problem, yet many of the huge water infrastructure investments such as the Three Gorges Dam are controversial and have been met with resistance. In addition, the remarkable successes in reducing the number of people living below the poverty line cannot hide the increasing disparity between rural and urban incomes and limited economic opportunities for rural citizens.

However, the solutions to these serious problems cannot be found in the choice of a different development path for agriculture. Rapid agricultural growth has certainly contributed to a moderation of food prices and this is very important for both the urban poor and net food buyers in rural areas. The challenge for China is to make both those who remain in agriculture and those who transition out of agriculture better off, and there is no credible alternative development model that does not include modern agriculture that can hope to accomplish this goal.

Observations of Note: Two complementary features of the Chinese experience are noteworthy. First, the agricultural sector largely has been and will continue to be dominated by small scale farms, very small ones in fact. So, in this case modern agriculture does not mean large, heavily mechanized farms where labor would have been substituted by capital. Second, the public sector has played and continues to play the key role. There is no hostility against large multinational corporations; many of them have very significant partnership agreements in China and have made large investments in its agriculture sector. But in this country, the private sector is not the dominant force. So, the Chinese case is one of heavy reliance on modern agriculture but unique in the absence of large farms and the secondary role of the private sector.

[24] Jin at al, 2002.

Agricultural Development in the Cerrados of Brazil

The Brazilian *Cerrados,* named for the native vegetation growing on the land, correspond to a large and heterogeneous tropical savannah occupying 2.04 million square kilometers, or about 23% of the country area. The region's primary vegetation is a mix of grass, shrubs and scattered trees over ancient soils, generally deep and well drained.[25] Annual rainfall averages between 1000 and 1400 mm but is concentrated between October and March. Rain can be very scarce between May to September, causing severe dry spells.[26]

Until the 1970s, the *Cerrados* were considered inappropriate for agricultural production, due to both their propensity to drought and the nature of the soils. Most of them are highly weathered, acidic, and have a high permeability that favors leaching, resulting in low nutrient availability and severe limitations for crop production. Moreover, these soils suffer from high aluminum saturation. These chemical problems, combined with frequent droughts, high evapotranspiration rates and limited rooting depth, severely restrain the natural soil fertility of the *Cerrados*.[27] In addition, the remoteness of the region and poor connection to the rest of the country helps explain why the traditional commercial agriculture fronts stopped moving northwards when they reached the *Cerrados* in the late 1960's. Government efforts to populate and bring agriculture to the area through the 1970's were largely unsuccessful.

Scope and Magnitude of the Successes: Beginning in the late 1970's, a rapid extension of modern agriculture, including more intensive and productive methods for cattle raising, occurred in the *Cerrados*.[28] Since then, it has become one of the most important agricultural production regions in Brazil. An important feature of the early stages of agricultural development in the area was the expansion of soybean cultivation. As of 1980, soybeans had not significantly penetrated the *Cerrados*, but the region was responsible for more than half of the country's total area in soybeans twenty years later. Between 1990 and 2000, the soybean planted area increased by only about 14%, but production doubled. This achievement is largely attributed to the development of no- or minimum-tillage practices and GM technologies. For the whole *Cerrado* region, soybean yield is now above the national average, and in parts of the region, it is among the highest in the world.

Primary Success Factors: The main drivers of this agricultural revolution in the *Cerrados* are found on both the supply and demand sides. Domestic and international demand for grains, especially for soybeans, was spurred by growth in animal product consumption and the resulting increase in the use of manufactured livestock feed. In addition, the United States embargo on soybean exports in the 70s boosted domestic and foreign investments in soybean production in Brazil.

Early on, key factors in the supply side contributing to success were:

- **Technological developments.** EMBRAPA (the state-owned company affiliated with the Brazilian Ministry of Agriculture, which is devoted to pure and applied research on

[25] Dias, 1992.
[26] Goedert, 1989.
[27] Scheid Lopes, 1996.
[28] Mueller, 1990.

agriculture) brought new technologies to the region that made crop production in the formerly inhospitable savannah possible. These included improved crop management practices, such as the application of lime to correct low pH and aluminum toxicity, and more widespread use of fertilizers. Better management of organic matter and the development of new soybean varieties adapted to the different agro-ecosystems of the *Cerrados* were also crucial to growth in production.

