THE GLOBAL FOOD CRISIS
Causes, prospects, solutions

Albert SASSON

Publication supported by the Hassan II Academy of Science and Technology
Rabat, Morocco

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Dépôt légal n° 2009/2052
ISBN n° 978-9954-8908-7-4

Edited by : **AGRI-BYS** s.a.r.l (a.u)

PREFACE

The Hassan II Academy of Science and Technology has been created by a Royal Decree on October 6, 1993 and enjoys the protection and tutorship of His Majesty the King of Morocco. The Academy's missions are to promote scientific and technological research particularly through assessing, supporting and funding research programmes and projects; to issue recommendations on the national science and technology policy and priorities; and to contribute to the dissemination of scientific culture and progress.

In addition to the *Proceedings* of its sessions, and in particular of its annual plenary session devoted to a specific theme of worldwide relevance, the Academy publishes a *Bulletin* and a *Newsletter*. It also promotes and supports publications and reports dealing with subjects of interest to its scientific sections. This publication, authored by Professor Albert Sasson, a founding member of the Academy, reviews the symptoms and causes of, and solutions to, the global food crisis that hit the world in 2007-2008 and which was the general theme of the Academy's plenary session in February 2009.

The Academy is very glad to support the publication of this review by one of its distinguished members who enjoys a long-standing reputation for disseminating scientific and technological knowledge, especially with respect to biotechnology in developing countries over the last 36 years.

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INTRODUCTION

In February 2008, financial markets experienced the combination of rising inflation and unemployment in the United States that reminded people of the decade of stagflation that ended the postwar period. Then was issued the report that the United Nations' World Food Programme might have to reduce food aid. This was announced when food prices were rising worldwide. Global food prices had risen in February 2008 by more than 75% since their lows of 2000, jumping more than 20% in 2007 alone (Thirlwell, 2008).

Soaring food prices have also revived some contemporary worries. When China's annual inflation rate climbed up to an 11-year high in January 2008 in the context of an 18% increase in food prices, China observers recalled the food-price rises of 1988 and the subsequent social unrest and protests that followed. Inflation is often considered a major factor behind the major demonstrations in 1989 (Thirlwell, 2008). In an article published on 17 April 2008 in Le Monde newspaper, Jacques Chirac, former president of France stated: "The world is confronted to the spectre of great famines, while it is going through a dangerous financial crisis… "this convergence of dangers implies an unprecedented risk for the world" (Chirac, 2008).

In September 2008, the United Nations secretary-general, Ban Ki-moon, stressed that the world was facing a financial, an energy and a food crisis, and that once again the negotiations on international trade had failed. He indicated that in September 2007 one ton of rice cost US$330, while one year later it rose to US$730; consequently consumers had to reduce their diet and those used to eat twice a day only did once. The United Nations intended to supply seeds and fertilizers to small farmers, a new "green revolution" was sought in Africa, but additional resources were lacking. The acts of the international community were not matching its speeches (Ban Ki-moon, 2008). He went on to state that climate change was the major problem of our time and that a common vision must be shared when a new global agreement on climate change will replace the Kyoto Protocol after 2012. The millennium development goals were to bring adequate solutions to the eradication of extreme poverty and to the glaring needs of humankind, such as access to drinking water, sanitation,

decent housing, electricity, etc., but progress is slow and uneven, so that in 2015 promises will not be held. However, we know that these goals are within our reach. The real challenge in this new world is increasingly that of collaboration, not of confrontation. A country cannot anymore defend its interests or improve the well-being of its population without partnering with other countries. Consequently, the whole action of the United Nations is based on the duty of responsibility (Ban Ki-moon, 2008).

Former President Jacques Chirac came to the same conclusion on 17 April 2008, when he stated that the international community ought to comply with its responsibilities in order to confront the global food crisis, within a full North-South cooperation, and focusing on precise objectives :

- first and foremost, taking the urgent measures aimed at avoiding the destabilization of the States that are most exposed to the food crisis, e.g. urgent and sustainable support for the World Food Programme, and this is a question of solidarity among all nations, particularly from those rich and powerful ones and those which derived huge profits from the increase in oil prices;
- secondly, think of another mode of development, particularly in the agricultural area, and act according to this new paradigm (Chirac, 2008).

SYMPTOMS

Soaring food prices

A historical perspective

Wheat and bread, a staple food and symbol in Europe, have a very old history associated with their supply at an affordable price to the consumers – a major concern of those in charge of government and holding the political power.

During the Antiquity, the priority task of those governing the cities was to feed the people and to ensure a sustainable supply of grains: wheat was bought on the markets of eastern Mediterranean countries, particularly Egypt. Later on, after conquering Sicily, North Africa and Egypt, Romans could make sure that bread was available in their towns and social unrest was avoided to a large extent (Chalmin, 2007).

The history of Europe since even before the Middle Ages until the late 1940s has been characterized by periods of famine and shortage of grains. Wheat trade has been for a long time controlled by the cities of the Hanseatic League, that linked the plains of Poland and Ukraine to the North Sea. The public management of agricultural markets was not always fair and it is not surprising that one of the first publications of politic economy of the Enlightment century dealt with the issue of free trade of wheat; titled *Dialogues sur le commerce des bleds,* it had been written by Ferdinando Galiani, a clergyman of Naples who used to attend Parisian cenacles (Chalmin, 2007).

France's history is full of riots due to the lack of bread. Speculators were generally the target of angry mobs; grains and flours were often confiscated, and a "fair" price was sometimes applied according to collective norms ("popular taxation"); often supported by local authorities, women took the lead of an uprise or of people gatherings,

always considered a sign of serious social unrest by the power. People gathered to prevent the transport of cereals at night, considered suspicious (Kaplan, 2008).

The common element between the French historical experience and the contemporary dramas is the political characteristic of the bread issue. The classical illustration is the march in 1789, during a major food shortage period, of thousands of women to Versailles, in order to bring back to Paris the royal family, who could guarantee the supply of bread. The social contract of subsistence which Louis XVI did not respect, is still today the tie between those in charge of government and their fellow citizens. The lack of bread is always the fault of government according to the consumers (Kaplan, 2008).

In 1947, 6,000 people invaded the facilities of the Nièvre prefecture upon hearing a rumour about the export of a large volume of wheat to a foreign country; while the communist trade-union (CGT) was organizing "night sentinels" near the city of Caen to thwart a "mysterious trafficking of wheat". There was a consensus among those who took to the streets: they wanted bread in sufficient quantity, at an affordable price and of a reasonable quality (Kaplan, 2008).

These demands had been well expressed by the French writer Jules Romains on the eve of the 20th century: "Let us raise bakery at the level of a national institution: free and compulsory bread", a programme as utopian for France at that time as today for the poor countries where food riots took place after food prices soared (Kaplan, 2008).

Immediately after the second world war, in a context of durable food penuria, the political issue of bread was again raised like during the Enlightment period: bread imposed the political fundamental choice between a liberal economy and a state-directed one. Beyond the issue of subsistence, the responsibilities of the state had to be redefined and how one should lead the modernization of France at the political and institutional level (Kaplan, 2008).

Nowadays, as formerly, the issue remains a political one. When the Egyptian regime has mobilized the army in 2008 to make and distribute bread, after riots burst in front of bakeries, it was because it feared a national uprise against the lack of subsidized bread. In 1951, in France, where bread quality was questioned, the people used to say: "bad bread, bad government" (Kaplan, 2008).

One cannot nevertheless exclude the role of natural factors such as weather vagaries (drought, floods) in the generation of food shortages, but inappropriate decisions and / or choices play a key role and should be revised, in both the developed and developing countries to find and apply the right remedies. In other words, according to Kaplan (2008), bread as a shared food inspires solidarity with those who cannot afford it, but it would be better if, beyond compassion, a real political reflection is undertaken to tackle the shortage and affordability issues.

Regarding wheat trade, the market became increasingly global during the 19th century with new suppliers such as Argentina, the United States, Australia and Russia until 1914. While shortages were less frequent, at least in the developed countries, surpluses had to be managed from the 1920s, as well as the collapse in prices for the farmers. The first agricultural policies aimed at stabilizing commodity prices as well as the farmers' income were initiated with wheat. In France, for instance, the wheat office was created in 1936 and this was the beginning of an era of stable prices for the French, and later on the European, consumers (Chalmin, 2007).

At least until 2003, the European price of wheat had been controlled by the European Commission; the price fluctuation margins were strictly controlled, once the prices had been fixed by the council of agriculture ministers at the beginning of each campaign. Since 2003, the European Commission started to be less rigorous; there is still a bottom price (intervention price at €101 per ton), but the ceiling price has virtually disappeared. Consequently, when the international price is higher than the intervention price, as it occurred in 2007, the wheat price (fob Rouen) varies in tune with other export prices (Gulf of Mexico, Rio de la Plata and Black Sea) and with the prices on the Chicago market. Thus, after seventy years of administration and political regulation, French producers and consumers discovered the instability of wheat prices (Chalmin, 2007).

Chalmin (2007) considers that, beyond the concerns raised by the food crisis and soaring food prices, wheat has lost part of its economic importance in developed countries: in France, wheat represents only 5% to 10 % of the cost of a loaf of bread. By contrast, the current level of wheat and other agricultural commodity prices should draw the attention to the major challenge of the 21st century which is to feed the world and the poor who really suffer from the "wheat crisis".

Fluctuations of food prices

Cereals

Over the past half-century grain prices have spiked from time to time because of weather-related events, such as the 1972 crop failure in the former Soviet Union that led to a doubling of world wheat, rice and maize prices. Surges in food prices in the 1970s and then again in the mid-1990s both prompted warnings that agricultural capacity was failing to keep pace with a growing world population. Each time, the prices rose it proved to be temporary as supply responded. The situation today is considered entirely different, as the doubling of grain prices (or even more) is trend-driven, the cumulative effect of some trends that are accelerating growth in demand and other trends that are slowing the growth in supply (Brown, 2008).

By early September 2007, at Chicago's market, the price of wheat rose above US$8 (€5,85) a bushel (≃27 kg) for the first time in history, i.e. three times its price seven years earlier and a level close in real value to that of the early 1970s, the era when food was used as a weapon. In 1996, at Chicago's market, the record price was US$7,50 a bushel. In Rouen, the main French exporting port of wheat, the price soared to €280 per ton "free on board (fob)", while in 2005-2006, it did not rise beyond the €100-per-ton threshold (Chalmin, 2007).

In September 2007, on the world market, the price of rice reached US$330-340 per ton and that of maize was slightly above US$150 per ton. It was also estimated that the bill of grain imports in 2007-2008 would increase by 22% for Africa, 17% for Europe, 7% for Asia, 6% for the Pacific and 1% for Latin America and the Caribbean. Over the period 2000-2007, the bill of food imports had increased by 90% for the least developed countries, compared with +22% for the developed ones. It should be recalled that the share of food in household's expenses varies between 60% and 90% in the least developed countries compared with 10% to 20% in the developed ones (Clavreul, 2007f).

Soybeans

The United States is the world's largest soybean producer, with a market share of about 38%, according to the Deutsche Bank. It is the country's third most cultivated crop, after maize and wheat with production concentrated in the States of Illinois and Iowa. Brazil and Argentina are the

second- and third-largest producers, with the two countries supplying about 44% of the world's total (Blas, 2007).

Soybean prices have risen to their highest level in 34 years, boosted by strong Chinese demand and fears that current prices are not high enough to swing acreage from maize to soybeans in the United States. In Chicago, by the end of November 2007, soybean prices hit US$11.14 a bushel, the highest level since July 1973, helped by rising demand from the agrofuel industry as crude oil prices approached US$100 a barrel and also by worries about the Brazilian crop after dry weather in Mato Grosso State, the key producing area. On 28 November 2007, soybeans traded at US$10.85 a bushel. This price rise threatened to impact the supply chain, boosting meat and poultry prices because soybean is used largely for animal feed, analysts warned (Blas, 2007).

Food inflation was clearly a major concern for policy-makers in developed and developing countries. German inflation had hit 3% in November 2007 for the first time since at least 1995 on higher food and energy costs. Peter Thoenes, an oilseeds specialist at the Food and Agriculture Organization of the United Nations (FAO), stated that Brazil and other South American soybean producers were key to offsetting the shortfall from the United States, after farmers in the world's largest soybean-growing region converted some of their acreage to maize. The lower soybean harvest coupled with higher demand for animal feed and for some biodiesel production had led to a fall in global stocks, with the stock-to-use ratio at the lowest level for at least five years, according to FAO estimates. By the end of 2007, stocks were equivalent to 10% of annual demand (Blas, 2007).

World oil, the Hamburg-based consultants, on 28 November 2007, stated additional large-scale Chinese purchases were "likely in the near to medium term". China is the largest world importer, purchasing about 40% of the world's traded soybeans, followed at a large distance by the European Union and Japan. Concurrently, the US soybean-planted area dropped in 2007 by about 16% to 63.7 million acres, according to the US Department of Agriculture (USDA). This acreage fall, together with lower yield productivity, cut soybean supply to 2.6 billion bushels, down 19% from 2006 record production. Traders were of the opinion that without more production from Brazil and the United States, the cost of soybeans would remain high. Gavin Maguire, of Iowa Grains in Chicago, stated that "soybeans will need to scale the US$12-a-bushel mark, in order to establish the key 3-to-1 ratio (with respect to US$4 a bushel of maize) that would bring about a ramp-up in soybean production" (Blas, 2007). However, by mid-

2008, due to the financial and economic crisis, soybean prices (as well as those of other agricultural commodities and raw materials) have tumbled, but it was forecast that in the medium term they would increase again.

Vegetable oils

In 2007, the food price index of the FAO, based on export prices for 60 internationally trade foodstuffs, climbed 37%. That was on top of a 14% increase in 2006, and the trend had accelerated during the winter of 2008. No category of food prices had risen as quickly as so-called edible oils. In the developing world, cooking oil is an important source of calories and represents one of the biggest cash outlays for poor families, who grow much of their own food but have to buy oil in which to cook it (Bradsher, 2008a).

Palm-oil price had jumped nearly 70% in 2007 because supply had grown slowly while demand had soared. A drought in Indonesia in 2007 and flooding in Peninsular Malaysia helped constrain supply. At the same time, palm-oil demand is growing steeply for a variety of reasons: rising consumer demand in China and India for edible oils, and western subsidies for agrofuel production. China was the world's biggest palm-oil importer in 2007 and it also doubled its soybean oil imports (Bradsher, 2008a).

Palm-oil was long regarded in the "Western" world as unhealthy, but it has become an attractive option to replace the chemically altered fats known as transfats, which have come to be seen as the least healthy of all fats. Across the United States, manufacturers are trying to replace transfats, and US palm-oil imports nearly doubled in the first 11 months of 2007 (Bradsher, 2008a).

Many of the hardest-hit victims of rising edible oil prices were in the vast slums that surround cities in Africa and in poorer Asian nations. The people living there had to cut on their food ration, seldom cooking vegetables, and slashing their staple food consumption.

Milk products

Soaring grain prices and costs for feeding livestock had an important impact on the prices of milk and milk products. For instance, in Japan, there has been a strong decrease in the supply of butter for several weeks during the first quarter of 2008. This was due to a collapse of milk production that fell down from 8.1 million tons during the fiscal year

(1 April-31 March) 2006 to 7.3 million tons a year later. The very warm summer of 2007 had a negative impact on yields, while the number of milk farms has been steadily decreasing (Mesmer, 2008).

To improve the supply of butter, the island of Hokkaido – the main agricultural region of Japan – increased its milk production by 3% in March 2008. But this was not enough. Industrial bakeries and confectioneries started buying all the available butter stocks in order to avoid imports. Japanese consumers had therefore to wait or to buy foreign products, particularly French butter, sold at the supermarkets for about 1,900 yens (€11.6) the 250 g (Mesmer, 2008).

This problem illustrates the difficulties of Japan's food supplies. Nowadays Japan can meet 39% of its caloric needs, compared with 70% after the second world war. Japan meets its rice needs, and to lesser extent those concerning vegetables, but this is not the case with regard to fruit, meat or fish. Having the financial means to provide an adequate supply of food, Japan did not modernize its agricultural sector. The latter contributes to only 1.4% of gross domestic product and includes 2.9 million farms, 98% of which have an acreage of less than 2 hectares. And 77% of the farmers are more than 55 years old (Mesmer, 2008).

In April 2007, a law modified the country's agricultural policy, and the policy of supporting prices was gradually abandoned. The improvement of competitivity is emphasized instead of pouring subsidies and overprotecting the domestic market against imports. The Japanese government encourages the settlement of young farmers, the cultivation of fallow land and the enlargement of farms. The goal is to increase the food self-sufficiency rate. Japanese authorities also wish to reassure consumers about the quality of imported products, particularly from China. Since January 2008, when the scandal about raviolis made in China contaminated by a pesticide was publicized, food imports from China have decreased by 40% creating a supply problem for Japanese restaurants (Mesmer, 2008).

Impact of the 2008 financial and economic crises

Tumbling of agricultural commodity prices

In August 2008, when the price of oil fell under US$120 the barrel, and therefore lost 20% compared with its peak of US$147.27 on 11 July 2008, maize (at Chicago's market) also went down to US$5.45 a bushel (Clavreul, 2008f). In September 2008, wheat prices on the international

market decreased by 7% compared with those one year earlier; maize prices were also on the downward trend, but remained 44% above those of September 2007. Such a decrease, qualified by the experts as simple "correction", was due the good news about world grain production in 2008 and to the drop in oil prices (Clavreul, 2008f).

For instance, in France production of soft wheat increased 20% to over 36 million tons in 2008. For the first time in 24 years, France grew wheat on 7.68 million hectares, i.e. 294,000 hectares more than in 2007, including 257,000 hectares for soft wheat. The acreage devoted to soft wheat - a major crop in France - could reach more than 5 million hectares. Durum wheat, maize and barley productions also increased. This favourable situation resulted from both the good yields that reached their usual level (after having decreased in 2007 due to bad weather conditions), and the increase in acreage, further to the European Union's decision to withdraw 230,000 hectares from fallow and cultivate them, i.e. 19% of total fallow land (Clavreul, 2008e). In France the increase in the acreage devoted to wheat was accompanied by the decrease in the acreage of oilseed crops (rapeseed, soybeans and peas): 135,000 hectares only were cultivated with these crops in 2008, compared with 600,000 hectares ten years earlier. As a result, wheat exports were to follow the increase of production: about 5 million tons, i.e. twice the 2007 amount. However, French wheat was relatively less exported than during the former campaign. Buyers like Egypt or Tunisia preferred to deal with Russia or Ukraine whose wheat was less expensive (US$ 60 per ton) [Clavreul, 2008e].

From its highest price of US$12.80 a bushel in February 2008, wheat tumbled by 60%, down to US$5.14 by the end of October 2008. However, on 14 November, at Chicago's market, the price of the wheat bushel was up to US$5.54, a slow but significant increase. According to Emmanuel Jayet, in charge of Agricultural Products at Société Générale Cross Asset Research, the period of falling prices was coming to an end and he forecast an increase in 2009. Another sign of this regain of wheat prices was the decision made by Japan to buy 100,000 tons of US wheat on 13 November 2008, after several months on stand-by, because of new sanitary regulations, but mostly because it was waiting for even lower prices (Faujas, 2008b).

It is true that since March 2008 the wheat harvest forecasts were very good, after two catastrophic years due to drought and weather vagaries. World production indeed was to reach a record 682 million tons for the 2008-2009 campaign that ends on 31 May 2009 (Faujas, 2008b).

Another reason for the non-decrease in wheat prices was that this cereal is above all devoted to human food and not to feeding livestock or producing bioethanol, such as maize and soybeans. One may eat less meat (7 kg of maize are needed to produce 1 kg of beef) or use more gasoline that has become more affordable, but there is no substitute for wheat for an increasing human population (Faujas, 2008b).

Impact of credit crunch

The collapse of global credit markets that occurred in the fall of 2008, pushing the United States, Europe and Japan into economic recession, also threatened farmers in Brazil, the world's biggest grower of coffee, citrus and sugar-cane, the second-largest producer of soybeans and third-largest of maize. Smaller harvests in Brazil were expected to increase cost of commodities in 2009, according to Andre Pessoa, an analyst at Agroconsult, who was conducting the country's broadest crop survey (Caminada, 2008).

Futures contracts in Chicago showed maize would jump 18% by the end of 2009 to US$4.1775 a bushel and soybeans would gain 2% to US$9.015 a bushel. Coffee would rise 10% to US$1.2545 a pound (Caminada, 2008).

Reduced fertilizer use would lower Brazil's soybean output as much as 2.7%, while maize might decline 7.3%, the government stated on 6 November 2008. Brazil's coffee harvest might drop 26% in 2009, stated Lucio Araujo, the commercial director at Cooxupe, a cooperative representing 11,000 growers in the Guaxupe region. Brazilian growers were short of at least 15 billion reais needed to invest in crops, agriculture minister Reinhold Stephanes stated on 9 October 2008. Bank and financial companies worldwide, suffering from US$969.5 billion of losses and write downs since the beginning of 2007, were restricting credit as they struggled to replenish reserves, according to data compiled by Bloomberg (Caminada, 2008).

The growth of Brazil's economy, the biggest of Latin America, might be cut in half in 2009 after credit dried up and slumping commodity prices reduced export revenue, stated Central Bank president Henrique de Campos Meirelles on 21 November 2008. He did not provide a specific forecast. The expansion would slow to 4.9% in 2008 and 3.6% in 2009, from 5.4% in 2007, according to a Bloomberg survey of 12 economists (Caminada, 2008).

Brazil freed about 20 billion reais of bank reserves for farm lending to alleviate damage from the credit squeeze and falling prices. The measures failed because lenders were hoarding cash. Banks were expected to hold funds until at least the end of the first quarter of 2009, stated Jose Antonio Gragnani, chief financial officer of Concordia Banco, the finance arm of Brazilian food-maker Sandia that lends to producers. Agricultural traders and crop processors including Archer Daniels Midland Co., Bunge Ltd. and Cargill Inc., have pared loans, stated Eduardo Daher, who represented the firms as president of the National Association of Fertilizer Distributors. The companies, which were the source of about a third of the farm credit in Brazil, funded farmers in exchange for part of future crops as payments (Caminada, 2008).

As Brazilian farmers might receive smaller than expected loans to buy fertilizer and pesticide they would be forced to scale back on plantings. Pedro Arantes, a farmer in Rio Verde in the centre-western State of Goías, stated he might cut maize production by about two-thirds after Bunge and other crop processors stopped financing his purchases and prices slumped. But Archer Daniels Midland's ability to provide credit to farmers in Brazil has not been affected by the credit crunch. Minnesota-based Cargill also stated that the amount available for financing increased 42% from 2007 to US$400 million. Nevertheless, if farmers reduced their plantings in 2008-2009, either because of the lack of credit or because of slumping prices, commodity prices would rise again in 2009 and 2010 (Caminada, 2008).

Fall of raw material prices

Another example of the fall of raw materials prices is that of metal ores. In 2006, copper traded at highs close to US$9,000 a ton. By October 2008, the impending global recession had driven the price below US$4,000. As a consequence, in Zambia's copperbelt region that stretches over the Congolese border, in Chingola, exploration projects have been stopped. Labour unions were braced for job losses and forecasts for future orders were bleak (Burgis, 2008).

"Zambia has done very well for five to six years when it rode the international wave of copper prices", stated Kapil Kapoor, the World Bank's country manager. He estimated that Zambia's government stood to lose out on annual revenues equivalent to at least 2% of total economic output, which it had hoped to channel into infrastructure investments. In Zambia, a landlocked country of 12 million poor and Africa's biggest

copper producer, the dependency on the metal is high. Copper, used mainly for electrical wiring, and cobalt accounted for 85% of exports and one in ten of all formal jobs in 2008. "Copper is the backbone of Zambia", and mining minister, while having to review the situation of some 20 exploration projects, was not ready to back down on plans to impose stricter terms on the foreign mining companies that bought prime assets in cut-price privatizations at the beginning of the decade. He stated that "the tax regime was designed to keep mining companies viable but the government had to take a bit more to support our own social and economic investment" (Burgis, 2008).

Mining investors – many now operating at close to the cost of production – were threatening legal action and warning of damage to Zambia's reputation. Over the border in the Democratic Republic of Congo, several mining corporations have suspended or delayed operations. Katanga Mining was reviewing plans to revive the country's biggest underground copper mine. Across much of sub-Saharan Africa, the story is the same. The region's mineral resources have fuelled its recent growth, but analysts foresaw depreciating currencies widening deficits and evaporating mining investment in at least 11 countries. Mozambique's future is linked to its bauxite seams, as are Namibia's to its diamond fields. Each was relying on commodities for two-thirds of their exports in 2008 (Burgis, 2008).

Ore-dependent countries were expected to rely on a continued demand from fast growing Asian giants and emergent economies. Yet price declines could distort the terms of the US$9 billion commodities-for-infrastructure deal Congo struck with China at the height of the boom in 2007. In Zambia, decisions by the Indian groups who controlled the biggest mines were to be all important. Deb Bandyopadhyay, resident director at Vedanta's Copperbelt venture stated rising costs were forcing him to ramp up and entering talks with unions on "restructuring". The government aimed to double copper production to 1 million tons a year by the end of the decade by attracting investments such as the Chingola smelter, Africa's biggest, in northern Zambia (Burgis, 2008).

Lonmin, the world's third-largest platinum miner, announced on 18 November 2008 it was cutting output and investment at its South African operations, providing more evidence that the decline in world metal prices was beginning to affect the country's mining industry. A thousand contract jobs of Lonmin's Marakana open coast mine were to go immediately with a further 1,620 potential job losses at the company's Limpopo operations (Lapper and MacNamara, 2008).

By mid-November 2008, Uranium One of Canada suspended its operations at its Dominion mine with the loss of 1,000 jobs. And 1,700 workers could be laid off at the ERPM mine, where gold producer DRD suspended operations by early November 2008. But in an industry that employed more than 300,000 people by October 2008 the eventual scale of the contraction could be much greater. Platinum producers such as Lonmin could come under particular pressure mainly because demand for the metal, used in catalytic converters in motor-cars, was particularly vulnerable to a slowdown in global demand (Lapper and MacNamara, 2008).