- **Public investments in transportation infrastructure,** the relocation of the national to Brasilia, and public policies aimed at promoting migration to the sparsely populated areas of the *Cerrados* strongly influenced the spatial patters of soybean cultivation expansion, reduced transportation costs, and improved the connection between the region and the rest of Brazil.
- **Low land prices, expectations of substantial profits, and government supports** to newcomers attracted many experienced agricultural entrepreneurs from the three southern states where soybeans were traditionally grown in Brazil before the expansion to the *Cerrado* region. Generous, subsidized credit to farmers was also an important driver of the growth of agriculture in the region.
- **The economic reforms** that began in the mid-1990s were instrumental in establishing the adequate macroeconomic conditions for the development of agriculture and fostering private sector initiatives. Market liberalization was particularly essential to improve the link between international and domestic markets, which permitted the direct transmission of international prices in Brazil.

A second wave of soybean expansion in the *Cerrados* has occurred over the last fifteen years, with substantial further increases in production. This boost may be attributed to:

- Further **improved tillage practices** and applications of **GM technology**.
- **A growing role of the private sector** following reduced government direct support to soybeans growers (input subsidies and low interest credit were eliminated) has driven the development process through **large investments in infrastructure.**[29]
- **Well functioning markets** for inputs and outputs, and a growing local demand for soybeans from Brazilian industries; and
- **Development of soybean varieties** adapted to almost all parts of the *Cerradso* region, initially by EMBRAPA and agricultural universities and then by the private sector.[30]

Criticisms and Controversies: Rapid agricultural development of the *Cerrados* has not been without criticism and controversy, most of which has been related to the environmental and social sustainability of the process. Land clearing raises issues of soil erosion, and the clearing of about 30 million hectares in the region between 1975 and 1996 has understandably caused erosion concerns. Techniques such as terracing can minimize these negative consequences, but they are not universally used. The introduction of no-till practices greatly reduced the risk of erosion, while at the same time led to criticisms related to the use of herbicides to control weeds. The increase in use of chemical fertilizers and pesticides associated with growth in production has also been opposed by some. The profitability of soybean cultivation has admittedly led to production expansion into fragile zones that should not come under cultivation, and the overall result has been the destruction of wooded areas, particularly riparian forests. However, public authorities at

[29] Rezende, 2003.
[30] Mueller, 2003.

the state and federal levels have reacted with greater and greater determination to protect these forests.[31]

At a social level, the primary concern relates to the situation of small settlers with or without solid land title. Some of them cultivate soybeans and can enjoy the benefits of the technological and economic advances associated with this crop. But others may be forced to relocate repeatedly as more land is cleared or placed at a disadvantage because they lack the capital for no-till machinery. When discussing the impact on poverty of the rapid agricultural development of the *Cerrados*, however, it is important to keep in mind the macroeconomic impact on the real prices of food in the country. These have declined, which is a benefit for the poor in both rural and urban areas, as they spend a large share of their income on food purchases.[32]

Observations of Note: The astounding transformation of agriculture in the *Cerrados* strongly relied on the adoption of new technologies developed by various actors, among whom EMBRAPA played a crucial role. The success of *Cerrado* agriculture corresponds to an improvement in land productivity (yields), which in turn induced a rise in labor productivity, thanks to a major intensification of the use of capital. The expansion of cropland in the region was made possible by the mechanization of agricultural practices, i.e., an increase in the capital to labor ratio. This success is that of a classical modern agriculture model, based mainly but not exclusively on large commercial farms.

Bt Cotton in India

The adoption of Bt cotton—plants that express a Bt protein which is protective against lepidopteron insects—by Indian farmers over the last few years has been very rapid, in fact it is one of the fastest adoption processes documented in agriculture all over the world. This transformation has taken place in spite of very vocal opposition by powerful civil society organizations, many of which are legitimate and committed to the greater public good.