Impact on Latin American countries

In the case of Latin American countries, the reliance on raw materials exports has long kept their economies from diversifying, driving them to take on huge foreign debt and triggering some of the world's biggest defaults. However, as commodity and raw materials prices soared in recent years, governments used that cash to pay back debts and build up reserves. Some countries rely on commodities exports for nearly half of government revenue and hundreds of millions of jobs (Bradley and Sibaja, 2008). Chile, for instance, had saved US$21 billion derived mainly from windfall copper revenues in reserve funds, and the government unveiled by the end of 2008 stimulus measures worth US$2 billion, including credit lines for small and medium businesses, and sectoral bail-outs for salmon farmers and housebuilders. Similar public savings could help the countries combat the global credit crunch resulting from the 2008 financial crisis, possibly enabling a rebound by 2010.

Prices for commodities including crops, metals, oil and other raw materials had dipped by a third by mid-October 2008 from their July peak. Latin America's major stock indices have lost at least 20% of their value during the first half of October 2008, as many investors pulled cash from emerging markets. Brazil's commodity-heavy benchmark Bovespa index had been leading losses, down 35% since 25 September 2008. Add to that the ways the financial crisis had dried up credit for farmers and mine operators, so that "it is difficult to determine whether this financial instability would be temporary or whether it would cause lasting harm", stated Luis Moreno, president of the Inter-American Development Bank (IDB). Investors worried that Argentina, one of the world's top grain exporters, might not be able to maintain a budget surplus and keep servicing its debt now that soybean and wheat prices had sunk more than 40% from their 2008 record peak. Chile, the world's top copper

producer, had its first trade deficit in eight years in September 2008, after copper prices had slid 45% since May 2008 (Bradley and Sibaja, 2008).

The hardest-hit countries were likely to be oil-reliant Venezuela and Mexico, according to analysts. Both draw more than 40% of their national budgets from oil, which had dropped drastically to hover around US$40 a barrel by December 2008, since hitting a record high of US$147.27 a barrel on 11 July 2008. In Mexico, falling crude oil prices have pushed the peso to record lows, prompting the Banco de México to auction US$8.9 billion in reserves by mid-October 2008 to stem the decline. President Felipe Calderón, unveiled US$4.4 billion in energy spending on roads, schools, hospitals and an oil refinery to create jobs and boost growth. But the finance secretariat still slashed its growth forecast for 2009 from 3% to 1.8%. According to a poll of private forecasters by its central bank, Mexico's growth rate would even be as low as 0.4% in 2009, due to its close ties to the US economy (Bradley and Sibaja, 2008).

Poorer countries have fewer options. In Bolivia, some hard-hit mining companies had pressed local officials to cut their water and electricity bills to make up for lost export income. Prices of zinc, Bolivia's top metal export, have lost 70% from a 2006 high, forcing mine operators to lay off workers. Limbert Paredes, manager of the Potosi Mineral Refiners Association, stated: "when the boom passes, you've partied away all the money you've earned over the last two years, and you are back in misery again" (Bradley and Sibaja, 2008).

A relative collapse of food prices

Regarding foodstuffs, Philippe Chalmin, professor at the university Paris-Dauphine, considered irrelevant to speak of a collapse, which might be the case if the world had returned to the 2005 grain prices. According to P. Chalmin, prices of agricultural commodities would remain at a high level, and energy prices as well, but not those of metals due to the uncertainties about China's demand. In June 2008, both the Food and Agriculture Organization of the United Nations (FAO) and the Organization of Economic Cooperation and Development (OECD) stated that agricultural commodity prices had reached a peak and would remain high at least for ten years. However, that trend seemed to be reversed during the fall and winter of 2008, but probably for just one production cycle. The economic crisis (October 2008) was restricting loans and farmers would have difficulties to buy their inputs (seeds, fertilizers and pesticides); that would result in the reduction of cultivated lands and of production, and finally in an increase of commodity prices. And by all

means, if prices go down, farmers will not be enticed to produce more (Clavreul, 2008f).

There was therefore a major concern about the implications of the financial crisis, which could lead to a slowdown of investments and agricultural production. Consequently, the endeavours made to remedy the reduction of global supply that occurred during the first term of 2008, would be nullified. But it should be underlined that the decrease in agricultural commodity prices was not having a favourable impact on the consumers of poor countries that were severely hit by the soaring food prices. Wayne Jones, economist at OECD, was of the opinion that "the most important impact of the financial crisis would be the inability of increasing food aid aimed at mitigating the negative effects of high food prices" (Clavreul, 2008f).

In order to monitor the changes in food and commodity prices the Food and Agriculture Organization of the United Nations has set up the National Basic Food Prices Data and Analysis Tool, which is an interactive data base displaying the prices of staple foods in the national markets of 55 developing countries in local currencies or US dollars, as well as for standard weights. The data therefore enable a comparison of prices among national and international markets. The data base has been set up with the financial assistance of Spain, as part of the FAO's Initiative relating to the increase in food prices. FAO intended to add another nine countries to the existing 55, if funding became available.

According to Liliana Balbi, an economist of FAO's Global System of Information and Early Warning, "the data base will be a valuable source of information for designing policies and making decisions with respect to agricultural production, trade, development and also to humanitarian assistance". She also stated that "although food prices fell down at the international level, the new FAO's tool shows that in developing countries these prices did not decrease so rapidly or even remained high". This is crucial in countries where people spend 60% to 80% of their income to buy food; the figure is only 10% to 20% in industrialized countries. See http://www.fao.org/news/story/en/item/10693/icode/

Food riots and social unrest

Rocketing food prices have sparked riots in many countries, which, according to an executive of an important international body attending the world Economic Forum, Davos, Switzerland, in January 2008, generated more concern among governments than the rise in gasoline price.

In West Africa, in Burkina Faso (Bobo-Dioulasso), on 20 February 2008, rioters that protested against a 65% rise of some foodstuffs in January, burnt government buildings and looted stores. Days later, in Cameroon, a taxi drivers' strike over fuel prices became a massive protest against soaring food prices, leaving around 20 people dead, while hundreds have been arrested. In Senegal, in March 2008, police in riot gear used tear gas and beat people protesting against high food prices and later raided a television station that broadcast images of the event (Lacey, 2008; Walt, 2008).

In Cairo, the military was put to work baking bread, as bread lines at bakeries that distribute state-subsidized bread, became the scene of fights. The government feared that these fights could become the spark that ignites wider anger at a repressive government. In Yemen, food riots turned deadly, taking at least a dozen lives (Brown, 2008; Lacey, 2008).

In Morocco, while trade-unions warned against the degradation of the consumers' purchasing power and its implications for social peace, and a newspaper requested the authorities to make sure that food prices should not go beyond some "red lines", people took to the streets at the end of September 2007 and clashed with police in the city of Sefrou, located in the center of the country. Some 50 persons were wounded and dozens of food rioters were arrested. In order to prevent a country-wide massive protest, the increase in bread price was cancelled and the state had to bear the brunt of the 25% rise of the price of a loaf of bread (1.50 dirhams or €0.14). Further to a poor cereal harvest in 2006-2007, due to a severe drought during spring (instead of 90 million quintals harvested in 2005-2006, only 20 million quintals were harvested in 2006-2007), Morocco had to import large quantities of soft wheat. The ministry of agriculture stated that stocks were sufficient to meet national needs and contracts were being signed with soft wheat suppliers in order to improve the overall situation (Tuquoi, 2007). See pp. 270-273.

In Asia, governments had to put in place measures to limit hoarding of rice after some shoppers panicked at price increases and bought everything they could. Even in Thailand, which produces 9 million tons of rice more than it consumes and is the world's largest rice exporter, supermarkets had placed signs limiting the amount of rice shoppers were allowed to purchase. In several provinces of the country, rustlers stole rice by harvesting fields at night. In response, Thai villages with distant fields have taken to guarding ripe rice fields at night with loaded shotguns (Brown, 2008; Lacey, 2008).

In the Philippines, the front pages of Manila's newspapers highlighted a "rice crisis", as politicians thought drastic solutions, such as forcing the country's leading firms to take up rice farming. The president of the Philippines, Gloria Macapagal Arroyo, in February 2008, pleaded with Vietnam – the second-largest exporter after Thailand – to guarantee supplies. The two countries signed an agreement on 26 March 2008, apparently to do that. Vietnam also announced export restrictions to try to curb soaring food prices at home. The Philippines became self sufficient in rice in the 1980s, but thereafter they relapsed into deficit, despite an expansion in its paddy fields (*The Economist,* 2008b).

Indonesia's president, Susilo Bambang Yudhoyono, had not abolished restrictions on rice imports. These, like Philippines' rice import tariffs, were intended to protect poor rice farmers when prices were low, but they hurt poor rice consumers, a larger group. By the end of March 2008, a senior Indonesian official stated the country had reached its goal of becoming self-sufficient in rice. Later on, the president contradicted that statement, by saying Indonesia would need to continue importing Thai rice.

In Pakistan, where flour prices have doubled, food insecurity is a national concern. Thousands of armed Pakistani troops have been assigned to guard grain elevators and to escort the trucks transporting grains. Voters trounced President Pervez Musharraf's party in crucial parliamentary elections in February 2008, in part because many could no longer afford staple foods and blamed the government. "We are worried about terrorism and those other things, but first we are worried about basic needs", stated a 24-year-old nurse in Islamabad, shopping in the capital's busy Aab Para market during the election period. "People want a person who can fix this problem" (Walt, 2008).

Indian protesters burnt hundreds of food-ration stores in West Bengal in October 2007, accusing the owners of selling government-subsidized food on the lucrative black market (Walt, 2008). A senior Indonesian official expressed fears on 26 February 2008 that surging food prices might lead to social unrest similar to that which brought down Suharto as president ten years earlier. Hundreds of meat sellers took to the streets in Jakarta by mid-February 2008 to complain about the rising price of beef. The government was forced to cut import taxes for soybeans in January 2008 after more than 10,000 people protested against soaring prices of tofu and tempeh. The price of tofu had jumped 50% in 2007, rice was up 25% and cooking oil almost 40%. The government introduced an export tax for crude palm oil in February 2008, in addition to cutting import taxes on soybeans, wheat and flour

as part of a US$4 billion (€2.7 billion) package to tackle the problem of rising prices. Apart from leading to more popular protests, higher food prices were also triggering inflation: consumer prices were 7.4% higher in January 2008 than a year earlier, a 16-month record and above the country's full year inflation target of 6% (Murray, 2008).

In a single day in February 2008, global wheat prices jumped 25% after Kazakhstan's government announced plans to restrict exports of its large wheat harvest for fear that its own citizens might go hungry. "Prices have risen at a much faster rate in the last few months", stated Fazlul Kader in Dhaka, Bangladesh, where he coordinated rural projects for the United Nations International Fund for Agricultural Development (IFAD); there soybean oil alone has shot up 60% in a year (Walt, 2008).

In Haiti, where three-quarters of the population earn less than US$2 a day and one in five children is chronically malnourished, President René Préval appeared to taunt the populace as the complaints about the repressive life grew. He stated if Haitians could afford cellphones, which many do carry, they should be able to feed their families. When thousands of protesters took to the streets of Port-au-Prince, he huddled inside the government palace and his presidential guards, while United Nations peace-keeping troops, rebuffed them. Within days, opposition law makers had voted out R. Préval's prime minister, Jacques-Edouard Alexis, forcing him to reconstitute his government. In Haiti, the one business booming amid all the gloom is the selling of patties made of mud, oil and sugar, consumed only by the most destitute (Lacey, 2008).

At the World Economic Forum on Latin America in Cancún, Mexico, President Elias Antonio Saca of El Salvador stated: "this is a perfect storm, how long can we withstand the situation? We have to feed our people, and commodities are becoming scarce. This scandalous storm might become a hurricane that could upset not only our economies, but also the stability of our countries"; while Jeffrey Sachs, the economist and special adviser to the United Nations secretary-general, Ban Ki-moon, delared: "it is the worst crisis of its kind in more than 30 years" (Lacey, 2008).

A new face of hunger

"We are seeing a new face of hunger", stated Josette Sheeran, executive director of the United Nations World Food Programme (WFP). "People who were not in the urgent category are now moving into that category". In Sudan, WFP is responsible for supplying grain to 2 million people in Darfur refugee camps, and during the first three months of 2008,

56 grain-laden trucks were hijacked. This threat to UN-supplied food to the Darfur camps has reduced the flow of food aid into the region by half, raising the specter of starvation if supply lines could not be secured (Brown, 2008; Walt, 2008).

In February 2008, J. Sheeran told Western donors that WFP would trim its aid programmes in 2008 unless an extra US$500 million was provided to cover the rising cost of the food that it had to supply to about 90 million people of the 860 million that suffer from starvation worldwide, including many who survive on just UScents 50 a day. She added: "The increase in cereal prices forces us to make a choice: either feed 40% people less, or decrease buy 40% the rations distributed" (Walt,2008; Lemaître, 2008a).

The US Agency for International Development (USAID) – the WFP's biggest donor – declared in February 2008 it had been forced to cut about US$120 million from future aid programmes to pay current commitments. The deputy-director of USAID's Food for Peace programme stated its commodity expenses had soared by 41% in six months (Walt, 2008).

Not only the WFP's director in Mauritania, who flew to a donors' meeting in Senegal, warmed Western aid officials that "2008 will be a very dangerous year", but also Joachim Von Braun, director-general of the International Food Policy Research Institute (IFPRI, Washington, D.C.), asserted "this is a serious security issue", after having warned US officials many times that a global food crisis was looming (Walt, 2008).

The World Food Programme reaches more people than any other humanitarian organization in the world. In 2008, it planned to feed about 90 million in 78 countries; almost all of the recipients of that food aid hover on the brink of starvation. It should be underlined that WFP was not designed to fight the deeper roots of hunger. That task is within the purview of other United Nations agencies like the Food and Agriculture Organization (FAO) and the UN Development Programme (UNDP). But WFP can help. Its Food for Assets Plan distributes rations to displaced persons in northern Uganda, for instance, who work to build and run local fish farms. Procurement officers can buy locally at above market prices if they show that it helps to develop the country's agriculture. Worldwide, WFP feeds about 20 million schoolchildren each year. That service is designed to help pupils concentrate in class and to give parents a reason to send their children to school in the first place. In some regions where girls' attendance is especially low, they receive bonus rations to take home. These programmes are crucial to what WFP workers call the

"exit strategy", i.e. reaching a point where food aid is unnecessary. But as food prices rise, these programmes are the first to be slashed. For instance, school feeding was cancelled in Cambodia for a month during the spring of 2008 because of a shortage of funds. In Sri Lanka, a food-for-work scheme to maintain irrigation systems was axed for the same reason (Blue, 2008).

"What we're seeing is that people living under US$2 a day are giving up health care and education", stated J. Sheeran. "Those living on under US$1 a day are giving up protein once a week or vegetables". And those on US-cents 50 a day or less are simply cutting out meals (Blue, 2008).

WFP had planned in 2007 that US$2.9 billion – donations that mainly come from rich countries – should cover operations for 2008. By late March 2008, rising food prices meant those same operations were going to cost an extra US$500 million; by the end of April 2008, the estimated shortfall was US$755 million. To fill the gap, Saudi Arabia pledged US$500 million in late May 2008. But if prices stay high in the longer term, WFP should raise those extra hundreds of millions, year after year, just to maintain services at their 2007 level. And WFP is facing new demand from people whom, in 2007, it did not expect to have to help (Blue, 2008).

Uganda is a good example of how WFP's worldwide operations have been hit by high food prices. WFP buys more food in Uganda than in any other country in the world. In 2007, WFP's administrative center in the capital city Kampala, then responsible for 11 countries in central and eastern Africa, handled some 15 million recipients and about one-third of WFP's annual global food distribution. In Uganda, there were more than 170,000 refugees from neighbouring countries, and nearly 1 million who have been "internally displaced" in northern Uganda by a long-running guerrilla war. Then there are the residents of drought-stricken Karamoja, in Uganda's semi-arid north-east corner, as well as pregnant and nursing mothers, and HIV/AIDS patients. Trains and trucks of food arrive from local traders and from the port city of Mombasa, Kenya, where ships bring donated food from the United States and other Western countries (about two-thirds of WFP's food in Uganda is purchased locally, and one-third is donated in kind) [Blue, 2008].

As food and fuel prices rose, suppliers began defaulting on their contracts; they were either unable to provide goods at a previously agreed price because input costs had increased, or unwilling to sell food at the old rate when others were ready to pay more. Although WFP boasted that its overhead costs were no more than 7% of total operating budget,

food and fuel shortage in 2008 did not just mean higher costs; they also introduced new elements of unpredictability to providing aid to those who needed it. In this regard, Africa presents logistical challenges for aid agencies: poor roads, unpredictable weather and political instability. For instance, after Kenya's disputed presidential election in December 2007, a US shipment of 9,000 tons of sorghum was blocked for more than 100 days in Mombasa. Violence returned to Burundi after a cease-fire deal failed, so WFP had to postpone plans to stop feeding Burundian refugees in Tanzania. Distribution was suspended briefly in Karamoja in 2007, after cattle rustlers ambushed a convoy and killed the lead driver; the trucks, returning from a delivery, were all empty (Blue, 2008).

By mid-December 2008, the World Food Programme launched an "urgent appeal" to governments to donate a record US$5.2 billion (€3.8 billion), as it confronted an increase in the numbers of those receiving aid at a time when food prices were still high and its coffers were empty. Record food prices in early 2008 had exhausted WFP's reserves, and the appeal showed that despite a drop in wholesale food prices, WFP's funding needs were increasing as more countries asked for food aid and relief. Josette Sheeran, WFP executive director, told the *Financial Times*: "We would run out of food for some key operations by March 2009". She warned that countries such as Ethiopia, Congo, Haiti, Sudan and Bangladesh were at risk. "Vulnerable nations have already depleted their food and financial reserves and now are being hit by the financial crisis"… "The drop in remittances is hitting a population that was already suffering from high food prices". As WFP had not enough funds left to spend in early 2009, J. Sheeran urged governments to donate 1% of their bail-out and programmes aimed at fostering economy to fighting poverty and hunger (Blas, 2008b).

Numbering the poor

World Bank's estimates

In April 2007, the World Bank announced that 986 million people worldwide suffered from extreme poverty; this was the first time the count had dropped below 1 billion. On 26 August 2008, another World Bank report concluded "the developing world is poorer than we thought". According to Shaoshua Chen and Martin Ravallion, two of its leading researchers, the number of poor was almost 1.4 billion in 2005 (*The Economist,* 2008i).

However, between 1981 and 2005, the number of poor worldwide had decreased by 500 million and their proportion among total population had dropped from 52% to 26%. Unfortunately Africa did not benefit from this improvement (Faujas, 2008a).

In fact, the World Bank has improved its estimates of the cost of living throughout the world and has revised its data on poverty. The Bank has taken account of 675 enquiries carried out at the household level in 146 developing countries, which represented 96% of the total population of these countries. Thanks to a vast effort to compare the price of hundreds of products, from packaged rice to folding umbrellas, the cost of living of 1.2 million households (random sample) was found steeper than previously thought, which meant more people fell short of the poverty line (Faujas, 2008a; *The Economist,* 2008i).

Using these freshly collected prices, S Chen and M. Ravallion have drawn a new poverty line. The World Bank used to count people who lived on less than "a dollar a day" (or US$1.08 in 1993 prices, to be precise). This definition of poverty was first unveiled in the Bank's 1990 *World Development Report* and was later on adopted by the United Nations when it decided to halve poverty by 2015. The researchers now prefer a threshold more typical of the 15 poorest countries that have credible poverty lines: people are poor if they cannot match the standard of living of someone living on US$1.25 a day in America in 2005. Such people would be recognized as poor even in Nepal, Tajikistan and African countries such as Uganda. But the World Bank's researchers also calculated the number of people living on less than US$1 at 2005 prices (*The Economist,* 2008i). It is true that poverty line was closer to US$1 a day in India and China and to US$2 in regions with intermediate income like Latin America and Eastern Europe (Faujas, 2008a).

With the yardstick of US$1 a day, the number of poor reached 879 million worldwide at 2005 purchasing-power parity, while the number totaled 1,399.6 million if the yardstick is US$1.25 a day. The discovery of another 400 million poor people does not satisfy those who still think that poverty is still undercounted. The World Bank's cost-of-living estimates were based on the prices faced by a "representative household", whose consumption mirrored national spending. But the poor are not representative. In particular, they used to buy in smaller quantities, and as a result "the poor paid more" (*The Economist,* 2008i).

Such concerns led the Asian Development Bank (ADB) to carry out its own study of the prices faced by the poor in 16 of its member countries

(not including China). Its results, released on 27 August 2008, showed that in nine of those countries the poor in fact paid less. Even though they bought in smaller quantities, they saved money by buying cut-price goods from cheaper outlets. In Indonesia, for instance, the poor's cost of living was 21% below the World Bank's estimate. The difference was narrower in smaller countries, such as Cambodia. This may be so because in big countries, such as India, the rich are larger in number, although a very small part of population. Perhaps their spending has an undue influence on the prices faced by the representative household (*The Economist,* 2008i).

Regionwide, the results of the struggle against poverty are contrasted. East Asia, which had in 1981 the world's highest poverty rate (80%), showed the most spectacular results: the rate fell to 18% and 600 million people had been drawn from extreme poverty between 1981 and 2005. The poverty rate also receded in South Asia, Latin America, the Caribbean, the Middle East and North Africa, but not enough to lower the number of very poor people (Faujas, 2008a).

By contrast, in sub-Saharan Africa, the poverty rate remained stable at 50% over 25 years. Even worse, the number of those living on US$0.70 a day doubled rising from 200 million to 400 million people in 2008. If this situation continues, one-third of the billion poor in the world in 2015 will be in sub-Saharan Africa (Faujas, 2008a).

The World Bank report stressed that "most of the 500-600 million people drawn out of extreme poverty between 1981 and 2005 – on the basis of US$1.25 a day – were still poor". The Bank deplored that "no significant progress was made to trespass the threshold of US$2 a day"… "In fact, the number of people living with US$1.25 to US$2 has doubled, from 600 million to 1.2 billion", and the number of people living worldwide with less than US$2 a day was 2.5 billion – a figure that has not changed since 1981 (Faujas, 2008a).

Since the World Bank has reviewed its figures, the soaring food prices, particularly of staple foodstuffs like rice, wheat or maize, have stricken households' budgets in developing countries. Consequently, as shown previously, experts have estimated that 500 million people would join the world's poor.

It should be mentioned that the US Census Bureau released its report on 26 August 2008, showing that 37.3 million Americans were living under the poverty line in 2007, compared with 36.5 million in 2006, and

that some 46 million had not medical insurance. Poverty affects children in particular, with 18% among those who are less than 18 years old, compared with 11% among those between 18 and 64 years old, and little less of 10% among those above 64 years. Poverty line in the United States had been estimated at US$21,000 a year for a household of four persons since the 1960s.

FAO's estimates

On 9 December 2008 the Food and Agriculture Organization of the United Nations (FAO) published its annual report on food insecurity in the world. In 2008, 963 million people suffered from hunger, 40 million more than in 2007, when the figure was already 75 million people more than during the period 2003-2005. The increase in starving people in 2008 was due to the very high rise in food prices, and the economic crisis might worsen the situation (Clavreul, 2008h, 2009g).

The percentage of underfed persons decreased from 20% in the 1990s to 16% before 2005, but it rose to 17% in 2007. This increase undermined the efforts made up to that year and made more difficult to reach the millennium objective of halving the number of starving people in 2015. In Asia and sub-Saharan Africa, the increase in the number of people suffering from hunger was highest. In 2007, 67% of underfed people were living in seven countries: India, China, Democratic Republic of Congo, Bangladesh, Indonesia, Pakistan and Ethiopia. However, some countries like Vietnam or Thailand were trying to reduce the number of underfed people (Clavreul, 2008h).

Households who do not farm land are the most vulnerable, particularly those where women are the heads of families and who tend to devote more of their income to food and have less access to loans and to farmland (and in this case benefit from the rise in the food prices and increase their production). Households who buy commodities such as maize and rice, which are traded internationally, are more vulnerable and have increasing difficulties to feed themselves. This is particularly true of those who live in the cities. To cope with the increase in food prices, households reduce the quantity and quality of foodstuffs they consume, they also spend less on health care and education, or sell their goods (Clavreul, 2008h).

According to FAO, the rise in food prices did not stimulate agriculture in poor countries. Cereal production was expected to rise 2.8% worldwide in 2008. In developing countries, it would increase by 0.9%, but if Brazil, India and China were excluded, it would decrease by 1.6%. Conversely,

cereal production would increase by 11% in developed countries. High prices of seeds and fertilizers, the lack of access to infrastructures (roads, silos, etc.) as well as to loans, explained why small farmers had difficulties to increase their yields and to benefit from the rise in commodity and food prices (Clavreul, 2008h).

However, the FAO's director-general in the foreword of the annual report was not pessimistic and considered that food prices, despite their sharp decrease in the fall of 2008, would remain rather high in the future and could offer a good opportunity for developing countries' farmers to increase their production. That is why FAO strongly recommended that public and private investments be made in agriculture and that small producers be supported, in order to create rural jobs (Clavreul, 2008h).

Thus, in the 14 African countries which were making efforts to reduce the number of underfed people, agriculture has been expanding. For instance in Ghana, people coming back to agriculture are twofold more numerous than those leaving it. Households have also been rather protected against the variations of international commodity prices, because their diet mainly consists of locally produced food (e.g. cassava and sorghum) [Clavreul, 2008h].

CAUSES

The spectre of Malthus : is it doomsday again?

The 2007-2008 food crisis was not the first in modern economic history that the Malthusian spectre of global food shortage has stalked the world economy. Thomas Malthus, a British economist and demographer at the turn of the 19th century, theorized that populations, which grow geometrically, will inevitably outpace food production which grows arithmetically. Famine would result. This theory has underlain doomsday scenarios both real and imagined, from the Great Irish Famine of 1845 to the Population Bomb of 1968 (McNeil, 2008).

Surges in food prices in the 1970s and then again in the 1990s both prompted warnings that agricultural capacity was failing to keep face with a growing world population. Each time, the prices soared it proved to be temporary as supply responded. Over the last 200 years, with the industrial revolution, the transportation revolution, the "green revolution" and the "biotechnology revolution", Malthus' theory has been largely discredited. Right now there is enough cereals grown on earth to feed 10 billion vegetarians, according to Joel E. Cohen, professor of populations at Rockefeller University in New York and the author of *How many people can the Earth support?* But much of it is being fed to livestock which are in turn consumed by the world's wealthy and the growing middle-class of the emergent countries. Theoretically, there is enough land already planted to keep the planet fed forever, because 10 billion humans is roughly where the United Nations predicts that the world population will reach a plateau in 2060 (McNeil, 2008).