Scope and Magnitude of the Successes: Cotton growers in the state of Gujarat began adopting Bt cotton in 2001, one year before the approval of the GMO varieties by the Government of India. Use of the technology spread rapidly to other cotton growing states, and between 2001 and 2008, the adoption rate by farmers across the country jumped from 1.3 to 81.1%.

This phenomenon is undoubtedly related to the fact that cotton yields increased very noticeably and quickly, at an average growth rate of more than 13% annually between 2002/03 and 2007/08. As a result, national production doubled in six years, and India became the second largest exporter of cotton in the world, with its 2007/08 crop valued at $1.9 billion. These figures, which do not cover benefits to farmers, rural areas and the economy of cotton industry overall, speak for themselves.

Criticisms and Controversies: From the beginning, many influential GMOs voiced strong opposition to genetically modified crops in India. A variety of arguments were raised, including concerns that small farmers would be hurt by failing crops.[33] While this movement was successful in delaying the adoption of Bt cotton, it could not block it. Yet it should be made clear

[31] Note here that this threat to forested areas should not be confused, as is often done in the international community, with the destruction of tropical moist forests in the Amazon region.
[32] Alves, Souza and Brandao, *Porque caíram os preços da cesta básica?* 2010.
[33] Voices of opposition by some thought leaders continue today; see www.*sumansahai-blog.blogspot.com.*

that the process over the last decade has not been smooth.[34,35] Opposition still exists, and some critics have even linked Bt cotton to farmer suicides. Concerns about farmer indebtedness resulting from crop failure remain high.

The cotton growing environment in India is quite heterogeneous, and the large number of transgenic varieties which have been approved (135 in 2007 and an estimated 150 in 2008) is a good indicator of the complexity and diversity of the adoption processes. In addition, there is an underground seed market for legal and illegal varieties, some of them being totally spurious. Low yields in some regions resulting from inadequate rainfall and counterfeit seeds have created hardships for growers and provided fodder for criticisms from those who are against GM technology.

Observations of Note: The lessons of this regional story regarding the role of modern agriculture are straightforward and important. Here again the role of science-based technological change has been critical. As in China, small holder farmers are involved; in the vast majority of cases, each grower has only a few hectares However, in this example, the private sector played a key role, with a local firm Mahyco, working under license from Monsanto, at the forefront. Even though the process has been on the whole largely beneficial to cotton growers and the local economies where they operate, there are examples of individual losers in the process, sometimes with tragic outcomes. In addition, one inherent conflict remains, revolving around the price farmers must pay for seeds. Governments have intervened to check the significant market power of seed producers, and in some instances, state governments have set seed prices. Clearly, however, the tension around pricing is not unique to Bt cotton, to India or even to modern agriculture.

West African Agriculture: A “Sleeping Giant”?

The case of Africa cannot be ignored in any reflection on the role of modern agriculture in the world. This is the continent where there has not been a green revolution, a phenomenon so striking that it is central to the name of the most encouraging initiative in recent years to boost agriculture there, the Alliance for a Green Revolution in Africa (AGRA), supported by the Bill & Melinda Gates and the Rockefeller Foundations. Fortunately, the general pessimism surrounding the growth of modern agriculture in Africa is ebbing, as reflected in the title of a recent World Bank publication, “Awakening Africa’s Sleeping Giant: Prospects for Commercial Agriculture in the Guinea Savannah Zone and Beyond,” presenting the results of a collaborative effort involving many partners.

Given the extreme heterogeneity and the sheer size of Africa, this “regional story” will be devoted to West Africa, a region that in itself is already huge and extremely diverse. More precisely, these comments focus on countries of the Economic Community of West African States (ECOWAS), which covers a large territory reaching from the Atlantic coast as far east as Niger and Nigeria, and from Mauritania, Mali and Niger in the North to the Gulf of Guinea coast in the South. This region includes a wide range of agri-ecological zones (arid, pastoral, agro-pastoral and humid forests) and production systems (cereal mixed cropping, cereal and tubers, and plantation tree crops), with many local variations. This diversity and heterogeneity must be kept in mind when discussing the aggregate performance of agriculture in the region.