But success depends on portion control. In the late 1980s, Brown University's World Hunger Program calculated that the world then could sustain 5.5 billion vegetarians, 3.7 billion South Americans or 2.8 billion North Americans, who ate more animal protein than South Americans. As Harriet Friedmann, an expert on food systems at the University of Toronto, pointed out, Malthus was writing in a United Kingdom that echoed the

dichotomy between today's rich countries and the third world: an elite of huge landowners practising "scientific farming" of wool and wheat who made fat profits; many subsistence farmers barely surviving, like millions of sub-Saharan farmers, cultivating land using hoes; migration by those farmers to London slums, followed by emigration. The main difference is that emigration then was to colonies where farmland was available, while nowadays it is to wealthier countries where jobs are. Farmers, defying Malthus' predictions, became much more productive (McNeil, 2008).

Today the argument is between those, like Harriet Friedmann, who think there is a Malthusian unsustainability to the way intensive agriculture is practised, that it degrades biological diversity and the environment so much that it will eventually reach a tipping point and hunger will spread; and those who argue that the world is almost endlessly bountiful. But they see the underlying problem in terms more Marxian than Malthusian: the rich grab too much of everything, including of biomass. Simply ending subsidies to American and European farmers would let poor farmers compete, which in addition to feeding their families, would push down American food prices and US taxes (McNeil, 2008).

Malthus stated the problem as too many people to feed. Nowadays, in the terms in which the global food crisis is partly explained, it is too many Chinese, Indians and Brazilians, etc., who can afford eating more milk products and meat, and can be responsible for raising food prices so much that poor Africans and Asians cannot afford porridge and rice. The truth is more complex, and the upward pressure was there before third world consumers added to it (McNeil, 2008).

Supply and demand issues

The 2007-2008 global food crisis raised a number of issues which lead to think that recovery will not be as easy as in the 1970s or 1990s. First, the lag in supply response to the stimulus provided by higher prices might prove to be of greater duration than its predecessors to the extent that the changes in energy markets – and hence the associated demand for agrofuels – are likely to be lasting ones. With climate change and environment degradation threatening agricultural capacity in several key regions, the elasticity of past supply responses might not be as effective (Thirlwell, 2008).

Secondly, during the extended period in which supply continues to lag behind demand, there are likely to be significant social and economic costs. Most important, a period of protracted higher food prices will

harm the world's poorest people as well as the poor economies. While the share of food in the consumption basket of a rich country such as the United States is relatively low, at about 10%, it averages about 30% in China and more than 60% in sub-Saharan Africa. The low-income net food importers are the most vulnerable, and heavily depend on food aid to meet their needs. The big losers are likely to be the urban poor, while many of the rural poor will also suffer (Thirlwell, 2008).

Finally, higher food prices will call for tighter monetary policy. Given the disparity in the share of food in consumption baskets, and the fact that rich country central banks tend to exclude food prices from their core inflation measures, the policy reaction will tend to be greater in developing economies. Authorities may also be tempted by price controls and other direct measures (Thirlwell, 2008).

To sum up, the rise in prices was a consequence of both demand and supply trends. On the demand size, the key factor has been the strong consumption growth in emerging markets, which in turn has been powered by those countries' impressive income gains. China, for instance, has accounted for up to 40% of the increase in global consumption of soybeans and meat over the past decade. At the same time, a series of supply-side disruptions in key commodity markets ranging from drought to disease have been at work. High oil prices have increased commodity transport costs by at least 30%, while they encouraged agrofuel production at the detriment of some food crop harvests (e.g. maize in the United States). But the impact of biofuel production on food prices should not be overemphasized.

Other causes of the global food crisis are the very low level of grain stockpiles (by the end of 2007, wheat stockpiles reached their lowest level in 32 years), as well as speculation. It is true that many experts were expecting a rise in cereal prices for structural reasons, but nobody had forecast the levels reached, which were considered the result of speculation (see pp. 52-53).

Population growth, improvement of the standard of living and increase in food consumption, climate change and weather vagaries and their impact on crop productivity, high oil prices and increase in transport costs and in agricultural inputs prices (e.g. pesticides, herbicides and fertilizers), commodity speculation, are the main causes of the global food crisis. But the key one is the error in policy: the priority to agricultural and food production was forgotten. In its development report, published in October 2007, the World Bank plainly recognized that during 20 years

decision-makers just ignored agriculture. While 75% of the world poor lived in rural areas, only 4% of public aid was devoted to agriculture in developing countries. Reversing the policy favoured up to 2007 by the Bank and the International Monetary Fund (IMF), the World Bank stated that agriculture growth and consequently poverty reduction depended on public investments into rural infrastructures (irrigation schemes and equipment, roads, transport, energy, etc.) [Lemaître, 2008b]. The obvious conclusion is therefore to produce more, most probably with lesser inputs – water, fertilizers and biocides – and with relatively little expansion of new farmland; intensification without destroying the environment, producing more and better. Agriculture has come back to the top of humankind's development agenda.

Weather vagaries and climate change

Crop-withering heat waves, more destructive storms and hurricanes, and the melting of Asian and South American mountain glaciers that sustain the dry-season flow of those regions' major rivers, are combining to make harvest expansion more difficult. In the past, the negative effect of unusual weather events was always temporary, but with climate change, there is no norm to return to (Brown, 2008).

Among the causes of the high rise in wheat prices, five interwoven factors played a key role: revised lower forecasts for the world 2007-2008 harvest, a sustained demand, the decrease in world stocks, speculation and the growth of agrofuel production. Drought in Australia and Ukraine – two major wheat exporters – , excessive rainfall in the European Union and the United States have been largely responsible for the high wheat prices prevailing in November 2007. On 23 August 2007, Canada reported that it will produce 20.3 million tons of wheat in 2007, i.e. 19.6% less than in 2006, because of the drought that prevailed in July 2007. In Western Europe and the US Midwest, rainfall and lower temperatures affected harvests. Consequently, the International Cereal Council revised its global forecast: 607 million tons of grain instead of 614 million tons (-0.3%) to be harvested in 2007-2008.

Australian drought

Drought is affecting every agricultural industry in Australia, not just wheat and rice production, from sheep herding to the cultivation of wine grapes, the fastest growing crop in Australia, often at the expense of rice. The chief executive of the National Farmers' Federation of Australia,

Ben Fargher, stated: "climate change is potentially the biggest risk to Australian agriculture" (Bradsher, 2008b).

That is why some scientists consider there is a strong case for making wild kangaroo the new red meat of choice, and thus decreasing the consumption of beef and lamb. The number of kangaroos in Australia ranges from 15 million to 50 million each year, depending on climatic conditions, compared with about 80 million sheep and 25 meat cattle, according to government estimates in 2008. Cattle and sheep are major emitters of methane, associated with greenhouse effect and global warming. They produce nearly 70% of Australia's agricultural emissions, which make up 11% of the country's total amount, according to the Department of Climate Change. Kangaroos, in contrast, emit negligible amounts of methane, thanks to special bacteria in their stomachs that aid in the digestion of grass. Eating less beef and lamb, more kangaroo, to mitigate climate change could give a new impetus to an old idea; environmentalists have long promoted kangaroo as an environmentally sound alternative to sheep and cattle, which erode Australia's drought-parched soils and damage waterways. Consequently, encouraging ranchers to sharply reduce sheep and cattle numbers, and consumers to eat more kangaroo meat could be a way to adapt to climate change and to drier conditions in the future (Foley, 2008).

Although a recent study by the University of New South Wales revealed that 80% of Australians were open to the idea of eating kangaroo, the kangaroo meat industry was worth only about A$110 million a year in 2007, compared with the A$11 billion market in Australia for beef and lamb (the country is one of the world's largest exporters of red meat and livestock on hoof to moslem countries). To partly substitute kangaroo meat to beef and lamb, is an idea that has merit, but to be applied on a larger scale it needs to be supported by major government incentives (Foley, 2008).

The Deniliquin mill, in Southern Australia, the largest rice mill in the Southern Hemisphere, once processed enough grain to meet the daily needs of 20 million people. But six years of drought have reduced Australia's rice harvest by 98% and led to closing the mill in December 2007. The collapse of Australia's rice production is one of the several factors contributing to a doubling of rice prices during the first 2008 quarter. For instance, imported rice in Dakar, Senegal, was traded at between US$400 to 500 a ton between January and February 2008. These price surges led the world's largest exporters to severely restrict exports and spurred panicked hoarding in Hong Kong and the Philippines (Bradsher, 2008b).

Severe drought is consistent with what climatologists predict will be a problem of increasing frequency. It has already spurred significant changes in Australia's agricultural heartland. Some farmers are abandoning rice, which requires large amounts of water, to plant crops like wheat or wine grapes. Other rice farmers have sold their fields or their water rights, usually to grape growers (Bradsher, 2008b).

Scientists and economists worry about that the reallocation of scarce water resources – away from rice and other grain to more lucrative crops and livestock – threatens poor countries that import rice as dietary staple. With rice, which is not used as agrofuel, the problem is availability. Even in normal times, little of the world's rice is actually exported – more than 90% is consumed in the countries where it is grown. The last quarter century has seen rice consumption growing faster than consumption, with global reserves falling by half since 2000. Scientists expect the problem to worsen in the decades ahead (Bradsher, 2008b).

Climate change and warming will affect Australia's agriculture. The country is reacting to the trend of warming and drought. For instance, rice farmers who do not give up and sell their land or water rights are experimenting with varieties or techniques that require less water – Australia has now some of the world's highest rice yields per megaliter of water. However, output in 2007 was far lower because rice farmers received just one-eight of the water they were usually promised by the government. Consequently, it is more profitable to grow wine grapes, especially after rice prices tumbled down following their peak by the fall of 2008, like other commodity prices (Bradsher, 2008b).

At the beginning of 2008, wine grapes produced a pre-tax profit of close to A$2,000 an acre, or 0.4 ha, while rice produced a pre-tax profit of about A$240 an acre. Regarding sheep farmers they have already worked out cooperative arrangements to send flocks to whatever fields have received enough rain for pastures and feed crops, sometimes herding or trucking them over long distances (Bradsher, 2008b).

All these changes were making rice harder to find. For instance, SunRice, the Australian rice trading and marketing giant owned by the country's rice growers, began preparing to dismantle the Deniliquin mill in November 2007, when it noticed that Australian farmers were planting almost no rice. To make sure that it could continue supplying the domestic market, as well as export markets in Papua New Guinea, South Pacific island nations, Taiwan and the Middle East, SunRice went into international markets and stepped up rice purchases from other countries. These

purchases became one among the many factors that made it harder for longtime rice importers to find supplies elsewhere (Bradsher, 2008b).

Researchers are looking for solutions to global rice shortages – for instance, rice that blooms earlier in the day, when it is cooler, to counter global warming. Rice plants that bloom on hot days are less likely to produce grains of rice, a difficulty that is being noticed in inland areas of China and other Asian countries as temperatures begin to climb. The flexibility of farmers in Australia has convinced some climate experts that, particularly in developed countries, the effects of climate change may be mitigated (Bradsher, 2008b).

Australia's overall cereal harvest fell to 10 million tons in 2007 from 25 million tons one year earlier. Ukraine had to restrict its exportations of wheat in 2007, because of bad harvests due to drought: 2.5 million tons of wheat exported in 2007, after a record 6.5 million tons in 2005 (Porier, 2007).

France

In July 2007, the French ministry of agriculture was still expecting a harvest of 34.7 million tons of soft wheat. But the actual production was to hover around 32.5 million tons, a 2.5% less than the 2006 harvest which had been a good one. Average yield was not to exceed 66.5 quintals of wheat per hectare, i.e. 3 quintals less than in 2006. The main explanation for this decrease was the weather vagaries. In 2006, a heat wave had burnt the plants. In 2007, rainfall was the culprit : after a warm and dry month of April, spring and summer were cold and humid, which slowed down the filling of grains. Both quantity and quality were affected, and humidity has triggered the development of brown rust and fusariosis (Porier, 2007).

Barley production has also been affected. Winter barley production was expected to be closer to that of 2006, while that of spring barley suffered a significant decrease. Rapeseed average yield also fell to only 29 quintals per hectare, compared with 33 to 35 quintals per hectare usually (Porier, 2007).

France's disappointing cereal harvest – France being the world's fifth-biggest cereal producer – had an impact on the rise of grain prices. This negative effect, due to excess rainfall in northern Europe, compounded that of severe droughts occurring in Australia and Ukraine. In fact, by the end of July 2007, the International Cereal Council (ICC) forecast that global wheat production would not exceed 607 million tons in 2007,

while consumption would amount to 617 million tons. Consumption has been steadily increasing for several years, in particular in emerging countries like India and China, but the demand from Mediterranean countries, especially from Egypt and Morocco, was largely responsible for the soaring prices of cereals (Porier, 2008).

Since 2004, global cereal production has been lagging behind consumption. In 2007, wheat stocks were at their lowest level in 32 years, according to the ICC. In the European Union, they could only meet the needs of 2.5 months of consumption. This situation and the resulting soaring prices have led the European Commission to take action. On 16 July 2007, the European Union's ministers of agriculture met and decided to cultivate fallow lands that represented 10% of farmland in 2007-2008, a measure that could result in a supplementary production of 10 million tons of cereals in the European Union in 2008 (Porier, 2008).

United States

The United States is the world's largest maize exporter and accounts for 70% of global trade. Maize surged to a record high of US$6.73 a bushel in Chicago by mid-June 2008, up 45% since January 2008. However, Mark Keenum, the US undersecretary of agriculture, stated "extensive rains" in the US Midwest during the planting season, from late April to mid-June, could reduce maize acreage because farmers were unable to access flooded fields, and this would reduce productivity. The US department of agriculture (USDA) had already forecast an 8.1% acreage drop as farmers were switching to more profitable wheat and soybeans. Even if dry weather allowed farmers to finish planting their intended acreage, maize yields could still be affected, because plants would not have long enough time to develop to withstand the summer heat, according to M. Keenum (Blas and Flood, 2008).

The magnitude of the problem led the USDA, on 10 June 2008, to unexpectedly cut maize yields to 148.9 bushels per acre, down 5 bushels from the year before and the lowest since 2005-2006. US maize production would fell in 2008-2009 to 11.73 billion bushels, down 10.2% from earlier 13.07 billion bushels, the USDA stated. This reduction reflected slow planting progress, slow plant emergence and persistent heavy rainfall across the corn belt. The fall in production meant maize stocks would shrink to 673 million tons by the summer of 2008 – the lowest level for 13 years (Blas and Flood, 2008).

The USDA did not cut its projection for how much land farmers will devote to maize production from May 2008 estimate of 86 million acres. But, because of the heavy rains in the Midwest, about 4 million acres of 2008 maize crop had still to be planted and some of the fields that had been flooded might have to be replanted (Blas and Flood, 2008).

The lower production, due to weather vagaries, and the warning of an even larger shortfall came as demand for US maize from the biofuel industry would consume about 33% of the 2008 season maize harvest (Blas and Flood, 2008).

Impact of climate change: the case of Africa

Climate change and global warming are considered a major threat to agriculture and food production. In 2007, the United Nations, in the case of Africa, predicted that "zones struck by drought in sub-Saharan might increase from 60 million to 90 million hectares from now to 2060"… and that "the number of people suffering from malnutrition might increase up to 600 million from now to 2080". On 1 February 2008, the journal *Science* published the forecasts of Stanford University, California, that predicted that South Africa could lose more than 30% of its maize production from now to 2030. Indonesia and South-East Asia would experience at least a 10% decrease in the production of their main crops (Lemaître, 2008a).

Catastrophic floods and severe droughts are inflicting heavy damage to sub-Saharan Africa's ecosystems and agroecosystems, threatening the life of tens of millions of people. For instance, on 25 August 2008, the United Nations humanitarian coordination in Chad announced that about 30,000 persons had been affected by floods in the south of the country. In Ethiopia, according to the Red Cross, 75,000 persons were severely hit by drought. It is not easy to correlate these events with climate change, but they enable the experts to forecast the dangers and threats of climate change in Africa, which produces only 5% of the world's emissions of greenhouse-effect gases (Kempf, 2008c).

Amidst the debates on climate change, Africa is "the forgotten continent", as stated by Yvo Boer, secretary general of the United Convention on Climate Change, in Accra (Ghana), during an international conference on the follow-up to the Kyoto Protocol, that ended on 27 August 2008. According to Ghana's president John Kufuor, Africa was already suffering from "climate shocks": in his country, rainfall had decreased by 20% over the last 30 years. This rainfall decrease has been confirmed, at a greater scale, by German and African scientists during a symposium held

in Ouagadougou (Burkina Faso) on 26 August 2008: the rainfall season in West Africa starts 30 days later than 40 years ago. According to the research programme Glawo, which was the subject of the Ouagadougou seminar, a "considerable warming" was expected in Africa as well as a "remarkable" reduction in rainfall in sub-Saharan Africa and along the southern rim of the Mediterranean from now to 2050. These forecasts confirm those of the Intergovernmental Group of Experts on Climate Change published in 2007. The Group's report forecast a 5%-8% extension of arid and semi-arid lands from now to 2080, an increase in the number of people suffering from lack of water from now to 2020, and worsening difficulties for agriculture that could halve agricultural production in some countries (Kempf, 2008c).

The elevation of sea level could also affect coastal countries such as Ghana, Nigeria, Gambia; Stefan Cramer, of the Heinrich Boll Foundation, who attended the conference in Accra, underlined that impact would he felt particularly in the deltas where populations are dense. For instance, Lagos, Nigeria's capital with 15 million inhabitants, would be seriously affected; several districts of this city, that are situated under sea level, are already regularly flooded. This overall situation is compounded by the increase in population growth and by the lack of resources. According to the United Nations Division of Population, the number of people living in Africa would rise from 922 millions in 2005 to 1,998 millions in 2050. While economic growth has been rather high over the last few years (6.2% in 2007, according to the Economic Report on Africa by the United Nations and the African Union), public aid from the rich countries was slumping (-8.4% in 2007, according to the Organization for Economic Cooperation and Development- OCDE) [Kempf, 2008c].

Can Africa cape with global climate change, using the means existing under the Kyoto Protocol? It does not seem to be the case. "The total amount of the projects funded in Africa by the Global Environment Facility (GEF) over the last 17 years was US$378 million, while the global amount was more than US$2.4 billion", stated Yvo de Boer in Accra. Regarding the "mechanism of clean development", which allows for the funding of technology projects aimed at decreasing the emissions of greenhouse-effect gases, it is spreading slowly on the continent. "Only 2% of the relevant projects existed in Africa, compared with 45% in China, 16% in India and 13% in Chile – an unacceptable situation", stated Ewah Otu Eleri, who leads the International Center for Energy, Environment and Development, based in Nigeria (Kempf, 2008c).

On 26 August 2008, at a GEF meeting, held in Cotonou (Benin), the French minister of ecology, Jean-Louis Borloo, made a strong plea on behalf of the French presidency of the European Union, for an alliance between Europe and Africa during the negotiations on climate change. Addressing his colleagues from 14 countries of Equatorial and West Africa, he wished that "Europe that has the historic responsibility of global warming", reviews new financial flows in order to control deforestation and to develop Africa's energy resources (Kempf, 2008c).

Such a statement and Europe's good will was to be echoed at a Carbon African Forum, held in Dakar on 3-5 September 2008, and where several projects of the mechanism of clean development were to be negotiated. It should be underlined that one of the main issues of the negotiations that will lead to the follow-up to the Kyoto Protocol is the inclusion of forests and forested areas into the deal, because reducing or eliminating deforestation leads to the prevention of emissions of greenhouse-effect gases. According to Brice Lalonde, the French ambassador for the negotiations on climate change, the inclusion of forests in these negotiations depends on the accuracy of measurement of their actual acreage and of their emissions. A consensus seems to be achievable, as satellite technologies and other methods are now available for measuring those emissions. A general agreement will be necessary for the inclusion of forests in the carbon market, because one is dealing with a very important volume of greenhouse-effect gases that surpasses Europe's emissions. Regarding Africa, if a mechanism were designed to avoid deforestation, the countries of the Congo basin would benefit (Kempf, 2008c). Another solution to deforestation carried out to clear out land for agriculture, is to support agricultural intensification through the rational distribution of fertilizers; if yields of food crops are increased, farmers will not clear the forests to extend farmland acreage.

Phytosanitary threats

Cereal crops are vulnerable to attacks by several pathogenic fungi, that could threaten the production and subsequently worsen the availability of grains and food. For instance, wheat black rust (*Puccinia graminis*) is a formidable parasite that has been known since Antiquity. A virulent strain that appeared in 1999 in Uganda (henceforth tagged Ug 99), has been detected in 2008 in Iran, after having been isolated in Kenya in 2001, thereafter in 2003 in Ethiopia, where it caused heavy damage, and finally in 2007 in Yemen (Galus, 2008).

For the experts of the Food and Agriculture Organization of the United Nations (FAO), "the detection of wheat black rust in Iran is a subject of great concern, because its spread could rapidly jeopardize wheat production in the countries at risk". FAO has launched an alert on its web site, because it feared that spores of the parasitic fungus, transported by dominant winds, might reach cereal-producing countries east of Iran: Afghanistan, India, Pakistan, Turkmenistan, Uzbekistan and Kazakhstan. There is a real threat, according to Yvan Sach, a specialist of wheat rusts at the French Agricultural Research Institute (INRA), who underlined that 80% of the wheat varieties grown worldwide were sensitive to this strain Ug 99. In order to halt its spread, one has to start controlling it very early, using fungicides. Once the epidemic has started and in the absence of protection of the crop, the fungus could completely destroy it (Galus, 2008).

In 1974, when wheat black rust was detected for the last time, it destroyed 40% of the wheat crop. Later on, the US breeder Norman Borlaug, Nobel Peace Prize Laureate in 1970, was able to breed several wheat varieties that were resistant to the fungus. But in 1999, a mutation of the fungus wiped out the resistance. Research is being carried out at the International Center of Maize and Wheat Improvement (CIMMYT), based in El Batan, Mexico, in order to develop new varieties of wheat resistant to the new fungal strain. These varieties are being tested in 27 pilot stations located in Nepal, India, Afghanistan and Pakistan, but their use in the fields will have to wait for a few years (Galus, 2008).

Puccinia graminis has a very high infectious capacity; its black spores once formed on green stalks and blades of wheat, can be produced massively every two weeks and look like a black cloud that spreads very rapidly by dominant winds over large areas. That was the case in 1986 when a epidemic of yellow rust started in northeastern Africa and then spread to Yemen and Iran, and finally reached Central Asia and India in 1997, causing crop losses estimated at several hundred million euros (Galus, 2008).

Also Europe had been struck in the past by black rust, but in France the fungus had been eradicated when at the beginning of the 19th century it was realized that a shrub, *Berberis vulgaris*, used in hedges was at the origin of the epidemics. It is on this plant that the fungus accomplished the sexual part of its life-cycle, while the spores are asexual. During this period of the reproductive cycle, genes are mixed and mutations could appear. Eradication of the shrub had been carried out in France

and many other countries, and the end result was a drastic reduction of black rust occurrence. The fungus remains nevertheless a serious threat, occasionally in Central and Eastern Europe where summers are warm and also for durum wheat in the south of Europe (Galus, 2008).

Biovigilance is therefore of outmost importance so as to follow the routes of the parasitic fungus, track it and take the phytosanitary measures that are deemed necessary. This is particularly relevant in the situation of food crisis that could be worsened by a decrease in grain production.

Rise in oil and agricultural input prices

Soaring crude oil prices (up to US$147.27 a barrel on 11 July 2008) have resulted in doubling the cost of sea freight and in making more expensive the transport by road of agricultural commodities and foodstuffs. The high cost of fuel had a direct impact on the price of food, particularly in landlocked countries where road transport plays a key role in their economy. Soaring crude oil prices had also a short-term impact on the cost of fertilizers and of the various chemicals needed in agriculture. These factors, and others, resulted in a 25% increase in the cost of food imports by developing countries in 2007, and in 35% increase in that of cereals, according to FAO (*Spore*, April 2008, no. 134, p. 2).

Even if the prices they achieved rose, higher production costs – particularly of fertilizers and diesel – often prevented farmers in the poor countries of sub-Saharan Africa and South-East Asia from profiting. In Pakistan, for instance, the government had forecast a lower wheat crop in the spring and summer of 2008, despite record prices. This was because farmers there halved their use of fertilizers after a price rise of almost 50% in 2007. A lower use of fertilizers cuts wheat yields, eroding farm income (Blas, 2008b).

Nestor Osorio, executive director at the International Coffee Organization, stated that rocketing oil prices had exerted a negative impact on the income of coffee farmers. “This could lead them to cut down on the use of fertilizers, with a consequent fall in productivity” (Blas, 2008b).

Overall global consumption of fertilizer increased by an estimated 31% from 1996 to 2008, driven by a 56% increase in developing countries, according to the International Fertilizer Industry Association. Worldwide fertilizer consumption amounted to more than 160 million tons in 2007 (Bradsher and Martin, 2008).

Some kinds of fertilizer had nearly tripled in price in 2007, preventing farmers from buying all they needed. In the United States, farmers in eastern Iowa eager to replenish nutrients in the soil have increased the age-old practice of spreading hog manure on fields. Partly replacing commercial fertilizer with hog manure could save some money, but such strategy has severe limitations: manure contains so little nitrogen that several metric tons are required on each hectare. That means farmers in Iowa and elsewhere have little choice but to pay the higher prices for commercial fertilizer. On the other hand, fertilizer inflation has created a crisis in countries that subsidize fertilizer use for farmers. In India, for instance, the government's subsidy bill could be as high as US$22 billion in 2008-2009, up from US$4 billion in 2004-2005 (Bradsher and Martin, 2008).

But in Malawi, maize production has been increased by 73% since 2005 thanks to a strong policy of subsidy to fertilizer and seeds. After the 2005 drought, Malawi's government decided not to follow the advice of its donors, including the World Bank, regarding the elimination of subsidies, particularly those for fertilizer. Malawi's president Bingu Wa Mutharika had launched a US$60 million programme that made available low-cost fertilizers to the farmers. Three years later, yields trebled and Malawi moved from a status of importer to that of a regional cereal exporter. Jeffrey Sachs, director of the Earth Institute at Columbia University, advocated, on the basis of the example of Malawi, that throughout Africa fertilizers should be distributed along with training in irrigation. This programme would cost US$10 billion per year, but yields could be doubled or trebled in African farms, where nowadays the average yield of 1 ton of grain per hectare is the lowest in the world (Rémy, 2008).

In addition, J. Sachs has suggested to break the current aid mechanisms, whose aim is to send to Africa "more food aid, the most harmful system for development". Instead of sending "subsidized grains from the United States at an incredibly high cost, amounting to more than half the total cost", J. Sachs considers more urgent and appropriate to distribute fertilizer to African farmers, to promote efficient irrigation and to use improved seeds, in order to increase yields markedly (Rémy, 2008).

The situation is different in the rich countries of Europe and the United States, where farm-gate prices are closer to those on the international market and, moreover, farmers enjoy generous government subsidies. The combination is pushing farmers to plant more in an effort to benefit as much as possible from surging demand. In 2008, the US department of agriculture (USDA) had forecast that US farmers would plant the highest

acreage since 1984, despite the higher costs of fuel and agricultural inputs. Net farm income the United States was forecast in 2008 to hit a record US$92.3 billion (€58.3 billion), up 4.1% from the 2007 level. Joseph Glauber, chief economist at the USDA, told farmers that there could be little dispute that 2007 was "one of the most remarkable years agriculture has ever seen". Western farmers also enjoyed access to commodities forward markets, which allowed them to lock in the high prices that prevailed in 2007-2008. In addition, they could insure their crops – at subsidized rates, thanks to government support – against weather damage (Blas, 2008b).

In France, in 2008, the value of farm production was estimated at €66.7 billion, up 3.9% compared with 2007, according to the forecasts published on 16 December 2008 by the National Institute of Statistics and Economic Studies (INSEE). However, the net result was only €23 billion, i.e. 8.9% less than one year earlier, because of the costs of fuel and fertilizers, and of the volatility of commodity soaring prices. In 2008, cereal production (volume) rose 18% and that of milk increased by 4%. French farmers have been encouraged to produce more because of soaring commodity prices, through the authorization to farm fallow land and unleashing milk quotas. During the first half of 2008, food prices continued to rise, but they fell down during the second half. Consequently the per capita incomes decreased by 15% in 2008, after two years of progress (Clavreul, 2008i).

Although French farmers were again going through difficult times, the increase in agricultural production was reducing the trade deficit, estimated at €60 billion in 2008. In October 2008, according to the data published by Agreste – the statistical service of the agriculture ministry – the surplus of agrifood exchanges remained stable at €1 billion. While the exports of wines, champagne and spirits were on the downward trend, commodities, such as wheat were on the rise, particularly with countries outside the European Union. From January to October 2008, the trade surplus amounted to €8 billion, which meant that the 2007 record of €9 billion could be renewed or even surpassed in 2008 (Clavreul, 2008i).

In 2009, French farmers feared that the decrease in food demand which occurred during the second half of 2008 would last longer. On the world markets uncertainties were also growing. According to the World Bank's forecasts, published on 9 December 2008, trade exchanges would decrease in 2009. In the United States and in Japan, and in North Africa and the Middle East, with respect to cereals, the purchases of French products could be lower (Clavreul, 2008i).

Commodity export curbs, falling stockpiles and speculation

Export curbs and tariff policies

Although staple grains are easily tradable, being non-perishable, it is striking how little is sold across international border. Thus, rice provides nearly one-third of the developing world's calories, but only 7% of world production is traded internationally, despite wide variations in productivity and price between different countries. This derives partly from the belief that "food security" – ensuring a regular supply of basic sustenance – is best met by keeping a large proportion of production at home, especially in countries where import supply chains are inefficient or controlled by monopolists who may restrict sales to hold up prices. As a result, the international market of rice is far from efficient, fragmented into a series of bilateral arrangements rather than one fluid exchange (Beattie and Blas, 2008).

For instance, on 24 April 2008, Brazil decided to suspend its rice exports and to sell part of its stocks in order to restrain the rise of food prices and to safeguard the supply of the country. The agriculture ministry announced the auction of 55,000 tons of rice on 5 May 2008, while wholesale prices were rising at 1% a day. Rice harvest in Brazil was expected to reach 12 million tons, almost entirely consumed domestically.

Governments impose tariffs and subsidies to keep farmers' incomes higher than they would be if subjected to free-market competition. For instance, the small-scale farmers of Japan and South Korea, for instance, who grow rice on terraced hillsides are among the most supported in the world : some of the rice tariffs in Japan that keep out cheaper foreign competition are higher than 700%. Also governments sometimes compensate their consumers with subsidies to keep down the price they pay. The Washington, D.C.-based International Food Policy Research Institute (IFPRI) estimated that domestic maize prices in Mexico had been up to 35% higher than world prices since the beginning of 2005, while in India rice was on average more than twice expensive as it was on the global market. But as target prices often stay fixed, signals from the world market are muted (Beattie and Blas, 2008). See also Clavreul (2009h).

In the case of Morocco, which has been severely hit by the global food crisis and suffered from recurrent droughts in 2007 and 2008, the good cereal harvest in 2009 (+162% compared with 2008; see pp. 270-273) led the government to raise taxes on imports of soft and durum wheat in order to protect Moroccan farmers from international competition.

Import taxes have been increased up to 135% (from 50%) for soft wheat for the seven-month period June to December 2009. The import tax was expected to return to 50% on 1 January 2010. Regarding durum wheat, the import tax has been raised up to 170% for the months of June and July 2009 only (Boukhalef, 2009).

But high and volatile prices that prevailed during the global food crisis made it increasingly costly to cushion the blow for consumers and many of the poorest countries' governments could not afford to hold food costs down. Instead they started to remove import tariffs and impose export bans in an attempt to transfer income directly to consumers – in effect preventing farmers from selling their produce at the highest price they could find on international markets (Beattie and Blas, 2008).

Such measures may alleviate domestic supply problems in the short term, particularly in those developing countries which have come to depend substantially on imports for staple commodities, such as wheat, maize and rice. Egypt, for instance, whose population has more than doubled over the past 20 years and is increasingly urbanized, imported around half of its staple food, wheat, in 2007. But when highly efficient net exporters of grain such as Argentina and Ukraine, or Thailand, restrict exports, they create shortages in global markets, and this has undoubtedly contributed to the soaring of commodity prices during the world food crisis (Beattie and Blas, 2008).

If therefore the first reaction of governments is to keep produce from the world market, prices will rise even higher. Particularly vulnerable are those poor countries, many in sub-Saharan Africa, whose variable and low-productivity agricultural sectors make them highly dependent on imported staple foods. Grains (including rice) accounted for 63% of the calorie consumed in low-income Asian countries and around half in sub-Saharan Africa in 2007. Eritrea, for instance, imported 87 % of its grain in 2007 and the country's export earnings covered only 25% of its food import bill, the rest being aid from rich donor countries. Sub-Saharan countries typically export tropical crops such as coffee, tea and fruit, whose prices have not kept pace with the basic staples (Beattie and Blas, 2008).

Within developing countries, city-dwellers who consume but do not produce food tend to do particularly badly when prices increase, but they are not the only ones. There is a perception that, since most poverty in the developing world is concentrated in rural areas, higher food prices are good for the poor. But this varies considerably from country

to country, depending on how many smallholders sell more staple food than they buy. The poor in Bangladesh, for instance, on average tend to lose: 22% of the income of net food buyers went on staples, while only 4% of the income of net sellers of food came from selling staples in 2007. In Vietnam, on the other hand, there were more competitive small producers who tended to benefit from high prices. Overall, according to Joachim von Braun, director-general of IFPRI, "there is not much supporting evidence for the idea that higher farm prices would generally cause poor households to gain more on the income side than they would lose on the consumption-expenditure side" (Beattie and Blas, 2008).

Falling stockpiles; new investors in agriculture

During seven of the last eight years, grain consumption exceeded production. After seven years of drawing down stockpiles, world grain carry-over stockpiles in 2008 have fallen to 55 days of world consumption, the lowest record. The result has been tightening food supplies and rising food prices (Brown, 2008).

Another factor which played a significant role in the global food crisis is speculation by new investors in agriculture and the farm economy. When commodity prices are climbing, holding inventory for future sale can yield higher profits than selling to meet current demand, for instance. Or if prices diverge in different parts of the world, inventory can be shipped to the more profitable market. "It is a huge advantage to not be able to trade the physical commodity", stated Andrew J. Redleaf, founder of Whitebox Advisors, a hedge fund management firm in Minneapolis (Henriques, 2008). See also Tricornot (2009).

The executives making such bets stated that fears about their new role were unfounded, and that their investments will be good for farming and ultimately for consumers. "The world is asking for more food, more energy", stated Axel Hinsch, chief executive of Calyx Agro, a division of the giant Louis Dreyfus Commodities, which is buying tens of thousands of hectares of cropland in Brazil (that has become to many commodities such as sugar, soybeans, orange juice and chicken and beef, what China is to manufactured goods and India to outsourced business services) with the backing of big institutional investors, including AIG Investments (Henriques, 2008).

Perhaps the most ambitious plans are those of Susan Payne, founder and chief executive of Emergent Asset Management, based near London. Emergent was raising US$450 million to US$750 million to invest in

farmland in sub-Saharan Africa, where it planned to consolidate small plots into more productive holdings and introduce better equipment. Emergent also intended to provide clinics and schools for local labour. Braemar Group, near Manchester, is investing exclusively in the United Kingdom. For Gary Blumenthal, chief executive of World Perspectives, an agricultural consulting firm in Washington, D.C., the new investments by big financial players, if sustained and not focused on profits above all else, could be what global agriculture needs (Henriques, 2008).

Production of agrofuels

Maize, sugar and oilseeds for food or for fuel?

Among the causes of the global food crisis that started in 2007, the production of agrofuels has been considered as reducing the area devoted to food crops and decreasing the volume of food commodities, mainly cereals. In addition to questioning their economic, energy and environmental efficiency, agrofuels have been denounced as a threat to food supply. Not only non-governmental organizations have done so, but also politicians have been critical. For instance, the German minister for cooperation and devolopment called for the suspension of agrofuels from cereals until the end of the crisis. On 21 April 2008, the president of Peru stated that agrofuels were at the origin of the current food crisis. Slovenia's prime minister, who was chairing the European Union, stated in April 2008 that the objective of incorporating 10% agrofuels into gasoline by 2020 throughout the Union might be revised (Caramel, 2008a; Clavreul, 2008b).

Earlier on, former president Fidel Castro, in his first article published on 29 March 2007 in several Cuban newspapers (*Granma, Juventud Rebelde*, etc.) since he has been operated on 27 July 2006, stated that "more than 3 billion people worldwide were condemned to a premature death because of starvation or thirst". This statement was issued after it was announced that the US president met with motorcar manufacturers and made a strong plea in favour of biodiesel and bioethanol. F. Castro considered "sinistrous the idea to transform foods into ethanol". He also criticized those in Cuba who "dream to transform sugar-cane into biofuels"…"Lands devoted to direct production of alcohol can be better used to produce foodstuffs for the people". Nevertheless, Cuban sugar refineries have been dismantled to a large extent, without significantly improving food production. Cuba annually imports large quantities of rice, beans, soybeans and chicken from the United States (Paranagua, 2007). See also pp. 263-266.

Cuban president's strong criticism was also directed against the agreement signed on 9 March 2007 between the United States and Brazil's presidents in order to develop cooperation for the worldwide expansion of bioethanol production. The reply by Celso Amorim, Brazil's minister of foreign affairs, was clearcut: "F. Castro is rather outdated in this area. He pretended that Brazil's projects for ethanol production would not work. But nowadays, everybody can realize that ethanol is an option to avoid dependence on oil. A world market of ethanol would be profitable for Cuba" (Paranagua, 2007).

According to C. Ford Runge and Benjamin Senauer, two economists: "About 204 kg of maize are needed to produce 94.5 liters of ethanol and fill the tank of a sport utility vehicle (SUV), i.e. enough calories to feed a person for a whole year". The same economists suggested that more research should be carried out on alternative agrofuels. In 2050, to feed 9 billion people, food production should be doubled, while cultivable land will be scarcer. There will be therefore some kind of competition between food and agrofuel production. This may be true for wheat and rice, as foodstuffs, and also for maize, used as food and feed, but less for sugar-cane and cotton (Clavreul, 2007a).

Jacques Diouf, FAO's director-general, stated: "Biofuels are both a risk and an opportunity. A risk if they substitute food crops, an opportunity if they provide an additional income to the producers". As recalled by an adviser to Brazil's president: "The world problem is not the lack of food, but the lack of income" (Clavreul, 2007a).

Amidst the polemics on agrofuels, Brazil – the world's second biggest producer of bioethanol derived from sugar-cane – has been the focus of harsh criticism, along with the United States, the world's biggest producer of bioethanol derived from maize. For instance, Dominique Strauss-Kahn, director-general of the International Monetary Fund (IMF), stated that agrofuels raised "a real moral issue", while the former special rapporteur to the United Nations Human Rights Council on the right to food, Jean Ziegler, even spoke of a possible "crime against humankind". The president of France, Nicolas Sarkozy, strongly criticized the "unprecedented fiscal dumping" practised by the United States and Brazil to promote the production of "some biofuels" (Langellier, 2008).

Brazilians, and their president Luiz Inácio Lula da Silva at their head, consider these attacks as unfair and that they are victims of a misinformation campaign as well as of the harsh criticism, probably more justified, addressed to the United States. They indeed claim that there is a difference between the "good" ethanol – theirs - and the "bad" one –

that produced by the United States. Bioethanol derived from cane sugar is less costly to produce than gasoline, and one hectare of sugar-cane produces more than the double of bioethanol than one hectare of maize. Cultivation and transformation of maize into ethanol consume sevenfold more energy than those of sugar-cane. In addition, the cultivation of sugar-cane and the production of sugar do not deprive humankind of a staple food such as maize. Brazil claims that the cultivation and yields of both cereals and sugar-cane have increased, sugar-cane being grown on only 12% of arable lands. "We fill without problem both stomachs and motorcar tanks" summarized President Lula da Silva, who therefore concluded that accusing bioethanol for threatening food security was "a shameful lie" (Langellier, 2008).

At the 30th regional FAO conference which ended on 18 April 2008 in Brazilia, President Lula da Silva rejected any linkage between the production of agrofuels and the increase in foodstuff prices. Once again he mentioned the reasons for such an increase: adverse weather conditions in grain-producing and exporting countries, demand not met by supply and increase in food consumption in a number of developing countries. "There are many more people that can afford a meal three times a day; Chinese eat, Indians eat, Brazilians eat, and people live longer" he stated (Langellier, 2008). "Don't tell me, for God's sake, that food is more expensive because of biofuels. It is costly because the world is not ready to see millions of Chinese, Indians, Africans, Brazilians and Latino-Americans eating three times a day"… "Biofuels are not the evil products that threaten food security, on the contrary they decrease the dependence on fossil fuels without jeopardizing food supply", he added (Langellier, 2008).

It is true that the growth of bioethanol production from cane sugar has not prevented Brazil from becoming one of the world's major agricultural products exporter. The expansion of sugar-cane cultivation takes place mainly on abandoned grazing lands. Brazil's president stressed that the increase in oil price has raised the cost of food transport as well as of fertilizers, that the world financial and real estate crisis has led speculators to place their assets in the promising agricultural market. He went even further and condemned the rich countries' protectionist policies, in the form of subsidies (that protect their farmers) and tariffs (that hamper the competitivity of products exported by developing countries). For instance, the European Union imposes a 60% tariff on ethanol and Brazil, which supplies 30% of the ethanol consumed by the Europeans, considers this tariff absurd and has been negotiating on this issue with the European Commission since October 2007. Brazil is deeply

interested in the European market of agrofuels – ethanol and biodiesel - that may represent about 20 billion liters per year by 2020. President Lula da Silva considers that Brazil has "the land, water, knowledge, technology and 30 years of experience" and is therefore "an unbeatable competitor" that can legitimately win a large portion of the European agrofuel market. Finally, without naming him, President Lula da Silva replied to Jean Ziegler, that "the true crime against humankind would be to discredit *a priori* biofuels and to condemn the countries that lack food and energy to remain dependent and insecure" (Langellier, 2008).

In Brazil, although sugar-cane cultivation coexists with food crops such as soybeans, groundnuts and common beans, it has its shortcomings, even though bioethanol production has brought wealth to some regions, and created about 1 million jobs and slowed down rural exodus by mid-2008. The fact is that 90% of marketed new cars are flex-fuel cars, using bioethanol or gasoline, but for the first time in April 2008 bioethanol has been more consumed than gasoline. Brazil expects that other large countries like China or India would follow its energy policies. If this is to happen in a remote future, bioethanol could become a commodity listed on the stock exchange on the global market, where Brazil wishes to be the unchallenged leader (Langellier, 2008).

Impact of bioethanol production on grain output

The US department of agriculture (USDA) projected that distilleries would require only 60 million tons of maize from the 2008 harvest (312 million tons). But the Earth Policy Institute (EPI) - Lester R. Brown - estimated that distilleries would need 139 million tons, more than twice as much. Consequently, the competition between agrofuel consumption and grain for food would likely drive world grain prices to high levels. The USDA heavily relies on the Renewable Fuels Association (RFA), a trade group, for data on ethanol distilleries under construction. The other three firms providing the relevant data are Europe-based F.O. Licht, the publisher of *World Ethanol and Biofuels Report*; BBI International, which publishes *Ethanol Producer Magazine*; and the American Coalition for Ethanol (ACE), publisher of *Ethanol Today* (Brown, 2007).

According to the EPI compilation, the 116 plants in production on 31 December 2006 were using 53 million tons of grain per year, while the 75 plants under construction – mostly larger facilities – will use 51 million tons of grain when they come on line. Expansions of existing plants will use another 8 million tons of grain (1 ton of maize = 39.4 bushels = 110 gallons of ethanol) [Brown, 2007].

In addition, 200 ethanol plants were in the planning stage by the end of 2006. If construction were carried out between January 1st and June 30th, 2007, at the same rate that plants did during the final six months of 2006, then an additional 3 billion gallons of capacity requiring 27 million more tons of grain were expected to come online by 1st September 2008, the start of the 2008 maize harvest. This would raise the maize needed for distilleries to 139 million tons, and would yield nearly 15 billion gallons of bioethanol, meeting 6% of US auto fuel needs (Brown, 2007).

The US maize crop, accounting for 40% of the global harvest and supplying 70% of the world's maize exports, looms large in the world food economy. Annual US maize exports of some 55 million tons account for nearly one-fourth of world grain exports. The maize harvest of Iowa alone, which edges out Illinois as the leading producer, exceeds the entire grain harvest of Canada. Substantially reducing this export flow would have a significant impact on the world economy (Brown, 2007).

Fuel ethanol proponents point out, and rightly so, that the use of maize to produce ethanol is not a total loss to the food economy, because 30% of the maize is recovered in distillers dried grains that can be fed to beef and dairy cattle, pigs, and chickens, though only in limited amounts. They also argue that the US distillery demand for maize can be met by expanding land under maize, mostly at the expense of soybeans, and by raising yields. While it is true that the maize crop can be expanded, there is no precedent for growth on the scale needed. And this soaring demand for maize comes when world grain production has fallen below consumption in six of the last seven years, dropping grain stocks to their lowest level in 34 years (Brown, 2007).

The policy goal, according to Brown (2007), should be therefore to use just enough fuel ethanol to support maize prices and farm incomes but not so much that it disrupts the world food economy. Meanwhile, a much greater effort is needed to produce bioethanol from cellulosic sources such as switch grass, a feedstock that is not used for food. As the leading grain producer, grain exporter and bioethanol producer, the United States need to make sure that in trying to decrease its dependence on imported oil, it does not create serious disturbance in the world food economy.

Although it has been often stated that increased maize use for biofuels in the United States would cause food shortages in Africa and elsewhere because of reduced stocks and exports, the facts show that US maize exports, though less in 2006-2007 than in 2005-2006, were still above the average of the past ten years: they reached 2.45 billion bushels. It is

also important to highlight that most of the maize exported by the United States is used for cattle feed, not for human food in developing countries. In 2008, the production of biofuels would require about 60 million tons of cereals versus a worldwide cereal production well in excess of 2 billion tons. The increase in maize production of about 65 million tons in the United States alone in 2006-2007 would be sufficient to meet that need (*EuropaBio Biofuels Factsheet*, April 2008).

Increase in food prices

According to the US department of agriculture's calculations, maize prices were expected to increase by 3%-6% per billion gallon increase in the demand for maize-derived ethanol in the United States. The impact on wheat prices per billion gallon increase in the demand for bioethanol could range from 0.6% to 2.1% rise. A 14% share of biofuels in the European Union's transportation sector would imply an increase in price of 6% for wheat and 13% for rapeseed oil, but would cause the prices of rapeseed meal and soybean meal to fall by approximately 40%. Overall, the studies in the European Union and United States indicated that price rises for agricultural commodities for industry would be limited relative to the prices in force in 2008 (*EuropaBio Biofuels Factsheet*, April 2008).

It seems, therefore, that the amount of the contribution of agrofuel production to higher food prices (and even shortages) is disputed. Work by the International Food Policy Research Institute (IFPRI, Washington, D.C.) suggested that agrofuel production accounted for a quarter to a third of the increase in global commodity prices. The Food and Agriculture Organization of the United Nations (FAO) predicted by late 2007 that agrofuel production, assuming that current mandates continue, would increase food costs by 10% to 15%. Ron Litterer, president of the National Growers Association of the United States, stated that "there is no question that they (agrofuels) are a factor but they are really a smaller factor than other things that are driving up prices" (Martin, 2008).

About a fifth of the United States maize crop is now used to produce bioethanol for motor fuel, and as farmers have planted more maize, they have cut acreage of other crops, particularly soybeans. That may have contributed to a global shortfall of cooking oil. C. Ford Runge, an economist at the University of Minnesota, stated it was "extremely difficult to disentangle" the effect of agrofuels on food costs. Nevertheless, he said there was little that could be done to mitigate the effect of droughts and the growing demand for protein in some developing countries. "Ethanol is the one thing we can do something about", he stated. But

August Schumacher, a former US undersecretary of agriculture, who is a consultant for the Kellogg Foundation, stated the criticism of agrofuels might be misdirected. He noted that many of the upheavals over food prices abroad have concerned rice and wheat, neither of which is used as a biofuel. For both crops, global demand has soared at the same time that droughts (in Australia, Ukraine, etc.) suppressed the output from farms (Martin, 2008).

While the aid non-governmental organization Oxfam underlined that agrofuels were a major cause of the increase in global food prices, it called on rich countries to dismantle subsidies for agrofuels and reduce tariffs on imports. Oxfam's June report stated: "Rich countries, spent up to US$15 billion in 2007 supporting agrofuels, while blocking Brazil's cheaper bioethanol, which is far less damaging for global security" (Harrison, 2008). This statement recognized the difference between maize mainly grown in the United States and its transformation into bioethanol, and cane sugar, the feedstock used by Brazil for producing bioethanol. In a way, it strengthens the position of Brazil who has consistently defended its agrofuel policy and denied it was responsible for food scarcity or shortage.

Agrofuels, indeed, are fast becoming a new source of debate in global diplomacy, putting pressure on developed countries to reconsider their policies, even as they argue that agrofuels are only one factor in the rise in food prices. A number of food policy specialists consider government mandates for agrofuels to be ill advised, agreeing that the diversion of crops like maize into fuel production has contributed to the higher prices. But other factors have played big roles, including droughts that have limited output, particularly in grain-exporting countries, and rapid global economic growth that has created higher demand for food. Such a growth, much faster since 2003 than the historical norm, is lifting millions of people out of poverty and giving them access to better diets. But farmers could not keep up with the surge in demand (Martin, 2008). See also Energy Transition – Creative Energy (2008).

Is it realistic to reconsider agrofuel production targets?

Despite the fact that available data and detailed reviews do not lead to the conclusion that agrofuel production worldwide is the most important cause of the increase in food prices, Oxfam urged countries to scrap agrofuel targets, including European Union's plans to derive 10% of transport fuels from renewable sources by 2020. The NGO estimated that by 2020, CO_2 emissions from changes in land use in the oil-palm sector

might reach more than 3.1 billion tons, largely as a result of the European Union target, and, that it would take more than 46 years of agrofuel use at 2020 levels to repay this "carbon debt" (Harrison, 2008).

Is it realistic? For instance, France has launched an ambitious plan in 2005 to build some 20 agrofuel plants with important subsidies. In 2008, the new French government was lukewarm about carrying out such a plan; but the director of Sofiprotéol, which is the financial arm of the cultivation and processing of sunflower and oilseed-rape in France, and had invested more than €500 million over two years in the agrofuel business, while owning seven biodiesel plants, stated that "they needed more visibility and that their strategy was to optimize their production tool, emphasizing sustainability" (Clavreul, 2008b).

With respect to bioethanol, €1 billion had been invested by various actors. Tereos, a cooperative that owned five plants and aimed at pursuing its development in Brazil, expected the French government not to change the rules of the game, especially with regard to tax exemption (Clavreul, 2006, 2008b).

On 22 April 2008, in Rome, at the International Energy Forum, the French minister of ecology and energy development made a plea in favour of a "pause on building new capacities" for the first-generation fuels derived from grains and oilseed-rape. At the same time, he stated that the investments already launched will be "honoured", and the minister emphasized the need to focus on second-generation fuels that will use non-food crops and cellulosic wastes (Clavreul and Bezat, 2008).

The French agriculture minister replied to his colleague the day after (23 April 2008) on a French radio channel: "The issue is no that of agrofuels", but "the place they occupy". He underlined that France in 2010 will devote only 7% to 12% of its arable lands to the production of agrofuels, far behind the United States and Brazil (20%-30%). Whatever the position of each minister, the objective is the same, i.e. to mix 7% of agrofuel in motorcar fuel by 2010. The president of the French Republic did confirm this objective at the beginning of April 2008 at the congress of the main federation of agricultural trade-unions. That was not the case of the Confédération paysanne – the other association of farmers – which was not initially opposed to agrofuels, but then voiced its concerns about their impact on the price of food and feed in the world and also in France; livestock husbandry was particularly hurt by the increase in feed prices. On the other hand, the farmers who signed contracts to supply bioethanol plants, were losing money according to the trade-union, particularly

those who were delivering grains to Tereos' plant at Lillebonne (Seine-Maritime) and who committed themselves for five to ten years to supply wheat at a price twice less expensive than that of 2008 (Clavreul, 2008b; Clavreul and Bezat, 2008).