[34] Smale, Zambrano, and Cartel, 2006
[35] Quaim et al.

Scope and Magnitude of the Successes: The rate of agricultural growth in West Africa over recent decades has been striking. Production of export-oriented "industrial crops" such as cotton, cocoa, coffee, palm oil, and peanuts, doubled between 1980 and 2006, from 19 to 38 million metric tons, which corresponds to a respectable average rate of growth of 2.8% per year.[36] More striking yet, the production of subsistence crops increased from 59 to 212 million tons, an astounding growth rate of 5% per year over a 26-year period.[37]

Despite uncertainty related to the data, there is no doubt that the performance of agriculture in the region has been much better than generally believed. Supporting evidence is provided by data indicating that the aggregate net agricultural trade balance of the region moved from a trade deficit in 1982-84to a net trade surplus of more than $500 million twenty years later. Of note, this change is not due to Nigeria, as the value of that country's trade deficit has not changed significantly.

Another indication of the good performance of the agricultural sector in the region is found in the breakdown by subsectors. The production of cereals (particularly maize), cotton, fruits and vegetables increased rapidly, consistent with what multiple partial indicators suggest. The growth of fruits and vegetables is especially noteworthy since this seems to correspond to increased demand from a swiftly growing urban population benefiting from better incomes. By contrast, livestock production increased at a slower pace, and it is estimated that the availability of meat is only 8.7 kg/person/year and milk availability is a very low, 7.7 liters/person/year.

Primary Success Factors: The primary causes of agricultural growth in West Africa can be outlined as follows:

- **Expansion of crop area.** This has been the most important factor of growth; cropped area increased by 229%, from 35 to 69 million hectares, between 1980 and 2005. This extension has mainly been driven by demographic pressure, and there is a demonstrable link between population density and the proportion of cultivable land actually under crops. A variety of factors have contributed to more land coming under cultivation, including elimination of diseases and deforestation to plant coffee and cocoa trees in the humid forests. Deforestation, however, only accounts for one third of the increase in cultivated area; the majority of the expansion was on to previously fallow land.
- **Intensification of agriculture**. Although it has not been to the degree advocated by almost all the agronomists, governments, donors, domestic and international NGOs who have worked in Africa for decades, some intensification has taken place. Average yields have increased for several, if not all, crops, and total calories available for human consumption have also increased.
- **Research.** Yield increases for maize and cassava are largely due to new varieties brought by public research institutions, such as the Consultative Group on International Agricultural Research (CGIAR). Control of the cassava mealy bug , which can cause great damage to the crop, can also be attributed to public research.
- **Export growth.** Plantation and industrial crops comprise much of the agricultural growth witnessed in West Africa, as noted earlier, and exports of these crops have been instrumental to wider economic growth in these nations. For example, cotton exports

[36] Blein et al., 2008.
[37] These estimates are based on FAO data supplied by member governments, and as such there are inherent questions of credibility, particularly related to data from Nigeria, the largest economy in the region (Fuglie, SSA, 2009).

comprise 90 percent of total exports in a nation like Mali and generatemore than 80 percent of the government's fiscal resources.

Criticisms and Controversies:
Even as production has increased and agricultural land has expanded, increases in yields have been relatively minor: sorghum and millet hardly increased, maize has increased about 70 percent, and rice and cassava 55 percent. Thus, there has been extension but limited intensification of agriculture, fueling concerns about soil degradation and production practices that are not sustainable.

The lack of intensification in West African agriculture can largely be explained by economic fundamentals. West Africa, like the rest of the continent, has an abundance of land and labor, but capital is very scarce. In such conditions, it makes economic sense to respond to a growing demand by expanding the area under cultivation and to do so through labor intensive practices, using labor intensive technologies. The problem of course is that this does little to improve labor productivity or the income situation of the workers. All indicators of poverty illustrate the poor performances of West African countries on this front. For instance, 11 of the 15 ECOWAS countries belong to the "least advanced countries" category in the United Nations classification. In addition, rural poverty is remains high in countries such as Nigeria, which does not belong to the LAC category only because it exports large quantities of petroleum products.