Bioethanol producers replied that "without agrofuels, France will not be able to meet its commitments in terms of renewable sources of energy" (20% in 2020). In fact, they should not be worried, because the 20 agrofuel plants foreseen to meet the 2010 target were already in service or under construction. The French Union of Oil Industries (UFIP) considered that it would be difficult to reach the objective of 5.75% of agrofuel in the transportation fuels in 2008, and it demanded to come back to the European norm, less ambitious and gradually reaching 10% by 2020. In its report *Perspectives énergétiques de la France à l'horizon 2020-2050* (Energy prospects for France for 2020-2050), delivered to the French prime minister in September 2007, Jean Syrota supported the end of tax exemption for bioethanol and "the halt of new investments in the production of first-generation biofuels" (Clavreul and Bezat, 2008).

While France was chairing the European Council from July to December 2008, a decision was to be made regarding the target of 10% of agrofuel in transportation fuels by 2020. The United Kingdom and Belgium seemed to be willing to review the issue if it were demonstrated that agrofuels had a direct impact on the steep rise in commodity prices. Germany stated on 23 April 2008 that it kept the European objective, but reduced what was set up for 2010 for bioethanol production (Clavreul and Bezat, 2008).

Conclusions

Maize production in the United States, by far the largest producer and exporter, has increased from 265 million tons (2006) to 327 million tons in 2007 (312 million tons in 2008), thus helping to adjust to the new market demand. In the past 40 years, yields of maize have steadily increased from about 4.5 tons per hectare to 9.4 tons per hectare in the United States, and from 2.3 tons/ha to 4.8 tons/ ha (average) worldwide. By 2015, yield in the United States was expected by the National Corn Growers Association to further increase to 11.2 tons/ha.

In Brazil, conventional sugar-cane produces up to 110 tons per hectare which are transformed into approximately 7,500 liters of ethanol (per hectare) plus sugar. A new genetically engineered variety of sugar-cane could produce up to 200 tons per hectare. Coupling the conventional

agrofuel production with a second-generation (cellulosic) processing technique, the total cane production could be transformed into 22,000 liters of ethanol. According to Fernando Reinach, chief executive of Votorantim Ventures (Votorantim is Brazil's biggest industrial conglomerate), plant science and biotechnology could treble agrofuel production from a hectare of land (*EuropaBio Biofuels Factsheet*, April 2008).

Meeting the European targets for a replacement of liquid fuel for transportation by 10% in 2020 in a sustainable and competitive way, entails the available biomass should be increased. Cultivating energy crops on set-aside and non-cultivated land would help, but it would not be sufficient to fulfill all the demand. It would be also critical to increase land productivity, i.e. more biomass output per hectare, as well as crop quality, e.g. crops that produce more fermentable carbohydrates or contain more oil. This can be achieved through modern plant breeding techniques and biotechnology. Another important step will be the competitive production of agrofuels from (hemi) cellulose and organic agricultural wastes instead of from starch, sugar and oils; these are the second-generation agrofuels, which need important investments in research and development (Sasson, 2008).

Thirdly, innovation in crop breeding and improvement should aim at reducing the amounts of water used in agriculture. In regions where maize or sugar-cane is irrigated, the water withdrawal per liter of agrofuel can be up to 3,500 liters. This withdrawal has a direct impact on immediate water availability for human consumption and food production. In Europe, where rainfed oilseed-rape or cereal is used, the amount of water for agrofuel crop through irrigation is small. In the United States, where mainly rainfed maize is used, only 3% of all irrigation withdrawals are devoted to agrofuel crop production, corresponding to 400 liters of water per liter of bioethanol. The breeding of drought-tolerant crops to minimize water use is therefore a promising area of research. Thus, agricultural and plant biotechnology can help to: increase biomass yield per hectare, while reducing inputs; improve crop quality (higher agrofuel yields); reduce land-use competition through higher productivity and reduced losses from biotic (pests, viruses) and abiotic (drought, salinity) stresses; contribute to the cultivation of energy crops in marginal lands; develop efficient micro-organisms and enzymes to convert hemicelluloses and cellulose into fermentable sugars (Sasson, 2008).

To sum up, although a report produced by an independent arm of the Organization for Economic Cooperation and Development (OECD) warned that agrofuel development could cause food shortages and damage to

biological diversity while providing limited benefits, we should not ignore the gains made in crop yields and overlook the benefits of reducing oil consumption. In the developing countries, the impact of agrofuel will vary from country to country. John Hoddinot, a senior research fellow at the International Food Policy Research Institute (IFPRI) in Washington, D.C., stated that farmers in Brazil and other countries that produced more food than they used stood to gain. In the United States, bioenergy industry officials express confidence that advances in technology, including higher crop yields and efficient production processes for second-generation agrofuels, will ensure that agrofuels do not increase food shortages, or starvation situations. Erik Fyrwald, group vice-president for DuPont Agriculture and Nutrition, stated that "technology can enable agriculture to continue to meet the food needs of the world very economically and, at the same time, play a very important role in meeting the world's needs in biofuels and biomaterials" (Brasher, 2007).

In its annual report on global food situation, published at the beginning of October 2008, the FAO made a strong call for a revision of policies and subsidies of OECD countries regarding agrofuels, in order to keep the objective of world food security and to guarantee a sustainable environment. Jacques Diouf, FAO's director-general, stated that "the opportunities for developing countries to draw a benefit from the demand for agrofuels would be enhanced by the suppression of agricultural subsidies and trade barriers, which create an artificial market and are frequently only beneficial for the producers of OECD countries, to the detriment of developing countries". Underlining that agrofuel production had trebled between 2000 and 2007 and that it should continue to grow during the next decade, with an impact on the increase in the price of food commodities, FAO made a strong plea for the reduction of risks and for better sharing the advantage offered by agrofuels (Le Hir, 2008).

The first international conference on biofuels, attended by some 2,000 experts and political decision-makers from 40 countries, was convened in São Paulo from 17 to 21 November 2008. President Inácio Lula da Silva participated in the closure ceremony, while the US president whose presence was expected because of the cooperation agreement on bioethanol signed in March 2007 between Brazil and the United States, could not attend the conference. Amidst the world financial and economic crisis, the overall mood was not very optimistic according to the journalists who reported the debates. The precipitous fall of the price of the barrel of oil (under US$50) could explain the lesser support for agrofuels (Gasnier, 2008).

The Brazilian Union of Sugar-Cane Industries was requesting assistance from the federal government in order to overcome the financial and economic crisis. According to Marcos Jank – an executive of the Union - only half of the 200 economic groups involved in the sugar industry would survive the heavy impact of the crisis. Nevertheless, the studies distributed during the São Paulo conference highlighted that agrofuel production was expected to rise 191% from 2008 to 2015 and sugar-cane plantations were to increase their acreage. According to the National Institute of Space Studies, this acreage rose 15.7% in a year in the south of Brazil (Gasnier, 2008).

The minister of mines and energy, Edison Lobao, announced that Brazil will increase bioethanol production by 150% in order to reach the level of 64 billion litres in 2017. Of the US$352 billion Brazil was expected to invest into energy projects during the eight-year period (2009-2017), US$23 billion (6.5%) would be devoted to bioenergy and agrofuels. Exports of bioethanol would increase from 5 billion litres in 2008 to 8 billion litres in 2017, thus consolidating Brazil's position as the world's leader.

Without overstating the role of agrofuels in the overall energy economy and balance, reasonable targets of production in those countries that choose the right crop species and bioengineering process, can contribute to the diversification of energy sources, particularly in transportation, without harming food production (Sasson, 2008).

Inadequate food supply: the key cause

Demand side

During the global food crisis, the chronically tight food supply the world has been facing was driven by the cumulative effect of several well established trends that affect global demand and supply. On the demand sides the trends include the continuing addition of 70 million people per year to the Earth's population and the desire of some 4 billion people to move up the food chain and consume livestock products. In China, for instance, annual per capita consumption of meat has risen from 20 kg to 50 kg in less than 30 years. About half of the grains produced in the world are used to feed the livestock. That was why the increase in cereal and fodder prices had a strong impact on livestock products: milk rose 80% to 200%, while poultry rose 10% (Brown, 2008; *Spore*, no.134, April 2008, p.2).

Thus, after about 40 years of decrease in the global prices of cereals (-60%), while production has been growing, two years were sufficient to send prices soaring. It was not therefore possible for several developing countries' governments to supply cheap food to their city dwellers. On the other hand, 80% of the 3 billion people surviving below poverty threshold live in rural areas and have increasing difficulties to feed themselves. The FAO listed about 30 countries for which the soaring prices of food has been dramatic: in Africa, Burundi, Central African Republic, Chad, Côte d'Ivoire, Democratic Republic of Congo, Eritrea, Ethiopia, Ghana, Guinea-Bissau, Kenya, Lesotho, Liberia, Mauritania, Republic of Congo, Sierra Leone, Somalia, Sudan, Swaziland, Uganda, Zimbabwe; in Asia, Afghanistan, Bangladesh, Indonesia, Iraq, North Korea, Nepal, Pakistan, Sri Lanka, and East Timor; in Latin America, Bolivia, Dominican Republic, Haiti, Nicaragua; in Europe, Moldavia and Chechnya (Russian Federation). Of these countries, one out of three is confronted with political problems, i.e. civil war and/or general insecurity (Tuquoi et al., 2008; Méhaignerie et al.,2008).

Still on the demand side, and without overestimating their impact, the use of maize to produce bioethanol in the United States has raised the annual global grain consumption.

Supply side

On the supply side, there is not much new land to be brought under the plough unless it comes from clearing tropical forests or from clearing the Brazilian cerradors (savannah-like regions south of the Amazon forest). This has heavy environmental costs, e.g. the increased rainfall run off and soil erosion. And in many countries prime cropland is being lost to both industrial and residential construction and to the paving of land for roads, highways and parking lots for fast-growing automobile fleets. Now, sources of irrigation water are even more scarce than new land to plough. During the last half of the 20th century, world irrigated area nearly trebled, expanding from 94 million hectares in 1950 to 276 million hectares in 2000. Since then, irrigated area per person has been shrinking by 1% a year (Brown, 2008).

It is therefore obvious that the global supply of food is insufficient. As stated by Jacques Chirac, the former president of France, "I have never ceased to fight against the freezing of production in Europe and to promote agricultural development in poor countries…." "Everybody at last realizes that humankind needs all its cropland. Food self-sufficiency is the first challenge developing countries should face and resolve" (Chirac, 2008).

This opinion was echoed by Méhaignerie et al. (2008) who stressed that the most urgent thing to do was to develop food crops worldwide and particularly in those countries whose population will grow rapidly in the coming years and decades. "It is in the South where humankind's food future lies". FAO has made a strong plea for devoting aid programmes to buy fertilizers, seeds and machinery so as to sustain agricultural and rural development for long periods of time. Europe, after the second world war, had to rebuild its agricultural production system in order to feed a growing urban population. It had to conduct a strong public policy to encourage and support farmers through a common tariff. It could therefore safeguard for half a century its food supply (Méhaignerie et al., 2008).

Neglect of agriculture

But agriculture has been neglected worldwide, receiving only 4% of public investments and 4% of development aid. This is the main cause of the global food crisis. Two reasons explain this unfair distribution of public expenses. Firstly, rural people, by contrast to city-dwellers, are not generally a strong pressure group. Paradoxically, it is in the developed countries where they are less numerous that farmers are most influential (and receive more aid). Secondly, the World Bank and most governments considered until the crisis that agriculture was not a major activity. As 4% of the population in the developed countries can feed the rest (96%), why is it necessary to help the farmers of poor countries who may find jobs in the industries and services? The World Bank is one of the major culprits of the crisis, because it had imposed for decades to poor countries measures aimed at reducing financial aid and administrative support for food crops and at privileging export crops. The result has been a dire lack of training and public investments, and food self-sufficiency has been considered for a long time as obsolete (Lemaître, 2008b).

After 20 years of errors and neglect, and confronted with the global food crisis, the World Bank changed mind and recognized that agriculture is a strategic sector. In this context the FAO, the International Fund for Agricultural Development (IFAD) and the United Nations Industrial Development Organization (UNIDO) organized the First World Forum of Agro-Industries in New Delhi from 8 to 11 April 2008; this was attended by 5,000 participants from 110 countries. At the Forum, Alain de Janvry, professor at Berkeley University, recalled that agriculture was a key sector for socio-economic growth. In China, India and Vietnam, for instance, agriculture has enabled hundreds of millions of people to move out of poverty as well as the economic take-off of these countries. In

addition, the creation of agrifood industries is often the first step towards a more industry-based economy. Even though the figures are extremely fragmentary because of the importance of the non-formal sector (it represents 60 % of jobs in some countries), agrifood industries are undoubtedly the first economic sector in the world (Lemaître, 2008b).

Not only the doubling demand of food by 2050 will have to be met, but also the processing of agricultural produce will be increasingly important; henceforth the closer relation between agriculture and industry. The farmers of poor countries need above all irrigation systems, good roads and a cold chain that would enable them to have access to the markets and to balance the weight and power of industry. India loses about 30 % of its harvest because of the lack of infrastructures (storage, cold chain and roads). In Asia, Africa, Latin America and Central Europe one comes to the same conclusions: farmers are deprived of a favourable environment, they need networking organizations such as production cooperatives, training and public infrastructures. Investments and loans are also needed (Lemaître, 2008b).

Consequently, current debates do not concern the gradual disappearance of agriculture, but its evolution. Developing countries will have to make their agriculture more competitive and to devote part of it to meet their basic food needs. Reaching a greater food self-sufficiency in Africa and Asia would have a positive impact on the developed countries who should drastically change their policies in the sense requested by their public opinion: more equality, less pollution and destruction of the environment, in other words carry out a more rational and environment-friendly agriculture. They should also review their tariff and subsidy policies so as to make the competition with developing countries fairer (Lemaître, 2008b; Méhaignerie et al., 2008).

The last time a global food crisis hit was in the early 1970s, during a combination of general rises in commodity prices, financial market turmoil and rising demand for food from the developing world. Policies then were twofold: change government interventions to encourage supply and increase productivity through new technology. In the 1970s, the United States reversed forty years of firm policy dating back to the Great Depression and changed its programmes to encourage output rather than support prices by limiting production. Subsequent reform, partly triggered by global trade agreements attempting to end distortions to agricultural markets, have since made little difference to this basic pattern. American farmers are paid to produce (Beattie and Blas, 2008).

In front of the 2007-2008 food crisis, the scope to do the same as in the early 1970s would be more limited. Taking away US and European Union subsidies to wheat and rice producers - a key demand of developing countries in trade talks - would increase, not lower the global commodity and food prices. In the medium term, the prospects for increasing supply rely on bringing more land into use, intensifying agriculture in the poor countries through the use of more fertilizers and improving farmers' access to finance and markets. In the longer term, hope may rest on technology, wider adoption of genetically modified crops and a repeat of the "green revolution" of the 1960s and 1970s. Work on similar breakthroughs for Africa, though being urgently pursued by donors such as the Bill and Melinda Gates Foundation and the Earth Institute at Columbia University, is at an early stage. Pedro de Camargo Neto, formerly chief agricultural negotiator for Brazil in global and regional trade talks, stated: "the solution is to create market signals that mean more production, better technology and more stability"(Beattie and Blas, 2008).

PROSPECTS AND CHALLENGES

Lester R. Brown of the Earth Policy Institute, Washington, D.C, stated that after the global food crisis that "business-as-usual is no longer a viable option". Food security will deteriorate further unless there is a worldwide mobilization to stabilize population, stop the deterioration of climate, stabilize water tables and aquifers, protect cropland and conserve soils. In this view, stabilizing population is not simply a matter of providing reproductive health care and family-planning services; it requires a worldwide effort to eradicate poverty. Eliminating water shortages depends on a global attempt to raise productivity similar to the effort made 50 years ago to raise land productivity, an initiative that nearly trebled the world grain yield per hectare (Brown, 2008). In the future, productivity should be measured in terms of a maximum yield per unit of land and unit of water.

The challenge is not simply to deal with a temporary rise in grain prices as in the past, but rather to alter those trends whose cumulative effects collectively threaten the food security. If the later cannot be restored quickly, social unrest and political instability will spread and the number of failing States will likely increase dramatically, threatening the very stability of the world (Brown, 2008). As the Roman philosopher Seneca stated: "a hungry person listens neither to religion nor to reason, nor is bent by prayers», stressing that where hunger prevails, peace cannot rule.

End of cheap food era

Olivier de Schutter, special rapporteur to the United Nations Human Rights Council on the right to food, appointed on 26 March 2008, and secretary-general of the International Federation of Human Rights Leagues since 2004, has stated in May 2008 that the global food crisis, particularly in developing countries, was the result of 20 years of errors and lack of investment in agriculture. The World Bank did recognize the fact by the end of 2007. And the programmes of structural adjustment promoted by

the International Monetary Fund have led the most indebted countries, particularly in sub-Saharan Africa, to develop export crops and to import their foodstuffs (Bolopion, 2008b).

Olivier de Schutter added that to just distribute food aid and not to understand the deep causes of the crisis will be a big mistake. The era of cheap food has ended, despite the fact that commodity prices (as those of raw materials and oil) have tumbled during the second half of 2008. We ought to produce more and better, and, as stressed by the French president Nicolas Sarkozy, on 11 September 2008 in his first speech on agricultural policy, agriculture is not an activity of the past, but of the present and future. In France, even though the number of farmers has decreased considerably, there were 800,000 full-time equivalents working in agriculture in 2008, and about the same number in the agrifood sector, i.e. a total of 1.6 million people, as many as in the construction sector, and just in agriculture threefold more than in the motorcar industry (Clavreul, 2007c; Bolopion, 2008b).

While the European Union used to manage food surpluses for many years, it may have to deal with deficits after the disappearance of huge stocks of meat, milk and grains. While in France many experts predicted a role of landscape caretakers for farmers, their role of producers has been underlined and considered a priority. Lucien Bourgeois, economist at the general assembly of chambers of agriculture, stated: "it is the end of what I call the Marie-Antoinette's concept of agriculture, the queen of France who considered that flocks of sheep were a breathtaking scenery in the alleys of Versailles castle" (Clavreul, 2007c).

Robert Zeigler of the International Rice Research Institute (IRRI, Los Baos, Philippines) – a driver of Asia's "green revolution" in the 1960s – also insisted on producing more after stating that governments are paying for years of neglect of agricultural research and irrigation. They have lost prime land and water supplies in the rush to industrialize. In March 2008, a report from the United Nations Economic Commission for Asia underlined that a boost in farm productivity could draw more than 200 million Asians, a third of the region's poor, out of poverty. Simply reducing disparities in productivity even between identical fields in a given district could solve Asia's rice worries for decades to come. That would require, for instance, that farmers could buy higher quality seeds, which in turn would entail more funding from governments for conventional agronomic research such as cross-breeding of existing strains of rice (*The Economist,* 2008c).

Food security and food sovereignty

Food security and food self-sufficiency

Feeding oneself is the first basic need of humankind. Among the economic, social and cultural rights of the Universal Declaration of Human Rights (1948), the right to food exemplifies the battle for putting economic and social rights on equal footing with the civic and political rights. This was the task of the United Nations special rapporteur, Jean Ziegler, for more than seven years, and now that of his successor, Olivier de Schutter. The global food crisis has been a sad reminder that hunger and starvation are still hitting 963 million people (or even more) worldwide. Sufficient food supply or food security is therefore a top national priority.

In this regard, the example of Malaysia is worth quoting .This country imported food worth 18 billion ringgit in 2007 and exported some 10 billion ringgit of edible goods, as stated by the agriculture minister in June 2007 (Muhyiddin Yassin, trade minister in 2009). "We have a problem with big import bills. You must be self-sufficient in many of the foodstuffs that you require", he stated. Agriculture, which accounted for almost a third of Malaysia's economy in 1970, accounted for 8.9% of gross domestic product in 2006 after decades spent promoting the country as a manufacturing base. The prime minister wanted to revive agriculture and agro-industry and to cut the country's dependence on food imports. About 100,000 hectares have been earmarked across Malaysia to rear shrimp and seafood, and cattle to boost domestic food supplies and increase food security. In 2007, the Malaysian government was seeking US$1.1 billion in private funding for these projects and the agriculture minister planned to more than double the value of fish caught and processed to 6.6 billion ringgit by 2010 (Whitley, 2007*).*

Creating more fish farms and cattle ranches is part of a five-year government plan stretching to 2010 to transform Malaysia's 840,000 farmers into competitive and highly productive entrepreneurs (Malaysia has a population of about 27 million people). Other projects include attempting to reverse declining exports of fruit, ornamental fish and seafood, and finding 10,000 agricultural entrepreneurs willing to take risks on new projects, according to the minister who was looking for assistance from local and overseas investors (Whitley, 2007).

Some 310 farms were to be set up across Malaysia, based around a cattle breeding centre at Gemas in the south-western State of Negeri Sembilan, to double the proportion of locally reared cattle in the country to 37%

by 2010. Convincing landowners to rear cattle is quite a challenge in a country where palm oil is the biggest agricultural export accounting for 56% of total overseas agricultural sales of 46.4 billion ringgit in 2006. At that time, the price of the commodity was at a record; it was still high in 2008 during the global food crisis and fell down by the end of 2008. Oil-palm plantations covered 4.1 million hectares in 2007, more than any other crop. Palm oil is dominating every aspect of Malaysia's agriculture (Whitley, 2007).

Food sovereignty

Three-quarters of the 963 million (or even more) underfed and malnourished people are small poor farmers, producers of staple foodstuffs. From this paradoxical situation was derived in 1996 the concept of food sovereignty launched by Via Campesina, a movement that involves more than 100 million small farmers. In February 2007, 500 representatives of associations of farmers, fishermen, livestock raisers, consumers and environmentalists gathered in Nyeleni, a village of Mali, to attend the first World Forum on Food Sovereignty. In their final statement, they defined their concept as "the right of people to healthy food, while respecting their cultures, and produced thanks to sustainable and environment-friendly techniques, as well as the right to define their own food and agricultural systems". They wished that this right of peoples to feed themselves be recognized by the States and international organizations, while allowing a fair retribution of work in family farms (*Spore*, no.128, April 2007, pp.1-2).

Food self-sufficiency advocated in the 1970s and supported by the States has been replaced in the 1990s by the concept of food security, whose objective is to make available all foodstuffs in sufficient quantities and with the adequate nutritional qualities, whatever is their origin, be they produced locally, imported or donated as food aid. That is why the promoters of free trade demand the opening of countries to imports of food, considering that consumers worldwide have the right to purchase their foodstuffs at the lowest cost possible. However, in a world market dominated by large agrifood companies and by the subsidized agricultures of Western countries, agricultural and food prices have been, since 1990, on the downward trend. This meant a very harsh competition for small producers from developing countries who have increasing difficulties to live from their farming activities. Their production costs are higher than imported food whose dumping prices discourage them to produce more (*Spore*, no.128, April 2007, pp.1-2).

In addition, food dependence of many developing countries has increased markedly. For instance, in West Africa, rice imports have been multiplied eightfold since 1960 and those of meat trebled in 20 years. Hard currency provided by agricultural exports from West Africa just pays for food imports, 70% of which compete with local products. Some countries feed themselves only thanks to imported food; this is the case of Seychelles, which imports everything, from grains to eggs, a recent trend due to the soaring number of tourists, costing US$500 million per year. Also many islands, such as those of the Pacific, depend on food imports; their inhabitants consume more and more processed foodstuffs and suffer from diseases associated with an unbalanced diet. In the Caribbean, rice and pork imported from the United States have a negative impact on local production of food. In a wide range of countries, consumers have changed their food habits and producers have stopped their farming activities due to the flooding of domestic markets by lower-cost agrifood products. Confronted with this situation, producers and consumers want to master their food production, processing and distribution (*Spore*, no.128, April 2007, pp.1-2).

Consequently, in Africa, Asia, and the Pacific, Latin America and the Caribbean, networks and coalitions of producers have been created in order to advocate and defend their right to food sovereignty. Their claims are directed to the World Trade Organization (WTO) with a view to changing the rules of world trade, and also to governments so as to adopt agricultural policies that support local producers. On its side, the Food and Agricultural Organization of the United Nations (FAO), through its *Voluntary Directives* developed in 2004, encouraged the States to translate the right to food in concrete terms, as the right for all to be able to feed oneself in a decent way (*Spore*, no.128, April 2007, pp.1-2).

Most claims focus on the right of developing countries to protect their agriculture as developed countries do through subsidies. Within WTO, these countries request, like farmers of the Asia and Pacific region in their May 2006 statement, that "food sovereignty prevails over free trade". It was on this point that international trade negotiations of the Doha cycle stumbled and have been interrupted in July 2006. Developed countries refused to wipe out subsidies to their farmers, while at the same time demanding the opening up of developing countries to imports. A group of developing countries, G33, has later on proposed that special safeguard measures be taken for "sensitive products" which would then benefit from some protection (*Spore*, no.128, April 2007, pp.1-2).

It has been estimated that some US$350 billion were transferred annually to farmers of the OECD (Organisation for Economic Cooperation and Development) countries compared with US$1 billion of aid for developing countries' agriculture (Bolopion, 2008b). It has been agreed in principle that these subsidies should be gradually reduced and even eliminated, so that those countries where agriculture is not directly subsidized could sell competitive products, including on their domestic markets. It is also true that if the United States and European Union's subsidies were eliminated at once, commodity and food imports would become more expensive for the countries who depend on them. This would also cause major social problems in the developed countries where farmers, although representing a small proportion of the active population, have an important political and economic weight.

Countries of Africa, the Caribbean and the Pacific (ACP) which signed the Lome Convention with the European Union, have made requests similar to those uttered at the WTO during the negotiations on the Agreements of Economic Partnership (AEP). They consider that "the reciprocity advocated by the European Commission does just mean the opening up of ACP countries' markets to the European Union's exporters" and that their producers will be harmed by Europe's subsidized agricultural imports. Some economists are of the opinion that "protectionism" is the only possible way to support agriculture in developing countries which cannot subsidize their farmers. A few countries are already doing so to protect some crops: Guinea for potatoes, Senegal for onions and Nigeria for cassava. In addition to limiting the consumption of imported products, some countries support the use of local cereals or starchy ingredients in making bread: since 2005, Nigeria has been requesting bakers to incorporate 10% of cassava flour in bread; likewise in Jamaica where bammy bread containing cassava is very popular; in Saint Lucia, domestic poultry breeds are being fed with substitutes to imported maize (*Spore*, no.128, April 2007, pp.1-2).

Food sovereignty also means the support for small farmers by governments in order to improve their productivity. It is closely related to agrarian reform that aims to redistribute land equitably and to improve access to water, agricultural inputs and loans (*Spore*, no.128, April 2007, pp.1-2).

Some countries or regions have put food sovereignty at the heart of their agricultural policies. In Africa, under ECOWAP (Framework of agricultural policy for West Africa) of the Economic and Development Community of West Africa (CEDEAO), adopted in January 2005, the goal is to "ensure food security of rural and urban population in West Africa, as well as the

safety of products, within the framework of food sovereignty of the region" and to "reduce the dependence on imports". In November 2006, the Niamey Forum in Niger has insisted on the need to defend this concept. In Mali, the agricultural bill of August 2006 had the same objectives. In Cameroon, farmers and consumers signed together a request addressed to the government, with a strong plea for the re-establishment of agricultural subsidies in order to increase local production. Political will is therefore crucial to channel investments towards rural and agricultural development – a key factor for reducing hunger in a sustainable way, as requested by FAO in its *2006 Status of food insecurity in the world* (*Spore*, no.128, April 2007, pp.1-2).

Food security and sovereignty were probably at the basis of the proposal made by Thailand at the end of April 2008 to create a "rice OPEC" in order to regulate rice prices on the international markets. Thailand – the world's biggest exporter of rice (10 million tons in 2007) – would be joined by its direct competitor, Vietnam (5 million tons of rice exported in 2007), as well as by Cambodia, Laos and Myanmar. The Philippines, a country that imports rice, was lukewarm about such a proposal.

Overseas investments for food security

The pursuit of farm investments overseas is also a clear sign of how countries want to ensure their food security following the world food crisis. Although prices for agricultural commodities have tumbled by about half from the very high levels reached by early 2008, countries remain concerned about long-term supplies. Consequently, some of them are trying to secure farmland overseas (Blas, 2008a).

South Korea

Thus, an agreement, concluded in July 2008 and revealed on 19 November 2008 by the *Financial Times*, between Daewoo Logistics of South Korea and the government of Madagascar concerned the leasing for 99 years of 1.3 million hectares in the Great Island. These areas are located in two distinct zones: in the west – Melaky and Menabe – and in the north-east – Sava. They are presently savanah grazing lands with a surface about half the size of Belgium. In Madagascar, 2 million hectares were cultivated in 2008, 8 million hectares were considered arable, and the overall agricultural potential was estimated at 35 million hectares. The country's surface is 588,000 km^2 and the population was 18.3 million people in 2007. Annual economic growth in 2007 reached 6.5% and the per capita domestic product amounted to US$370 (Tuquoi, 2008).

According to a statement by Daewoo Logistics' financial director on 17 November 2008, the company aimed to produce 500,000 tons per year of palm oil in the Sava region (north-east) and 4 million tons of maize in the western region(Melaky and Menabe), where 1.3 million hectares had been leased. The development of farmland will be implemented by local workers trained by South African and South Korean engineers, according to a statement made in July 2008 by Yong Nam-ahn, president of Daewoo Logistics – the agrifood subsidiary of the South Korean industrial conglomerate. The intention of the company, already present in Madagascar, was to substitute half of South Korea's maize imports (about 11 million tons per year) over the next 15 years of farming. South Korea, a heavily populated and resource-poor nation, is the world's fourth-biggest importer of maize and among the ten largest buyers of soybeans (Blas, 2008a; Tuquoi, 2008).

Daewoo Logistics, according to the agreement, will not provide cash to the state of Madagascar; but it will fund the development of the leased areas. According to Shin Dong-hyun, Daewoo Logistics' financial director, the company will invest US$6 billion over the following 25 years and build the necessary infrastructures. Oil-palm seeds will be imported from Indonesia and Costa Rica and those of maize from the United States. Carl Atkins of Consultants Bidwells Agribusiness stated that Daewoo Logistics' investment in Madagascar was the biggest he had seen. "The project does not surprise me, as countries are looking to improve food security, but its size does surprise me" (Blas, 2008a).

The agreement was cancelled on 18 March 2009 when Marc Ravalomanana was replaced by Andry Rajoelina – the former mayor of Madagascar's capital Antananarivo – as president of the country (Hervieu, 2009).

India

Another project also in Madagascar and carried out by the Indian company Varun International, may be doomed to failure in the new political context. The company intended to lease 465,000 hectares of farmland for 50 years, mainly in the regions of Sofia (170,000 hectares), Menabe (165,000 ha) and Antsinanana (100,000 ha). Most of these lands were already farmed and Varun International wanted to grow rice (80%), as well as maize and lentils (dal). Over more than a year, Varun International, a subsidiary of Varun Industries (kitchen utensils, oil, etc.), has been trying to carry out an agribusiness programme amounting to €1.5 billion over ten years. In a first stage, the authorization of Madagascar 's authorities had to be obtained and on 29 January 2009 Varun Industries' president,

Kiran Mahta, met with Marc Ravalomanana at that time head of state. The latter agreed on several conditions: Varun would have to make gifts to the president's foundation , sell at a retail price 15,000 utensils made from stainless steel to the president's agrifood group Tiko and dispatch Indian rice seeds to paddy farms also belonging to the president (Hervieu, 2009a).

Farmland belonging to the state and part of the project was rather small, as 85% of the land was already farmed, and consequently farmers' approval was necessary to strike the deal. Varun International proposed to them to lend their land for 50 years and they would receive 30% of the harvest. Farmers were to gain because of the foreseen high increase in yields (from 3 to 12 tons of rice per hectare), due to the use of more fertilizers and of machinery instead of draught cattle. Some farmers considered that a 50-year loan was too long, preferring 15 to 20 years, and fearing a new kind of colonization. An agricultural engineer living in Antsohihy, region of Sofia, raised a number of questions: "What to do with all the jobless farmers? Most of these live in remote areas and are illiterate; would they be employed by Varun International?" The Indian company stated that it would employ 10,000 people, i.e. 1% of all the farmers concerned in a country where unemployment is a major social problem. In contrast, the head of the regional administration (Sofia) claimed "this was a win-win project, that Varun International committed itself to bring electricity to the rural areas, drinking water and to build schools and health centres" (Hervieu, 2009a).

Whatever would be the future of this project, Varun International's efforts demonstrate that India's government is concerned about food security of the 1.1 billion Indians. The company does not deny that, but insists on the will to share the final food production with Madagascar's people who could become self-sufficient in the medium term; Varun would export 20 % of the rice output to India at the beginning of the project, and 60% ten years later (Hervieu, 2009).

The rush of a few countries

In 2008, according to the Barcelona-based non-governmental organization GRAIN, which aims to promote agricultural biodiversity and to defend the rights of small and poor farmers, as well as their food security, about 8 million hectares had been leased or acquired overseas by a few countries looking for securing farmland for their own needs. In addition to South Korea, Saudi Arabia, United Arab Emirates, Japan and China are also involved, and GRAIN has listed a dozen of countries with

important financial resources that had signed contracts to buy or lease farmland in developing countries : South Korea, 2,306,000 hectares; China, 2,090,796 ha; Saudi Arabia, 1,610,117 ha; United Arab Emirates, 1,280,500 ha; Japan, 324,262 ha. The United States have leased or sold farmland to Japan, Mexico and Cuba to China, Brazil to Japan, Argentina to South Korea; Algeria to the United Arab Emirates, Egypt to Japan, Sudan to South Korea, Saudi Arabia and United Arab Emirates, Cameroon to China, Uganda to China, Tanzania to China; Russia to China, Kazakhstan to China, Pakistan to United Arab Emirates, Mongolia to South Korea, Laos to China, Philippines to South Korea and United Arab Emirates, Indonesia to Saudi Arabia and South Korea; Australia to China, New Zealand to Japan (Tuquoi, 2008). GRAIN stated that in 2008 " the rush of the private sector to acquire agricultural land has been breathtaking"; the investors and countries concerned were convinced that population growth, climate change and the decrease in soil fertility will generate a rise in food prices and market tension, and they wanted to make sure that they would benefit from that trend.

On his side, Jean-Yves Carfantan, author of *Choc alimentaire mondial, ce qui nous attend demain* ("Global food crisis: what we shall expect tomorrow", published by Albin Michel, Paris, 2009), stated that "by the end of 2008, five countries had made important acquisitions of arable land overseas – China, South Korea, United Arab Emirates, Japan and Saudi Arabia; altogether they can farm 7.6 million hectares outside their national territory, which is the equivalent of 5.6-fold the useful agricultural area of Belgium"(Baudet and Clavreul, 2009).

China where 40 % of the world's active agricultural population is living, but has only 9% of global arable lands, had signed in 2006 agricultural cooperation agreements with several African states that included the setting up of 14 experimental farms in Zambia, Zimbabwe, Uganda and Tanzania. According to Jean-Yves Carfantan, economist and agricultural consultant in Brazil, "about 1 million Chinese farmers would be working in Africa by 2010". Most of these farmers are recruited among those who have been hit by the 2008-2009 economic crisis. This cooperation is based on the official reason that is to help African farmers increase their production through the transfer of Chinese technology. For instance, hybrid rice varieties, developed in China, could increase yields by 60% over the global average. But, according to J.-Y. Carfantan, a significant part of the harvests will be exported to China in order to guarantee the supply of national and local markets (Baudet and Clavreul, 2009).

In addition to farmland in Africa, the major land acquisitions by China were located in the Philippines (1,240,000 ha), Laos (700,000 ha), Russia (80,400 ha), Australia (43,000 ha) and Kazakhstan (7,000 ha). China's Fuhua Group stated it would invest US$4 billion to grow crops in the Philippines (*Time*, 8 December 2008, p.13).

Angola also attracts agrifood groups. About thirty years ago, this former Portuguese colony used to export agricultural products, while nowadays it imports half of its food, and nearly 10% of arable lands is cultivated. Consequently, Angola's government has launched a five-year development programme aimed at increasing food production. Foreign investors from Brazil, Canada, the United States and Portugal have been approached. With the British group Lonrho, which is widely present in Africa, negotiations were being carried out in 2008 for leasing 20,000 hectares. The company aimed to lease 2 million hectares in sub-Saharan Africa. During the spring of 2008, the US company Chiquita Brands – the world's biggest producer of bananas – announced its intention to massively invest in Angola, with a view to overcoming the hurdles set up by the European Union to banana imports from Latin America, where Chiquita Brands plays a key role (Tuquoi, 2008).

Arab States

By the end of 2008, Libya's president, Mouammar Khadafi, traveled to Ukraine to propose the exchange of oil and natural gas against the leasing of fertile farmland. This deal seemed to have been concluded. On 16 April 2009, a Jordanian delegation traveled to Sudan in order to strengthen Jordan's presence in agriculture that was initiated 10 years earlier (Baudet and Clavreul, 2009).

In the case of Saudi Arabia, it should be recalled that, despite unfavourable natural conditions, the kingdom ranked food self-sufficiency as a national cause, and between 1971 and 2000 the useful agricultural area rose from 0.4 to 1.6 million hectares, thanks to an irrigation policy supported with public funds. Arable lands were mainly located in the Hail and Qassim provinces, north of the capital Ryad, and in the southwestern provinces of Jizan and Najran. This policy was successful, as according to FAO, wheat production reached 2.5 million tons in 1995 and was higher than national consumption (1.8 million tons). Saudi Arabia was even able to export wheat, but its production cost was fourfold that of international prices. The high financial cost as well as the damage caused by pumping water from fossil water reserves led to questioning this agricultural development model, and the 2008 global food crisis made it unsustainable. In the

context of tensions on raw materials markets, strategic stockpiles built up by Iran during that period as well as speculative buyouts resulted in soaring prices that affected Saudi Arabia's staple food: rice (Paris, 2009).

Consequently, and despite the national policy aimed at subsidizing staple foodstuffs, Saudi Arabia's authorities thought of another policy to ensure the food security of the most populated country of the Arabian Peninsula (25 million people). While maintaining the subsidies for rice, Saudi Arabia has decided since December 2007 to abandon the cultivation of wheat and other crops. In January 2008, the government decided to decrease national wheat production by 12.5%. In 2015, the country will entirely depend on the imports of this cereal species (Paris, 2009).

However, the food self-sufficiency policy was not abandoned and in 2008 investments were made overseas, in particular to help private entrepreneurs who were willing to farm land and produce food to be exported to Saudi Arabia. A US$600 million fund was created and thereafter increased up to US$800 million in April 2008. It may even be increased again in the future. Agrifood companies initiated their exploration approach under the aegis of the agriculture and trade ministries. For instance, Hadco a company from Hail province, which stopped growing wheat, rented thousands of hectares in Sudan (with a view to cultivating 40,000 ha); it is also looking for opportunities in Turkey. The Ben Laden group, specialized in civil engineering, is engaged in Asia, wishing to manage 500,000 hectares of paddy fields in Indonesia, within an agricultural project of 1.6 million hectares including the production of agrofuels (Paris, 2009).

In January 2009, "Saudi" rice produced overseas was presented to King Abdallah for the first time. Consumers were still paying high prices for their food, despite the fall in international prices, because they made massive buyouts in 2008 to prevent any food crisis, when prices were very high (Paris, 2009).

Kuwait has followed the same pathway as Saudi Arabia: it agreed to offer loans totalling US$546 million to Cambodia to finance a dam on the Stueng Sen River for irrigation and hydropower and to build a road to the Thai border. The Kuwaitis may be offered in return 50,000 hectares of farmland, possibly on 99-year leases. This speculation raised political opposition, the chairman of the National Assembly foreign-affairs committee stating that if foreigners wanted Cambodian rice they should buy it, and not seek to control vast swatches of land (*The Economist*, 2009d).

Cambodian farmers were also suspicious because the government has a record of expelling them off their land in opaque deals involving rich people. Villagers in Battambang province, where the road funded by Kuwait will run, stated they knew almost nothing about the project, while conceding that such a new road would help them deliver their produce to markets. While the rumour indicated that Kuwait had agreed to buy all their produce, farmers were worried that their land would be confiscated, as it happened before. The government stressed the deal would be good for the country and for economic development (*The Economist,* 2009d).

It is true that Cambodia needs to modernize farming, which is the largest employer in the country (Cambodia's rice yields are about half of those in neighbouring Thailand and Vietnam – the world first- and second-biggest exporters of rice). International donors, including the Kuwaitis, hoped to improve the life of small-scale farmers by helping them to take advantage of world markets through investments into productivity, food processing and transport infrastructure. Other international businesses, including some from Israel, are seeking to bring foreign technology and capital into Cambodia's fledgling agribusiness sector (*The Economist*, 2009d).

In 2008, Qatar planned to invest US$200 million in Cambodian agriculture, and part of a US$1 billion development fund in Vietnam's agriculture (*Time*, 8 December 2008, p.13; *The Economist*, 2009d).

Al-Qudra Holding, an investment company based in Abu Dhabi, stated in August 2008 it planned to buy 400,000 hectares of arable land in countries of Africa and Asia by the end of the first quarter of 2009. Ethiopia's prime minister announced that his government was very "eager" to provide hundreds of thousands of hectares of farmland to Middle Eastern countries for investments (Blas, 2008a).

Securing farmland overseas: a neocolonial approach?

The Food and Agriculture Organization of the United Nations (FAO) has warned that securing farmland overseas might create a "neo-colonial" system. Paul Mathieu, an FAO expert on land tenure, declared to the French newspaper *Le Monde* that this trend was_accelerating and involved both risks, i.e. expropriation of land and opportunities, e.g. the supply of funds and technology to increase farmland productivity. If the agreements were well negotiated from the technological, legal, social and political viewpoints, it is possible to reach a win-win status. These agreements should be part of a rural development policy, and not just have the objective of increasing agricultural production; they

must improve the standard of living of the people, e.g. contribute to the development of transformation and processing industries that create jobs. These agreements should be concluded by the States themselves, in charge of increasing national wealth. FAO was to publish a guide for establishing leasing contracts and defining compensation methods (Clavreul, 2008g).

The situation of Mali, West Africa, illustrates these issues, and particularly shows whether foreign investments in agriculture benefit local farmers or mainly the foreign investors. The latter are interested in farming thousands of hectares, while resource-poor and smallholder farmers have an average of three hectares to farm in the region managed by the Niger Office. When this public entity was created in the 1930s by the French settlers, the farmland potential had been estimated at 1 million hectares. Nowadays, only 80,000 hectares are being cultivated. However, the government of Mali has requested the Office to cultivate 120,000 hectares by 2020. If this is done properly, Mali could become self-sufficient in rice and could even export significant quantities which would be an asset in a period of global food crisis. But due to the lack of funds, the country has to rely on foreign investments to develop the land, and build roads and irrigation canals (Clavreul, 2009c).

Small farmers are concerned because the development projects almost exclude them from the projects of land reclamation and new infrastructures. They are also afraid of expulsions from their land. For instance, the allocation of 100,000 hectares to the company Malibya, that is related with the family of Libya's head of state, has raised a lot of concerns, as small farmers considered that they would be deprived of water which would be used , in the first hand, to irrigate the lands of the foreign company. Resource-poor farmers were also concerned by Chinese projects aiming at developing sugar-cane plantations that will need a lot of water. The Chinese are already farming 6,000 hectares devoted to sugar-cane and control the sugar factory of Sukala (Clavreul, 2009c).

By contrast, at the Niger Office, officials in charge of these development projects are optimistic and claim that all partners wishing to help Mali are welcomed. Farm development projects need time and Seydou Traoré, president of the Office, indicated that the thirty-year (renewable) leases concluded with Libyans will start with 25,000 hectares. He also added to the list of already approved projects a sugar-cane cultivation project (15,000 hectares) funded by US and South African investors, and 11,000 hectares allocated to the West Africa Economic and Monetary Union (UEMOA), where farmers originating from the eight member countries

of the Union will be settled. S. Traoré could not hide that all these foreign investors were interested in exporting their farm products, but a small proportion will remain in Mali. However, he stated that local farmers should not become just agricultural workers, and that foreign investors have been requested to build schools and health centres. He also recognized that a fair distribution of water for irrigation will be difficult to achieve. For the first time, in 2009, the fee to use water flowing from irrigation canals during the second yearly rice crop has been raised to the same amount as that of water used for the first yearly crop (compared with only 10% of that rate earlier). Farmers' trade-unions stressed that this measure was taken in order to allocate more water to the sugar-cane plantations developed by the Chinese and Americans (Clavreul, 2009c).

On 10 April 2009, a shuffle in Mali's government converted the Niger Office into a Secretariat of State, attached to the prime minister, and farmers hope that their concerns and livelihood will be taken care of. They also want to benefit from the rise in food commodity prices; they tend to form cooperatives in order to sell their produce at a better price. They have enthusiastically supported the "rice initiative", launched by the government in 2008, that subsidized fertilizers up to 50%. A sign of hope was the effort made by 33 villages that had 3,500 hectares to develop outside the zone managed by the Niger Office; in fact they cultivated only 2,600 hectares in 2008 and planned to cultivate 3,050 hectares in 2009. Some farmers even benefited from the distribution of subsidies brought by a French foundation, and believed that in 2009 they would be able to feed themselves with enough rice, and even sell a small portion of the crop (Clavreul, 2009c).

The whole process of acquiring or renting farmland by foreign investors in Africa has been analyzed thoroughly and for the first time in eight African countries by experts from the International Institute for Environment and Development (IIED), in collaboration with two United Nations institutions, the International Fund for Agricultural Development (IFAD) and the Food and Agriculture Organization of the United Nations. The report published on 25 May 2009 and titled "Capturing farmland or opportunity for development", makes a strong plea for the consultation of rural populations under threat and for taking care of their interests in the negotiations. The report underlines the lack of transparency in the decision-making processes and in the investment circuits; henceforth the possibility of corruption (Clavreul, 2009e).

The report confirms the increase in the number large-scale operations. Over five years, in Ethiopia, Ghana, Mali, Madagascar and Sudan,

2.5 million hectares were the target of investors from overseas. Host countries have designed ways and means to attract these investors, and public agencies have been facilitating the deals. For instance, in Tanzania, a public agency identifies the lands, presents them to the investors and helps them to obtain the permits needed. Investors are generally private ones, but the States are often behind the deals. Direct investments by public agencies are not frequent and sovereign funds are less present than assumed. However, governments can be active through public enterprises or through being shareholders of private corporations. To that end, investment funds play a key role, e.g. that of Abu Dhabi for development. There are also bilateral agreements between governments such as that between Sudan and Syria (Clavreul, 2009e).

The report also highlights the presence of local investors in these large-scale deals (concerning areas between 1,000 and 500,000 hectares); they belong to urban wealthy social classes. This is the case in Ethiopia. The rise in the number of private Western funds or from the Gulf suggests that the acquisition of farmland would increase in the near future. In this regard, the report quotes the US fund Jarch Capital, which has targeted farmland in southern Sudan (Clavreul, 2009e).

As it is often the case in Africa, farmlands are state-owned and farmers have the right to use them. Investors are offered very low rights on the lands, because priority is given to the counterparts brought by the investors in terms of job creation and infrastructure building. But the report highlights that the contracts reviewed were mostly "short and simple, compared with the economic reality of the transaction". The investors' commitments are generally vague and the issue of the distribution of harvests between exports and local consumption is not thoroughly treated. But more importantly, the populations concerned do not participate in the negotiations, and the data relating to the area of the land acquired or rented and to the nature of the contracts are not made public. If it is true that private commercial deals need some confidentiality, "the lack of transparency is problematic" when discussions are held between governments. Jean-Philippe Audinet, director of IFAD's policy division, stated that he was worried by the fact that governments preferred "business to development" (Clavreul, 2009e).

However, should one condemn these concessions that may last up to 99 years, because they are not acquisitions in most cases? Paul Mathieu, an FAO expert, considers that this trend "is massive and everything should be done so that its impact is positive and damage be minimized". Everything depends on the terms of the deals and on the implication

of all actors (and not just investors and States). The report's authors underline that the efforts made by governments to attract large-scale investments should not detract their attention from the need to improve their populations' food security. Consequently, they request investors to explain their real intentions and/or goals at the outset of the negotiations; they recommend to the host countries to clarify their policy for receiving investments and to explain how the profits will be shared, as well as to respect local tenure rights. Deals should not only emphasize the volumes of production, but also the quality of products. Then, they can offer a real opportunity for improving agricultural productivity in the host countries. In particular, small and/or family agriculture should not be sacrificed to agribusiness (Clavreul, 2009e).

The challenge of food quality and safety

Food quality

What the food crisis emphasized was not only the insufficient world food supply, i.e. the quantity of food available presently and in the near future, but also the issue of quality. Beyond the 850 million people suffering from hunger, i.e. a chronic deficiency of calorie intake, over half of the world population is, in one way or another, struck by malnutrition, diseases of affluence or of deficiency of adequate nutrients. Women and youth are particularly suffering from nutritional deficiencies. Scientific research has demonstrated the huge negative impact of these diseases : increased mortality and morbidity, altered physical and mental development, diminished learning and working capacities are the short- or medium-term effects. At the same time, the widespread occurrence of chronic diseases associated with inadequate food habits – obesity, type 2 diabetes, cardiovascular and cerebrovascular diseases, some cancers – is a major concern for many developing countries. In 2006, the World Health Organization (WHO) reported that there were more persons with overweight or obese than the underfed people. It is now verified that most developing countries are affected by both kinds of pathologies and this is becoming a heavy burden for the health-care system (Delpeuch, 2007).

The 1996 World Summit on Food's main conclusion was taken up by the 2000 Millennium Summit of the United Nations: to halve the number of underfed people by 2015. But taking account of the advice of Amartya Sen, 1998 Nobel Economics Prize Laureate, emphasis has been laid less on the lack of food but much more on the eradication of poverty and the availability of work and jobs, i.e. on the access to food. People must

have the means to buy food which is often available or should become available thanks to higher agricultural productivity. But in addition to the challenge of supplying enough food and of giving the poor the means to purchase it, nutritional policies should also be set up and applied. These policies should be tuned with the global changes that underpin the way foodstuffs are produced, processed, marketed and consumed: food systems or chains are increasingly relying on industrial processes, population are concentrated in urban areas in both the North and the South, and large-scale distribution (hypermarkets) orients agricultural production. Nutritional policies should also be based on scientific facts and evidence, which is not often the case. The challenge is to integrate health and environmental objectives within the modalities of production and consumption of foodstuffs. New models are being formulated, for instance that of WHO European region which has three pillars: food safety, sustainable food supply and nutrition. On the basis of this regional model, national plans have been or are being formulated that try to convince economists, farmers, Agrifood industrialists, wholesale dealers and consumers. The goal of these national plans is to reverse the current trends and, for instance, to control the obesity epidemic from different perspectives (Delpeuch, 2007).

Food safety

Outbreaks of food-borne diseases

Outbreaks of food-borne diseases, whether caused by micro-organisms such as *Salmonella* or *Escherichia coli*, or synthetic chemicals, are rising sharply throughout the world , both emerging more rapidly than ever and spreading faster, according to the World Health Organization (WHO). The latter estimated that up to 30% of the population, even in some industrialized countries, were suffering from food-borne diseases each year; higher percentages were prevailing in the developing world. Jørgen Schlundt, WHO's director of food safety, stated: "I do not think we can say we have seen improvements in food safety – it is rather more going the other way" (Wiggins and Waldmeir, 2009).

Referring to the "troubling trend" about the rise in the average number of disease outbreaks due to food contamination to some 350 a year, up from just 100 or so in the early 1990s, the US president, Barack Obama, announced in April 2008 he was setting up a working group on food safety made up of cabinet secretaries and senior officials. He also promised to overhaul the "underfunded and understaffed" US Food and Drug Administration (Wiggins and Waldmeir, 2009).