Observations of Note: Many reasons have been suggested to explain the mediocre performance of African agriculture. Undoubtedly, many public policies have been extremely unfavorable. Also, a great majority of the "modern" institutions initially put in place by the colonial regimes and subsequently developed after independence are dysfunctional. This is particularly true in the field of agricultural research. Little sustainable progress will be feasible without addressing those issues. A discussion of these concerns, however, is outside the scope of this paper. Focusing on the role of modern agriculture, several points offer promise for the future:

- **Small holders must be at the center of any development strategy**. Establishing new large scale, capital intensive production units implementing modern practices could increase agricultural production and raise average yields, but the risks of social catastrophe under such a strategy are high. More than 70 percent of the population in West Africa resides in rural areas, and a move to large scale agriculture would leave many of them with no viable income stream. Consequently, small holders must be the key actors in agricultural growth — a challenge facing modern agriculture.
- **The solution must include support to farm organizations, a pro-business approach to agricultural development—particularly for collective actions by farmers' groups, a major boost in public and private investments, and a profound revamping of agricultural research and education.** One piece of good news is that the Gates Foundation, the new significant face on the scene, seems to take seriously the challenge of revamping agricultural research and education.
- **Multinational corporations must invent the business models that will yield the sufficient level of profits in the short to medium term to allow them to stay engaged long enough to take advantage of long-term opportunities.** Importantly, these models also must contribute to a far-reaching general strategy that contributes to development and prosperity in Africa, where they would find an amicable environment in the long term.

<u>The French Debate on "Productivism"</u>

French agriculture went through a true revolution during the three decades following World War II. Yet its undeniable success, due essentially to modern agriculture, has come under sharp criticism, here again largely because of negative unintended consequences of the modernization process. Of specific interest for our purpose is the use of the word "productivism" to characterize both the excesses of modernization and the doctrine underpinning the many public policies that promoted modernization. The term reflects the conviction that the essence of the modernization process has been the search for increased productivity.

Scope and Magnitude of the Successes: Before the war the French agricultural sector had been more stagnant than in other European countries. The annual rate of growth of output was 0.76% in France over the 1880-1930 period, compared to 2.07% in Denmark and 1.32% in Germany. Progress in labor productivity was also slow: 1.16% per year in France compared to 1.66% in Denmark and 1.42% in Germany. Declining prices during this period (in both real and current terms) and abundant labor supply due to overpopulated small farms and cheap rural wages reduced the incentives for innovation and structural changes. The French agricultural sector was depicted as poorly organized, characterized by low productivity, resistance to technical innovation and protection from international competition through high tariffs.[38,39,40] Sluggish demand for agricultural products and the absence of institutional infrastructure to support growth also contributed to the lack of growth in the French agricultural sector.[41]

After the war, promoting industrial development was seen as a high priority. Modernization of agriculture was perceived as the best way to reduce high food prices and the growing agricultural trade deficit at a time the country was struggling with both its trade balance and its balance of payments. The large number of small farmers, poorly educated and lacking capital, was seen as the main reason for the poor performance of agriculture. Modern techniques were not commonly employed, and yields were low. This resulted in both high production costs and low farm incomes, pushing public authorities to support prices at high costs to consumers and taxpayers.

This diagnosis led to the adoption of an array of modernization policies, and the resulting transformation of agriculture was indeed profound, as well as relatively rapid, with the following changes occurring between 1955 and 2007:[42]

- Number of people working in agriculture decreased from approximately 6 million to 1 million,
- Number of farms declined from 2.3 million to 500,000,
- Fertilizer use increased until 1979, then began declining in the early 1990s, and
- Crop and livestock yields roughly doubled in approximately 35-40 years, but with slowdowns occurring after 1988, particularly for wheat.

The value of agricultural production grew, particularly between 1963 and 1988, but the rate of growth even during that period, around 1.4% per year, pales in comparison with growth rates in China, Brazil or India previously cited. Note that growth slowed down after 1988, whereas the structural transformation of the sector, reflected by the average size of farms, continued. Finally, the balance of trade became positive, with a surplus of above 2 billion Euros in the 2000's.