It is true that food safety has drawn the public attention worldwide in 2007-2008 because of several events and scandals. For instance, the recall of Cadbury chocolates in Australia, Lipton green tea in Taiwan and Nabisco cheese crackers in South Korea, as well as the dozens of brands of infant milk formula in China contaminated with melamine, has shaken the confidence of consumers (Fuller, 2008).

In the United States, after an outbreak of illnesses across the country that started by the end of 2008, investigations showed that many of the patients had eaten products made by Peanut Corporation of America, a family-owned manufacturer based in Virginia. PCA supplied food companies, hospitals, nursing homes and cafeterias. Its spreads had become contaminated with a strain of *Salmonella*. By March 2009, nine persons had died, one of the biggest food-product recalls in the US history was under way and PCA had filed for bankruptcy. Officials have since been conducting hearings into what was wrong with the country's food supply – a reassessment similar to that being made by the Chinese government concerning the adulteration in 2008 of dairy products with melamine, which claimed six infant lives and made 300,000 babies ill (Wiggins and Waldmeir, 2009).

It should be mentioned that the peanut scare in the United States was followed in 2009 by the pistachio recall, again because *Salmonella* was found. In 2006, an *Escherichia coli* outbreak killed three Americans and led to the destruction of most of the country's spinach harvest, costing producers of the vegetable linked to the incidents some US$100 million (€76 million).

In China, the 2008 scandal over tainted baby milk with melamine has been mainly confined to mainland China, but melamine has been found in products as far away as the Netherlands and the United States, and recalls far from China affected food made by Chinese companies and multinational brands (Fuller, 2008).

Role of China

The Chinese government's attitude to the 2008 melamine scandal had been totally different from a previous scandal involving melamine contamination in pet food exported to the United States in 2007, according to Murray Lumpkin, deputy-commissioner of the US FDA, which has recently opened offices in China. "The Chinese have tried to be infinitely more transparent with the last incident", he stated, whereas in 2007 Chinese officials were said largely to have stone-walled overseas regulators (Wiggins and Waldmeir, 2009).

Big food companies, like Nestlé, Kraft and Danone, stated that while they did not use Chinese milk in their products outside China, they used other Chinese ingredients for goods sold throughout the world. " It is difficult sometimes to try to figure out how a certain product has been assembled and where a problem may have come from", stated Peter Hoejskov, a specialist in food quality and safety at the Food and Agriculture Organization of the United Nations (FAO) in Rome. Chinese companies are major suppliers of common ingredients and additives, like citric acid and many types of vitamins. The country is the world's largest exporter of seafood, most of it from fish farms, and a major exporter of chicken, fruit and vegetables. In the medical field, China sells large quantities of penicillin, heparin and paracetamol overseas (Fuller, 2008).

Chinese products have been failing food inspections for years. Hundreds of Chinese shipments have been stopped by inspectors in Europe, the United States and Asian countries in recent years. Because they contained banned chemicals or were unfit for consumption. In the European Union alone, Chinese fish and shrimp were rejected because they contained fungicides, antibiotics or other banned drugs; dried fruit and vegetables were found to have more than the allowed level of the preservative sulphite; peanuts had excessive amounts of mycotoxins (aflatoxin); and packaged foods tested positive for heavy metals that leaked from their packaging (Fuller, 2008).

Although only the world's eighth-largest food exporter, China ranked in first place in 2007 for the number of hazardous imports detected by regulators in the European Union. China had 352 notifications, its highest level ever, compared with 191 for the United States, which is the world's biggest agricultural exporter. By mid-October 2008, China's government announced measures intended to improve the quality and the safety of dairy products, as well as new regulations on the breeding of cows, and the production and sale of dairy products. It also called for tough penalties for people who violated safety standards (Fuller, 2008).

For instance, the antiseptic Ng Fung Hong slaughterhouse outside Shanghai, where every pig has its own water supply, its own shower and identity tags that follow it from piglet to pork chop, symbolizes a growing attention in China to food safety. Ng Fung Hong, a Honk Kong food company that owns a 51% stake in the Shanghai slaughterhouse, has built it to make it one of the most advanced in the world. It was chosen by Shanghai's government in 2006 to test a farm-to-store tracking programme for pork aimed to identify and isolate tainted foods. Shanghai now requires all pork producers to provide such tracking. Several other

provinces have small pilot tracking programmes for vegetables and other foodstuffs, including Beijing which instituted several such schemes for the 2008 Summer Olympic Games (Wiggins and Waldmeir, 2009).

Ng Fung Hong slaughterhouse uses radio frequency identification (RFID) to keep tabs on its carcasses. Each pig entering the slaughterhouse wears a plastic ear-tag with a number traceable back to its home farm. Everything that happens after that is tracked by computer. The pigs are induced to drink, relax and take a shower in the pigpen. They are thereafter knocked out by electric shock, bled and their carcasses are hung from metal hooks bearing RFID tags. When the carcass is split and inwards tumble into a pan below, the same RFID number goes on the pan " so that we know which pig insides are which", according to Wang Qianjiong of Shang Shi Wu Feng, the joint venture that operates the plant. This official also pointed out that five or six government inspectors were present full time at the plant. If any of the pig inwards cause problems, the company can locate the source and quickly recall all affected products. The process added about Rmb 2-3 per kilogramme to the cost of the pork in the supermarket. Although this technology was widely available, industry officials warned that in China it was used only sparsely; consumers were unwilling to pay extra for "psychological security" (Wiggins and Waldmeir, 2009).

It is true that China's melamine scandal had been particularly damaging to consumer confidence because it came after the Chinese government declared it had tightened regulations and heightened vigilance in the wake of problems with tainted dog food, also made in China, that sickened or killed thousands of dogs worldwide in 2007, and other tainted products. In July 2007, the government carried out the execution of the head of the food and drug safety agency, who was convicted of taking bribes in return for approving drugs. Regulators also closed 180 food manufactures that had been using banned drugs, hydrochloric acid and formaldehyde in candies, seafood, pickles and cookies. The whole system of food safety and traceability must be reviewed, the root causes of the failure being the intense competition for profits and the general lack of monitoring (Fuller, 2008).

It is also true that, according to Dali Yang, political science professor at the University of Chicago, the Chinese public has been spurred to demand better quality. "The Chinese media have been emboldened in the reporting of quality issues and there is a healthy interaction between media and regulators. This had led regulators to be more proactive… whereas previously they largely abdicated their responsibility in the case of the melamine-laced milk powder" (Wiggins and Waldmeir, 2009).

Local authorities at first tried to cover up the melamine problem (2008), but when Beijing central authorities learnt about it, they rapidly stepped in, dispatching an army of inspectors to dairy companies throughout China. One foreign infant formula brand that was not one of the 22 companies whose milk tested positive to melamine nevertheless had government inspectors resident 24 hours a day for several weeks, and still has daily visits from inspectors (Wiggins and Waldmeir, 2009).

A global issue and how to curb food-borne diseases

Food safety is a global issue and a major challenge. What can be done to curb deadly incidence of food-borne disease outbreaks on the rise? The ongoing industrialization of food production, which is not alien to the spread of new pathogens, is one reason. This was a factor in the new variant of Creutzfeldt-Jakob disease recognized in the 1990s, which was linked to exposure to bovine spongiform encephalopathy (or "mad cow disease"). Poor regulation is another reason. In March 2009, the US department of health and human services released results of an investigation showing that it could track only five out of 40 food products back through each stage of the supply chain. One bag of flour contained wheat from more than 100 farms (Wiggins and Waldmeir, 2009).

The European Union's annual report on food safety revealed that foodstuffs reported from well over 100 countries were contaminated. One of the difficulties for regulators is to know what to look for and having the human power to carry out the tests all along the food chain. In the case of the Chinese milk scandal, Fonterra, a New Zealand company that owned a large stake in one of the manufacturers that distributed tainted baby formula, stated it never occurred to them to check for melamine. After the scandal, a spokeswoman for the company stated that Fonterra had only recently become aware of one dairy company in the world which routinely tests for melamine – a white powder used to make plastics and when added to milk creates the false impression that diluted or poor-quality milk was up to standard (Fuller, 2008).

Governments often have not adequate resources to carry out more than basic, random testing. The USFDA only has the capacity to examine 1 % of all shipments into the country, according to a report published in 2007 by the Congressional Research Service, a non-partisan US government agency. The president of the Consumer Union of the Philippines, a private non-profit group, stated the country's food inspection agency "only takes action if someone complains or if the media reports about food products that are defective or pose serious threat to public health" (Fuller, 2008).

The globalization of the food chain, which has seen more and more food that is grown in one part of the world but processed and consumed in others, implies that a disease outbreak or food scare in one country can quickly be felt elsewhere. The chief supply office at one multinational food company stated that three to five years ago (2004), a food scare in the United States was likely to be confined to that country, because the ingredients for its products were sourced and manufactured there. But, nowadays, some 60 % of ingredients are sourced and used globally (Wiggins and Waldmeir, 2009).

Sourcing ingredients from around the world also make it more difficult to manage the whole food supply chain. There many different standards around the world, which is a major challenge for tracing foodstuffs. For instance, of the Kraft Foods' 168 manufacturing plants, 110 are located outside the United States, in some 45 countries. On the other hand, FAO pointed out that governments in the past had been reluctant to impose too many safety standards on food manufacturers, because they could hinder trade. They could also be costly. "When the levels of mycotoxins are very strict, they can become trade-restrictive", stated Ezzedine Boutrif, chief of food quality in FAO's food and nutrition division (Wiggins and Waldmeir, 2009).

Is it even possible to make the global food chain safe? There are no global food safety standards. In addition, although governments monitor locally produced foodstuffs for human consumption, regulatory systems have not yet been established to monitor the animal feed system – one of the sources of melamine contamination in China. Outside China, companies' shortcomings are also under increased scrutiny as governments realize how vulnerable their food chains are, not just to disease outbreaks but also to deliberate tampering. Consequently, food companies have been trying to address weaknesses in their supply chains, e.g. changing their quality control system in order to deal quickly with problems on a global basis, or making all products themselves then outsourcing some manufacturing to third parties. In China, for instance, everyone in the dairy industry is now testing for melamine; previously, such tests were not carried out because melamine should not be found in milk in the first place. Nowadays, companies with a brand to protect are trying to predict what other substances might be found in their dairy products (Wiggins and Waldmeir, 2009).

Some companies that used simply to batch-test products from suppliers have started testing every shipment; those which outsourced testing have brought procedure in house. "No one is trusting anymore, everyone is just

verifying", stated Gene Grabowsky of Levick Strategic Communications, an expert on managing food-quality scandals of overseas brands. Nestlé, which was among the companies not testing specifically for melamine, has introduced systematic testing across the world for raw milk delivered to the factory gate as well as for products leaving the factory. It is aiming for a "not detectable" result. Kraft Foods has brought in additional quality specialists to oversee suppliers. Companies have therefore increased incentive to respond to consumers' concerns about safety. In particular, foreign brands present in a country recognize that in order to satisfy public opinion, they need to uphold the best of standards (Wiggins and Waldmeir, 2009).

Nowadays, it is not enough to say a foodstuff is safe, it has to be proven. Solutions to the global food crisis should therefore include a good monitoring of food safety from "fork to farm", as the European Commission christened one of its research-and-development programmes. Produce more and better means more food, but also healthier and safe food for all.

The road ahead

2009 : the fall of raw material and commodity prices

2008 has been an exceptional year in many respects: financial crisis, economic recession and rise of unemployment, all kinds of financial frauds and abuses, and above all a formidable increase in the price of raw materials, from crude oil to cereals, from copper, steel, rubber to maritime transport; all basic products have been affected by this skyrocketing trend. The barrel of oil reached US$147.27 (€108) on 11 July 2008, a few weeks after soaring prices of cereals and the subsequent hunger riots. A few days before the opening of the Olympic Games in Beijing, new purchases by China of ores and metals sent their prices to summits; that was also the case of sea freight cost (Chalmin, 2009).

But nobody could give a rational explanation to the fact that prices tumbled by the end of 2008 and early 2009. The decrease rate was 95% for sea freight, 75% for all metals and oil, and only 50% for cereals. That was an unprecedented fall. One explanation, however, was that China - a big buyer of most of the raw materials – had reduced its purchases drastically, for both reducing the precautionary stocks made before the Olympic Games and adjusting to the slowdown of industrial growth. In addition, there has been the impact of recession that struck all industrialized countries. Finally, the financial crisis and the withdrawal of speculative funds have certainly played a role. The overall result was that,

at the beginning of 2009, prices were close to those prevailing in 2004 and 2005.

On an annual average basis, however, global indicators have been on rise by only +27%, and even 10 % if energy (oil and gas) were included. The strongest increase rates concerned agrifood products (+30 % to +40% for cereals and oilseeds) and oil (+35%, i.e. an average cost of US$100 a barrel). In contrast, metal prices were on a downward trend (-2% for copper and aluminium) or even collapsing (-42% for zinc and nickel) [Chalmin, 2009].

In fact, unlike oil and metal ores, agricultural goods were still more expensive in February 2009 than they were 12 months earlier. A. Chatham House report released by the end of January 2009 noted that even the recent fall from peak prices in July 2008 was only temporary, as future supply is likely to be constrained in part by a continuing lack of investment into agriculture. The economic crisis meant small farmers could not afford to plant to full capacity, and there were early signs that the credit crunch had dried up some of the private investment that was supposed to foster agrifood production. Instead, the world is facing a renewed food crisis (Foroohar, 2009).

It should also be stressed that the fall in the prices of agricultural commodities was due to a record harvest in 2008-2009: +5.3% for the global cereal harvest, up to 2.2 billion tons. Cereal stockpiles could be beefed up after the very low levels of 30 June 2008 (Chalmin, 2009).

But such a trend may not be sustainable, due to weather vagaries and climate change, and the 2009-2010 harvest may not be a bumper one. Severe droughts struck northern China, and particularly the region of Beijing, at the beginning of 2009; Argentina experienced in 2009 the most severe drought in decades, which will reduce its agricultural output; Australia continues to suffer from drought and the State of Victoria has been devastated by scorching fires in February 2009.

While California has suffered severe dry spells before including a three-year stint ending in 1977 and a five-year drought in the late 1980s and early 1990s, the negative effects were compounded in 2009 by the economic recession and other factors. Richard Howitt, chairman of the agricultural and resource economics department at the University of California, Davis, estimated that 60,000 to 80,000 jobs could be lost and that as much as US$2.2 billion in crop and other losses could be caused by restrictions on water and the drought. In 2008, during the second

year of a severe drought, more than 100,000 acres or more than 40,000 hectares of the 4.7 million in the Central Valley were left unplanted; and experts predicted that the number could soar to nearly 850,000 acres in 2009. The State has put the 2008 drought losses at more than US$300 millions and economists forecast that losses in 2009 could swell past US$2 billion, with as many as 80,000 jobs lost (McKinley, 2009).

Even as rains have fallen across some regions of California in February 2009, agriculture officials stated a lack of rain and the prospect of minimal State and federal water supplies had led many farmers to fallow fields and retreat into survival mode with low-maintenance and low-labour crops. All this could mean shorter supplies and higher prices in US grocery stores – California being the biggest US producer of tomatoes, almonds, avocados, grapes, artichokes, onions, lettuce, olives and many other vegetables and fruit. The situation is particularly acute in towns along the western side of the Central Valley, where farmers were informed on 20 February 2009 that US government officials anticipated a "zero allocation" of water from the Central Valley Project, the massive New Deal system of canals and reservoirs that irrigates 3 million acres of farmland. If the estimate holds and the spring of 2009 remains dry, it would be the first time ever that farmers faced a season-long cutoff from a federal water system (McKinley, 2009).

Towards another rise in agrifood prices

Agricultural commodity prices may increase again, because the supply of food would not be adequate. That seemed already the case of sugar: since 1 January 2009 the price of raw sugar has been rising up to UScents13.26 per pound on 13 February 2009; that price was for a three-month delivery. One should recall that the price of raw sugar was very low in 2007, less than UScents10 per pound by the end of that year. Conversely, the price of wheat was so attractive that farmers in India (Gujarat and Rajasthan States), Ukraine and Russia proposed to plant the cereal rather than sugar-beet or sugar-cane. This shift was supported by governments which feared a grain deficit and subsequent social unrest. The European Union, on its part, has been decreasing the acreage of sugar-beet in the framework of its common agricultural policy (Faujas, 2009).

By mid-May 2005, prices of raw sugar in New York rallied to a three-year high UScents16.03 per pound, up about 35% so far in 2009, boosted by a crop failure in India, the world's largest consumer. India's sugar production was expected to fall from 26.5 million tons down to 18 million tons during the 2008-2009 campaign. The Lausanne-based Kingsman SA

sugar consultancy predicted a world sugar production deficit amounting to 9.6 million tons for the 2008-2009 harvest. By contrast, Brazil was set for a record sugar crop of 36.4-37.9 million tons during the 2009 season, up from 31.6 million tons in the previous season (Blas and Wheatley, 2009; Faujas, 2009).

Brazil's capital-intensive sugar industry, which leveraged its expansion on cheap debt, has suffered under the weight of the 2008-2009 credit crunch and low prices for most of 2007 and early 2008. Brazil remains the world's biggest exporter of sugar (41.3% of total in 2007), compared with Thailand (9.3%), Australia (7.7%), European Union (4.3%) and others (37.4%). But in 2009 five sugar companies with about 1 million tons of production – about 4% of the country's exports – have applied for "judicial recuperation", the Brazilian form of US chapter 11 bankruptcy protection (Blas and Wheatley, 2009).

According to Kingsman SA, credit both to trade and to expand was no longer available to the Brazilian sugar mills as it was when the industry was growing rapidly in the early 2000s. Manoel Fernando Garcia, president of S/A Fluxo, one of the biggest sugar traders in Brazil, stated credit lines used to finance future contracts had been cut drastically compared with the level of 2007-2008, at least more than 50%. "To fix contracts for October 2009 or March 2010, I would have to have credit lines to cover margin calls as prices go on rising. But the banks are being extremely cautious and we just do not have the lines", M. F. Garcia told the *Financial Times*. "Relative to historic levels, we are seeing a massive restriction on the selling side of the sugar market", stated Toby Cohen, at London-based sugar merchant Czarnikov, echoing a view widely shared by other participants in the sugar market (Blas and Wheatley, 2009).

It remains that India's hefty imports and speculative buying, as well as credit crunch affecting Brazilian sugar mills are all acting towards the increase in sugar prices.

Another sign of future increase in commodity prices was the nearly 8% rise of soybean prices in Chicago by mid-March 2009, as well as those of wheat, maize and meat, further to the halt of sales of grains, oilseeds and beef by Argentine farmers until midnight on Friday 20 March 2009. The strike threats occurred after the Argentine government rejected the farmers' demand to cut a 35 % export tariff on soybeans and sought political support by sharing proceeds of the levy with Argentina's provinces instead. "This stand-off between Argentine farmers and their government is worsening, threatening further drawdown of an already

tight US soybean carry over", stated Richard Feltes, head of commodities research at MF Global, a brokerage in Chicago. The US department of agriculture saw US soybean inventory falling in 2009 to a five-year low of 5 million tons, down from 15.6 million tons in 2006-2007 (Webber and Blas, 2009).

Argentina is the world's second-biggest exporter of agricultural commodities and its sales of soybeans and maize were critical in March 2009 to importers such as China, who turn to Argentina and Brazil until US harvests become available. But in addition to a severe drought in 2009, Argentina has become increasingly unreliable in world markets. Farmers have used halting overseas sales as a main bargaining tool since the confrontation over export tariffs in 2008. The government at times banned maize, meat and beef exports to protect local supplies and prices. On 22 March 2009, the farmers were protesting at about 60 locations in northern and central Argentina and have staged roadblocks, occasionally forcing truckers to dump loads. They saw the government's plan to share 30% of the estimated US$5 billion (€3.7 billion) due in 2008-2009 from soybeans tariffs as a bid to buy the support of governors of farming provinces (Webber and Blas, 2009).

Hugo Biolcatti, president of the Rural Society, Argentina's biggest producers' group, warned farming province governors that "the situation will not be calm", if they make the deal with the government. The latter cannot afford a prolonged conflict with the farmers, who consider it is "strangling them to the point of asphyxiation", according to Eduardo Buzzi, head of the agrarian federation, a key producer group (Webber and Blas, 2009).

Despite the prediction of the International Monetary Fund that global gross domestic product (GDP) would contract by 1.3% in 2009 – the next severe recession since the 1930s – the prices of a number of raw materials and commodities have rallied for the first quarter of 2009. Oil was some 60% more expensive by mid-May 2009 than in December 2008. Palm oil has surged more than 50% in 2009, partly because demand from India was holding up. China imported a record amount of iron ore and coal, while imports of crude oil hit a 12-month high. Demand for raw materials and commodities was recovering and experts were optimistic that China's US$586 billion stimulus would drive a turnaround in the sagging economy. Commodity traders were bidding up market prices in general on expectations that supply shortages would return with just a modest improvement in demand (Schuman, 2009).

On the other hand, the impact of the persistent food crisis is compounded by the deepening of the global economic recession, the rise in unemployment, while the price of staple foods remains relatively high. By the end of January 2009, the International Labour Organization (ILO) predicted that some 200 million workers, mostly in developing countries, would be pushed into extreme poverty by job losses or wage cuts in 2009. Given that the very poor already spend 50% of their income on food, officials worried that the number of starving people could spike during 2009. There were already 963 million, up from 923 million in 2007, before the last food crisis began (Foroohar, 2009).

The regions with the most working poor – sub-Saharan Africa and South Asia – also have the world's highest starvation levels. At a global food security summit in Madrid early February 2009, United Nations and government officials warned that hunger was likely to increase in 2009 in these and other vulnerable regions like the Caribbean and parts of Central Asia, due to not only deteriorating employment prospects at home, but also because of dramatically decreasing remittances from abroad (which accounted for as much as a quarter of gross domestic product – GDP – in some poor countries). Worsening public finances would not help either (Foroohar, 2009). In fact, poorer countries will be less and less likely to subsidize food prizes for their own populations because of the deterioration of their economies (the International Monetary Fund's projections for emerging market GDP growth were down from 5% to 3% for 2009). At the same time, of the record US$22 billion in pledges for food aid and agricultural development made by industrialized countries during the height of the global food crisis in 2008, only US$2.5 billion had been disbursed by mid-2009 (Foroohar, 2009; Clavreul and Tricornot, 2009).

How to meet the challenges?

We know what should be done to meet the challenges raised by the global food crisis in a sustainable way and regarding rural infrastructures, storage of agricultural produce, irrigation and water management, transport, funding of harvest campaigns, organization of markets, loans and microcredit to farmers. Emphasizing the growing disbalance between the demand of food worldwide and the supply which is shrinking as the main cause of the food crisis and of future similar events, experts have stressed that only a "double" green revolution i.e. both ecological and hypertechnological, could feed 9 billion of people, while providing a decent income to small farmers (who represent three-quarters of the poor in the world), and becoming more respectful of the environment. "It is through research and innovation by the farming communities that the

world could feed itself", stated Marion Guillou, president of the French National Agricultural Research Institute (INRA) (Le Boucher, 2008a).

Nicolas Baverez, a French economist and historian, has underlined that solutions to the food crisis should be envisaged in terms of production, investment, innovation, and not of protectionism, subsidies, control of stocks and prices. And for the following three reasons: market prices are the best way to increase the supply, to reduce poverty and to thwart rural exodus. Agricultural protectionism tends to slowdown production and productivity gains. Finally, barriers to trade, because of the rather small proportions of crop harvests that are traded internationally (17.2% of wheat production, 12.5% of maize and 7% of rice), worsen the lack of supply and stimulate the artificial rise in commodity prices (Baverez, 2008).

If the right decisions are made, agriculture can enjoy a bright future during the 21st century. Europe has a key role to play in this respect. At the time when the Common Agricultural Policy (CAP) is to be reviewed and evaluated in principle in 2013, but probably before as its opponents raise their concerns and denounce its annual budget (€48 billion in 2013), many experts have stressed the urgent ploughing of 3.5 million hectares that had been kept idle (fallow). Agriculture in the European Union should be rethought, according to N. Baverez (2008), as a sector of economic production and not as a means to look after the rural landscapes. Export subsidies should be dismantled as they create big distortions that harm developing countries. A real priority should be given to the harmonization of standards within the common market, particularly of food safety norms. The CAP must be reinvented completely, but its commercial part should not question the opening up of borders that are a source of competition, or the aid for development, a key contribution to justice (Baverez, 2008; Le Boucher, 2008a).

France, for instance, can draw a great benefit from the new emphasis laid on the economic dimension of agriculture and its insertion into the world market. While France's share in world exports is being eroded, that its external trade balance is increasingly accumulating deficits (€40 billion in 2007), the country had an agrifood trade surplus of €9.1 billion in 2007. This has led to consider that agriculture was the first competitive advantage of France; henceforth, the need to choose an opening up policy and innovation. This means, for instance, that genetically modified crops should be regulated and not forbidden; otherwise, France runs the risk to be excluded from the agricultural revolution of the 21st century (Baverez, 2008).

SOLUTIONS

By mid-April 2008, the former president of the French Republic, Jacques Chirac, underlined that solutions for the global food crisis existed. He highlighted that food crops should be encouraged and subsistence agriculture must be rehabilitated and protected from the unfair competition by food imports, which destabilize the economy of developing countries and discourage local producers (Chirac, 2008).

To that end, it is necessary to invest in both research – with a view to developing productions and varieties adapted to climate change and to the scarcity of water - and training and extension of agricultural techniques. One should rely on local producers who must receive a fair reward for their efforts. Trade exchanges should follow equitable rules that respect both the consumer and the producer. Free trade cannot be carried out at the detriment of the most vulnerable producers (Chirac, 2008).

Investment needs are massive and for long periods. It is vital to keep the objective of 0.7% of domestic gross product to be devoted to public aid for development. It is equally crucial to find additional resources for innovative funding modalities, such as the tax on air tickets that provided several hundred million euros for the purchase of drugs for developing countries (particularly against HIV/AIDS). As suggested by the World Bank's president Robert Zoellick, one may explore how much of sovereign funds could be channeled towards productive investments in sub-Saharan Africa (Chirac, 2008).

Can the Earth feed 9 to 10 billion people?