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[38] Grantham, 1975.
[39] Hohenberg, 1972.
[40] Roehl, 1976, cited in Ruttan, 1978.
[41] Ruttan, 1978.
[42] Agreste (French Ministry of Agriculture Statistical Service), INSEE, FAOSTAT.

Primary Success Factors:

- **Expansion of support to agriculture**. Measures included investment in research, improved agricultural education and extension, and allocation of subsidies to support farm mechanization, as well as land consolidation.
- **Increase in farm size.** Specific measures were adopted to encourage older farmers to retire and leave their land to younger farmers established on larger farms. These measures were later prolonged and strengthened when a structural policy component was added to the common market regimes within the European Common Agricultural Policy (CAP).
- **Growth in the wider economy.** In addition to public policies, a powerful force of modernization was exerted by the pull of labor out of agriculture resulting from a rapid and steady general economic growth during the thirty years following the war, a period called tellingly in French: "les trente glorieuses."

Criticisms and Controversies: The first criticisms of the modernization process came from agrarian conservatives, who lamented the "exodus" from the countryside, the loss of traditions and often implicitly, the loss of conservative voter support from rural areas. This criticism was soon picked up by those concerned about the growth of Paris and its suburban area and the "desertification" of the rest of the country.[43] Although land use policies were developed to address the population imbalance, concerns for balanced territorial developments remain very much alive and have influenced the implementation of several agricultural policy measures that have likely slowed the modernization process somewhat.

The greatest controversies, however, were caused by the structural transformation process itself. Those who were forced to leave agriculture in search of better economic opportunities had little voice in the debate. Many medium-size farmers opposed the straightforward concentration process, which they felt unfairly favored larger farms. In the early 1960's some farmer groups successfully fought for a series of structural measures, slowing down the concentration process and favoring the emergence of a new group of modern, medium-size farmers.

Many farmers attempting to catch the train of modernization were faced by what has been called in the United States the technological "treadmill": striving modernize and grow, becoming more and more indebted, and seeing one's income stagnate, leading to pressures for higher support prices and other forms of government support.[44] Another criticism of the process related to the growing dependency of farmers on private companies, sometimes large ones, selling inputs or buying products. Here, the concentration in both the input supply industry and in the agri-processing sector was perceived as a threat to farmers because of unequal market power relationships.

More recently, new societal concerns have changed the nature of the public debates about agriculture, with more stakeholders involved and new issues being raised both about food safety and environmental impact. Modern agricultural practices have been held responsible for a series of food safety issues, ranging from dioxin in poultry meat to mad cow disease caused by industrial livestock feed. Environmental concerns related to "productivism" in agriculture and its excesses have also been raised, including water pollution due to nitrates and effluents from large

[43] Gravier, "*Paris et le desert François,*" 1947.
[44] Cochrane.

livestock feeding facilities, underground water depletions caused by excessive pumping for irrigation, and loss of biodiversity caused by drainage of wetlands and elimination of hedgerows.

Observations of Note: Having successfully confronted the twin challenges of increasing both production and labor productivity in the decades following World War II, French agriculture must now face very different challenges. Modern agriculture played a critical role in past successes. It also can greatly contribute to the solution of the new problems, but it will have to adjust significantly in order to do so. Beyond the food safety preoccupations already noted, issues of food quality include concerns for taste, authenticity and even cultural identity, which explain the popularity of Geographic Indicators and organic foods. Attention has shifted to entire value chains, including the agricultural input industry, farmers, food processors and food retailers, and it is in this broader context that the role of modern agriculture must be discussed.

Concerns for the environment, harmony in land use, the quality of landscapes and more generally, for the amenities of rural life led to the invention of the concept of multifunctionality. In the same vein, the European Commission proposed the idea of a specific European model of agriculture that was less intensive and more responsive to these new societal concerns.

Modern agriculture has much to contribute in these new situations, because many of the solutions to these problems are knowledge intensive, and science is obviously a powerful source of new knowledge. One challenge as new technologies and practices are developed will be to find ways to combine new scientific knowledge and traditional sources of knowledge, often embodied in old traditions.