In 1798, Thomas Malthus, a British clergyman and economist, was convinced that population growth was the cause of our environmental hardships, but also of wars, and political and social unrest and upheavals. Maybe Thomas Malthus was right at his time, as Paul Krugman, the 2008 Economics Nobel Prize Laureate, stated: "In 1789 French farmers used

to live in chronic food efficiency and 20% of them were suffering from malnutrition. However, during the 19th century, T. Malthus' predicaments were not substantiated because agricultural yields rose, international trade increased, subsistence goods became more abundant, while migration reached an unprecedented magnitude (Joignot, 2008).

Yet, the fears about overpopulation continued. In 1932, when global population reached 2 billion people, the French philosopher Henri Bergson wrote: "Let Venus act, she will bring you Mars." In 1948, Albert Einstein warned Abbé Pierre – the French clergyman who devoted his life to defend the rights of the poor – that three "explosions" threatened our "mortal world": the atomic bomb, the information bomb and the population one. In 1971, under the aegis of the Club of Rome, the ecologist Paul Ehrlich, who was a specialist of insect populations, published the best selling book *The P Bomb*. He announced "human proliferation", which he compared to a "cancer": "too many motorcars, too many factories, too much detergents and pesticides,… too much carbon dioxide. The cause is always the same: too many people on Earth" (Joignot, 2009).

Although these fears were sometimes irrational, it is true that humankind's "ecological footprint" and acceleration of climate change, combined with a strong growth of human population, may lead to a "Malthusian" situation. Many are of this opinion and not only those who strongly recommended a deceleration of growth or those who belong to the neomalthusian movement Negative Population Growth (NPG). In fact, the Canadian non-governmental organization, Global Footprint Network, founded in 2003, has been trying to quantify the "ecological footprint" of human activities. This tool was designed in 1992 after the Earth Summit in Rio de Janeiro by William Rees and Mathis Wackernagel. It is nowadays recognized by the Organization for Economic Cooperation and Development (OECD). To evaluate it, Global Footprint Network compares the annual rhythm of production of resources – foodstuffs, fuels, etc. – and assimilation of wastes by nature with the rhythm of consumption of these resources by humankind and of waste generation. The last calculation made showed that the Earth can only provide 1.78 global hectare (gha) per inhabitant, while world consumption has been estimated at 2.23 gha per capita. It was also calculated that if the global population followed the way of life of Europeans and Americans – motorcars, hot water widely available, daily consumption of meat, fossil energy – the area needed would be equivalent to four or five times that of the planet Earth (Joignot, 2009).

The French demographer Hervé Le Bras, of the National Institute of Demographic Studies, has underlined that dire predictions about global population were often unrealistic. In less than 200 years, humankind rose

from 1 billion people at the beginning of the 19th century to 6 billion in 1999. Between 1987 and 1999, i.e. in 13 years, it increased from 5 billion to 6 billion. Presently, many forecasts for 2050 hover between 8.4 and 9.5 billion people, i.e. 3 billion more than in 2008. Reacting against alarmist predictions, all demographers agree that there is a strong decrease in women's fertility across the world, and subsequently a decrease in population growth rate. According to them and the United Nations, the "P bomb" will not explode. Hervé Le Bras has quoted the case of Iran: women's fertility fell down from 6.5 children per woman in 1985 to 2 children per woman, like in France. In China, the ratio is 1.75 children per woman, which means that 400 million Chinese who were announced by demographic curbs were not born. In India, although the ratio was 4.5 in the northern part of the country, the average was under 3. H. Le Bras stated that the population growth rate was slowing down: from 1.21% in 2006 to 0.37% expected in 2050, because of the decrease of women's fertility worldwide. While in Mexico and Brazil the number of children per woman is between 2.1 and 2.3, and 2.4 in Indonesia, in Kenya that number went down from 8 in the 1970s to 4 nowadays (Joignot, 2009). In the Islamic world, the same trend prevailed: from 6.8 (average) in 1975 to 3.7 nowadays, and even 2.2 in Morocco and 2.1 in Tunisia, the reasons being the spread of literacy among women and marriage at an older age. Consequently, if this overall trend continues, the United Nations' demographers estimate the global population at 8.2 billion in 2030, 9 billion in 2050 and a stabilization at 10.5 billon in 2100. Humankind would have achieved its "demographic transition" (Joignot, 2009).

The question is therefore: would the Earth be able to feed and withstand a population of 9 or 10 billion people? In 2050, 86% of world population will live in poor or emergent countries – half in China and India, which will promote an anti-natalist policy. The impact of population will vary widely from one region or country to the other, depending on soil fertility, water and land quality, and even more on agricultural, economic and social policies. Amartya Sen has shown that poverty and famine were not so much due to overpopulation, but rather to the lack of democracy and the absence of a social state. For instance, famine prevailed in India until 1947, when the country became independent. Later on, the existence of a free press, of several political parties and of a parliamentary opposition allowed forecasting and mitigating the disasters. Nowadays, India feeds a population of over 1 billion people because it has achieved its "green revolution", supported by the state policy oriented towards food security. Conversely, in other parts of the world, cash crops for export have been promoted at the expense of food crops. Sub-Saharan Africa, once self-sufficient, has to import most of its food, and according to Amartya Sen,

one should not consider population growth as the main culprit, but rather wrong development policies. That is why FAO has requested a global agricultural governance, under the aegis of the World Trade Organization (WTO) and with the help of the World Bank in order to foster food and cereal crops. With such a coordinated world policy, the planet could meet the needs of a 10-billion population. Otherwise, as also stated in the 2008 OECD report on *Environment Prospects in 2030*, the predicament would be bleak: a global temperature increase of 1.7°C to 2.4°C, droughts, floods, storms and heavy damage to infrastructures, an increase in water stress for 3 billion people, and ecosystems delivering less services in terms of environment preservation (Joignot, 2009).

OECD experts criticize wrong policies in many countries and among industry managers, such as heavy subsidizes to intensive agriculture, to oil companies, laxist regulation on chemicals use, massive production of carbon dioxide, overfishing. They stated that consumption habits were largely responsible for the degradation of the planet's ecosystems and resources. What is at stake is the change in behaviour regarding consumption, e.g. according to the *World Energy Output 2008,* in 2030 millions of motorcars will still use gasoline and generate massive quantities of carbon dioxide, because the automobile industry is not moving enough rapidly to building "green" cars (some car manufacturers have started but this is not enough). Should the Western countries reduce their large consumption of meat, as recommended by the US economist Jeremy Rifkin? (Joignot, 2009).

To sum up, the Earth can feed its population if a concerted action is carried out to decrease humankind's "ecological footprint" through a drastic revision of current consumption habits, and agricultural and economic policies at global, regional and national level.

Meeting the immediate needs

The first and most urgent measure is to meet immediate basic needs. The World Food Program needed by mid-2008 at least €488 million to buy supplementary foodstuffs for starving people. The United States, the European Union and Japan were requested to provide the needed funds. Robert B. Zoellick, president of the World Bank, stated that the world should move from the traditional aid to a wider concept of food and nutrition aid. Very often, funds rather than supplies of foodstuffs are needed so as to develop local food markets and agricultural production. When there is a scarcity of food, buying it from local farmers contributes to the strengthening of the communities concerned (Zoellick, 2008).

The World Bank can support urgent measures addressed to the poor, while at the same time encouraging the production and commercialization of food within the framework of sustainable development. In the struggle against poverty, progress in agriculture has an impact three times more important than that of other sectors. It should be recalled that 75% of the poor worldwide live in rural areas and most of them derive their living from agriculture. Sub-Saharan Africa is the primary focus of World Bank's assistance: its loans will increase up to US$800 million from UD$450 million, in addition to assistance for the management of systemic hazards, such as droughts, at the level of countries and farmers (Zoellick, 2008).

On 21 April 2008, in Accra, Ghana, the United Nations' secretary-general Ban Ki-moon highlighted the threats – economic, social and even political – of the global food crisis and underlined that 37 countries were already confronted with urgent food needs. He encouraged the international community to provide the World Food Programme with an amount of US$755 million, urgently needed for paying the increasing costs of food and its transport. He also requested the countries to adopt local measures aimed at supplying food at an affordable price, even for the poorest (Bolopion, 2008a).

The International Fund for Agricultural Development (IFAD) stressed that in many countries poor farmers, who are key actors in providing solutions to the crisis, were unable to benefit from the increase in commodity prices because they could not buy the fertilizers and seeds needed for the following harvest. That is why IFAD was planning to devote US$200 million of urgent aid to these farmers (Bolopion, 2008a).

A world plan of action

On 28 April 2008, in Bern, Switzerland, the United Nations' secretary-general Ban Ki-moon met with the chief executives of 27 United Nations agencies and funds or programmes in order to draft a world plan of action aimed at responding to the global food crisis. The day after, the secretary-general announced the creation of a crisis unit, the task of which was to provide the adequate answers to the crisis. The secretary-general's advisers suggested the organization of a summit of heads of state and government at FAO headquarters in Rome from 3 to 5 June 2008, in addition to a meeting on food security already planned for those dates. The meeting in Bern reviewed the range of solutions to the global food crisis and also meant to unify the voices of the international institutions on such issues as the real impact of a agrofuel production on the rise in commodity and food prices, in relation with the right to

food debated at the United Nations Human Rights Council, or with the International Monetary Fund's policies that promoted cash crops and harmed subsistence agriculture (Bolopion, 2008a).

World Food Summit (2008)

From 3 to 5 June 2008, 40 heads of government gathered in Rome under the auspices of the United Nations' secretary-general and FAO. Joachim Von Braun, head of the International Food Policy Research Institute (IFPRI), based in Washington, D.C., and one of the 18 centers or institutes of the Consultative Group on International Agricultural Research (CGIAR), stated that the Rome summit should focus on five key issues.

Firstly, food aid. At the Summit, the World Food Programme (WFP) announced an extra US$1.2 billion of food aid, thanks partly to Saudi Arabia, which just before the meeting pledged US$500 million. This was a remarkable donation, while most announcements of "new money" turned out to be old promises repackaged (*The Economist*, 2008f).

Secondly, biofuels. Some non-governmental organizations wanted a moratorium on bioethanol production, stating this would cut grain price by 20%. Some big food companies and parts of the United Nations system were in favour of international restrictions on the production of maize-derived ethanol. Still others argued that biofuels were fine as an idea but were beset by a tangle of subsidies, tariffs and production targets. The summit made no headway in unravelling that tangle. Just before it, the US agriculture secretary, Ed Schafer, claimed that bioethanol accounted for only 2% - 3% of the increase in world food prices – a contentious view, but one that left the summit split over biofuels (*The Economist*, 2008f).

In 2004, almost 14 million hectares had been devoted to agrofuel production, i.e., 1% of total arable land (mainly in the United States, Canada, Latin America and the European Union). According to FAO, two scenarios could be envisaged: in 2030, if current trends continue 34.5 million hectares would be used for agrofuel production, i.e. 2.5% of total arable land; still in 2030, if countries adopt the currently discussed policies on energy security and emissions of carbon dioxide, then 52.8 million hectares would be used for the production of agrofuels, i.e. 3.8% of total arable land (Clavreul, 2008b).

Thirdly, the summit could have come up with more short-term solutions, beyond food aid, to increase farmers' incentives and to cut world prices. The most obvious fix was to reduce export bans. Around 40

food-exporting countries had imposed some sorts of trade restrictions on food: taxes, quotas or across-the-board bans. A study of the IFPRI estimated that eliminating these bans would reduce world cereal prices by an average of 30%. Vietnam, Cambodia and India have all promised to resume some of their rice exports. Japan, a big importer stated that it would release about a fifth of its government-controlled rice stockpile. But Egypt extended its ban on rice trade for another year. This once again reflected the divergence of countries' interests. Most developing countries are net importers, but some are net exporters. In Botswana and South Africa, for instance, food accounts for a fifth of the consumer price index; in Sri Lanka and Bangladesh, it accounts for two-thirds. And most poor nations are victims or beneficiaries of food inflation (*The Economist*, 2008f).

At the summit, many speakers argued that the value of short-term measures were limited. "The underlying problem is the decline in agricultural productivity growth," stated Lennart Bage, head of the International Fund for Agricultural Development. "Unless we reverse that, we'll be back in the same situation in a few years' time" (*The Economist*, 2008f).

Indeed, the Rome summit did make a start on the long-term goal: **a second "green revolution"**. The United Nations' secretary-general stated that food output needed to double by 2050, taking account of population growth rate and the change in food habits (e.g. increase in the consumption of meat and dairy products as well as of grains to feed livestock). According to IFPRI, the world would need a supplement of 200 million tons of cereals (in addition to the 2.1 billion tons produced in 2007) (Clavreul 2008b).

Producing more food requires the extension of arable lands and/or yield increase (intensification). Countries indeed are issuing or at least preparing a long list of promises to help finance research on improved seeds, build irrigation canals and spread fertilizers use among small farmers (seeds, irrigation and fertilizers were the main components of the first "green revolution" in the 1960s). These promises could well be the main achievements of the Rome summit (*The Economist*, 2008f).

Implications and risks of the lower priority given to agriculture

However, at the G20 meeting in London, early April 2009, agriculture was not a priority issue, although the United States stated after the summit they would duplicate their assistance to agricultural production in poor

regions, and France expressed its will to launch an investment fund for helping Africa's agriculture(about €500 million) (Clavreul, 2009b).

Sophie Bessis, research director of the French International and Strategic Relations Institute (IRIS), underlined that the underestimation of the importance of agriculture has been prevailing for thirty years, well before 2008-2009 economic and social crisis. She recognized that geostrategic experts, who start showing their interest in water management, were still neglecting the agricultural issue. She distinguishes two types of political destabilization generated by agriculture: at the international level, for the last ten years, agriculture is the stumbling block of the free-trade negotiations carried out under the aegis of the World Trade organization (WTO); at the national level, high food prices can lead to social unrest and destabilization of governments that are not always legitimate (Clavreul, 2009b).

In wealthy countries, high food prices have led consumers to buy differently, "in Africa, it is an issue of life and death and this even threatens the existence of states", recalled Aly Abou Sabaa, of the African Development Bank, during a symposium organized at the Bank of France. Several African participants in this symposium have underlined the serious implications of soaring food prices: riots, but also the increase in the magnitude of migrations and terror, in the use of drug addiction, e.g. in West Africa (Clavreul, 2009b).

But more than inflation of food prices, the hypervolatility of prices that cannot be mastered is an even more serious risk. According to Jacques Carle, who chairs a French think tank (MUMA), the price of a ton of wheat would vary between €80 and €320 during the forthcoming years. In these conditions, it is difficult to forecast a stable global production, because farmers regulate their sowings according to the level of prices. Thus, in 2009, US farmers decided to let a lot of farmland idle (fallow), in order to wait for more favourable prices (Clavreul, 2009b).

Another factor that hinders the necessary increase in agrifood production and heightens the risks of soaring food prices is the limited access to credit and loans due to the financial crisis. In agriculture, everything is linked to borrowing money for buying seeds, fertilizers and biocides. At the US Federal Reserve, there were concerns regarding the impact on exports of the restriction to access to credit, while the World Trade Organization forecast a decrease in international trade in 2009. That had a heavy negative impact on big food importers, which include many poor countries (Clavreul, 2009b).

Finally, there is the issue of the budget capacity of States to guarantee reasonable food prices. According to Philibert Andzembé, governor of the Bank of Central African States, "in 2008 some countries could take appropriate measures thanks to the budget surpluses generated by the very high oil prices since 2006. In 2009, they were not able to intervene in the same way." In 2008, subsidies to bread prices, waiving of custom tariffs to facilitate food imports and even the rise of salaries, could assist households. For instance, the eight member States of the Economic and Monetary West African Union had to sacrifice more than €457 million in fiscal revenue to try to maintain food security (Clavreul, 2009b).

Another region that must draw the urgent attention of such bodies as G20 or G8 is the south and east of the Mediterranean basin. Due to the increase in population growth and environment degradation, the countries of that region will be increasingly facing food security problems in the coming years. To meet this challenge, the International Centre for Higher Agronomic Mediterranean Studies (CIHEAM) – an intergovernmental organization – has made an urgent call to rethink rural development in the whole region, in a report published on 8 April 2009. "Food riots have reminded everybody about the dependence of the region on world markets", stated Bertrand Hervieu, CIHEAM's director. In the Maghreb lives 1% of the world population, but the region imports 8% of global wheat imports. B. Hervieu believes that there is an increasing awareness of the agricultural and food issues, but it is not sufficient. He considers that "no one can imagine that peace would prevail throughout the region, if every person is not meeting its basic food needs". CIHEAM scientists have been struck by the fact that the standard of living is worsening in rural areas and not improving (Clavreul, 2009b).

By contrast with the countries of the northern rim of the Mediterranean basin, rural population and even agricultural population increases in the southern rim and in the eastern Mediterranean region, where rural migration is slowed down by the misery prevailing in the cities. Consequently, the size of farms decreases. The only activity in the rural environment is agriculture, which is the source of living. Agricultural development is the solution to all these ailments, when climate change imposes major constraints in terms of water and land availability; henceforth the urgent need to rethink this agricultural and rural development. B. Hervieu warned that, "the bipolarity of the current model, with a non-sustainable agriculture based on exports and derelict small and family agriculture, is not offering satisfactory prospects". He also added that a third type of agriculture, survival agriculture, was spreading rapidly, but was a sign of bad development (Clavreul, 2009b).

On 7 April 2009, the *Financial Times* revealed that a report prepared for the G8 meeting on agriculture requested "immediate interventions". The report indicated that food crisis, which could become structural if nothing were done, "will have major implications not only for trade relations, but also for social and international relations, which will have a direct impact on security and stability of international political situation." The G8 meeting on agriculture was scheduled from 18 to 20 April 2009 in Italy (Cison di Valmarino, near Trevise, in the north-east of the country.) In addition to agriculture ministers of the United States, Russia, Germany, Japan, Canada, United Kingdom and Italy, those of Brazil, China, India, Mexico and South Africa (G5) were invited, as well as those of Argentina, Australia and Egypt, and representatives of international institutions (e.g. World Bank, FAO and African Union). This meeting is a follow-up to the decision made by the heads of state and government of the G8, at their meeting in Japan in 2008, who requested their agriculture ministers to meet and make concrete proposals on food security and on the means to limit the volatility of food prices. The ministers were expected to submit a document to the G8 summit to be held in July 2009 in L'Aquila, Italy. The major issue is to keep food security at the top of the political agenda, because it is closely related with peace and social stability – which was not the case at the G20 summit in London at the beginning of April. FAO recalled that €30 billion per year would be sufficient to control hunger, through a sustainable and strong support for family agriculture (Clavreul, 2009b). See also Clavreul and Tricornot (2009).

On the other hand, a conference on investment opportunities in agriculture in Africa was organized from 20 to 24 April 2009 in Addis Ababa, upon the invitation of the department of rural economy and agriculture of the African Union Commission. The conference had on its agenda: the promotion of investments in agriculture within a context of climate change; the development of regional trade and markets; and funding mechanisms. In addition, the conference dealt with the ways and means to: stimulate the participation of poor and vulnerable social groups living in rural areas in economic activities; promote policies that strengthen land-tenure rights; and improve agrifood productivity and subsistence means.

On Friday 10 July 2009, in L'Aquila (Abruzzi, Italy), at the G8 summit, the heads of the world's major industrial nations (United States, United Kingdom, France, Germany, Italy, Japan, Canada and Russia), together with the G5 (China, India, Brazil, Mexico and South Africa), Egypt and international organizations (G8+5+1+5), made the commitment to

levy US$20 billion over three years in order to struggle against hunger worldwide. Italy's prime minister, Silvio Berlusconi, who was the host of the summit, stated that further to the discussions held between the G8 and heads of emergent and African countries, the pledges rose from US$15 billion to US$20 billion. The following African countries were represented : Algeria, Angola, Egypt, Ethiopia, Libya, Nigeria, Senegal, South Africa, as well as the African Union. The L'Aquila Declaration on Food Security that was adopted by all countries attending the summit, stated :
"We (…) remain highly concerned about global food security, the impact of financial and economic crisis and soaring food prices in 2008, which hit the least developed countries, that are confronted with the worsening of hunger and poverty… "Although staple food prices have fallen from their 2008 record high, they are still high and volatile".

The president of the International Fund for Agricultural Development (IFAD), Kanayo Nwanze, expressed his satisfaction about the G8 commitment, which he considered "a major shift". Increasing investments into agriculture in developing countries is, according to him, moving "from food aid, which consists of delivering a medicine to a child who is already ill, to assistance to countries which will set up the appropriate policies aimed at producing their own food". Jacques Diouf, FAO's director-general, also hailed "a happy and encouraging change in policy".

The G8 also approved a set of principles concerning "international agricultural investments", aimed at avoiding that poor countries lose their farmland, while foreign investors are rushing to several regions, particularly in Africa, to buy or lease arable lands. Industrial nations also announced the strengthening of their partnership in order to improve the access to water throughout the African continent.

Finally, the G8 renewed its commitment to increase public aid for development, in favour of Africa, and to increase, together with other donors, this aid by US$25 billion per year over the period 2004-2010.

The L'Aquila G8 meeting was undoubtedly a turning point in global governance, because the world's eight major industrial nations opened their ranks and welcomed a wide range of countries as well as young leaders (the Junior 8), in order to discuss major political, economic, cooperation issues, as well as actions to mitigate climate change. A total of 40 countries representing 90% of the world economy attended the L'Aquila summit and meetings.

Extension of arable lands and/or yield increase

According to FAO, in 2008, 1.5 billion hectares were cultivated worldwide and 4 billion hectares were arable, more or less successfully, because those currently cultivated are the most fertile and accessible ones. Bruno Dorin, a researcher at the French International Cooperation Centre on Agricultural Research for Development (CIRAD), stated that it was possible to increase the area of arable land, but this would occur through deforestation and the use of grazing lands, causing therefore damage to the planet's biological diversity and reducing the capacity of carbon storage. Each region of the world has its potential and limitations in terms of arable land availability and intensification as mapped by the technical institute Arvalis in its review *Perspectives agricoles* (Agricultural Prospects) (Clavreul, 2008c).

South America

There is an important potential in this region of arable lands, excluding the Amazon forest and pastures, mainly in Brazil. In this case, however, "the more rangelands are ploughed, the more one gets closer to the centre of the country, i.e. far from the areas of consumption and harbours; logistics is a limiting factor as the road network is not dense enough", explained Crystel L'Herbier, economist at Arvalis. In Argentina, yields could be increased further if farmers could invest in the appropriate technologies (the windfall tax on agricultural exports had been increased up to 32% by the government after months of strikes and protests; investment capacities are therefore limited) [Clavreul, 2008c].

North America

According to the statistical data published by OECD and FAO in *Agricultural Prospects 2007-2008,* on 29 May 2008, cereals could be grown on more land in Canada and the United States. While available lands are not numerous, there are fertile lands (13 million hectares of fallow lands in the United States). With respect to yield increase, innovations are expected for maize, and the United States emphasizes the use of agrofuels (Clavreul, 2008c).

European Union

The European Commission considers that the European Union could increase its cereal production by 50 million tons within ten years (the 2007 output was 256 million tons). Of this increase 38 million tons would result

from a 1% increase in annual yields, the rest being harvested from new ploughed lands (fallow will be eliminated). Yields were expected to rise in the new member States, while in the countries with high productivity such as France, Germany and the United Kingdom, they have reached a maximum. A study by the French agriculture ministry, published on 30 May 2008, indicated that the yield of wheat had remained at 70 quintals per hectare for ten years, compared with less than 30 quintals per hectare (3 tons per hectare) in the early 1960s (Clavreul, 2008c).

Russia and the Black Sea region

There is an important potential for increasing agricultural production, because old agricultural lands could be ploughed again. In Russia, according to Arvalis, more than 20 million hectares of cereal land had disappeared during the last 15 years. If prices are rewarding, investors could be interested.

"All the Black Sea countries have an enormous potential, and the global food crisis has increased their growth opportunities", stated Abdolreza Abbassian, economist at FAO. In fact, Russia and its two neighbours, Ukraine and Kazakhstan, where farmlands cultivated before the "economic transition" (i.e. the collapse of the Soviet Union) are available in large acreages, have the will to become the world's wheat granary. In 2007, they made a remarkable come back on international markets and exported heavily to North Africa, the Middle East and South America (Clavreul, 2009f).

In 2008-2009, the three countries made up 26.6% of world wheat exports: 33 million tons (Russia, 17.5 million tons; Ukraine, 10.5 million tons; Kazakhstan, 5 million tons); compared with 21.4% for the United States (26.5 million tons), 16.9% for the European Union (21 million tons), 13.7% for Canada (17 million tons), 9.7% for Australia (12 million tons), and 11.7% for other exporters (14.5 million tons) [Clavreul, 2009f].

Regarding wheat production, the 2008 global output amounted to about 685 million tons, the main producers being the European Union (150 million tons), China (112.5 million tons), India (78.4 million tons), United States (68 million tons), Russia (63.8 million tons), Canada (28.6 million tons) and Ukraine (25.9 million tons) [Clavreul, 2009f].

On the eve of the Cereal World Forum to be held in Saint-Petersburg (6-7 June 2009), the Russian president Dmitri Medvedev sent a letter

widely disseminated on the internet, where he underlined the need to diversify his country's economy and consequently he emphasized the agricultural vocation of Russia. Despite fertile soils (tchernozium), Russian agriculture acknowledged ups and downs during 70 years of collectivization and central planning. Nowadays, when it is forecast that the consumption of cereals will increase by 30% to 40%, Russia needs to attract foreign investors to develop its agriculture. To that end, the president created in March 2009 the Unified Cereal Company (OZK), where the state owns 25% of equity. OZK is to become the main body that buys and exports Russia's cereals. Foreign traders such Bunge, Cargill or Louis Dreyfus, present in Russia, are afraid from being excluded from the cereal market (Clavreul, 2009f).

In addition and before the Forum, Russia indicated it wanted to seize this opportunity in order to launch the creation of a cereal pool of the Black Sea countries, as a first step towards the creation of a world organization, a sort of a cereal OPEP. While the latter might be utopian, the creation of a pool among the Black Sea countries makes sense, because it would stabilize exports and win the trust of markets (nowadays, flows of wheat produced in this region are irregular and their traceability is poor). However, experts underline that the political relation between Russia and Ukraine should be improved before thinking of an alliance in the area of wheat production and export. The fact that Russia threatens Ukraine to cut its supply of natural gas is not favourable to such an alliance; but on the other hand, collaboration with Ukraine would allow Russia to widen its access to the Black Sea, where its former main ports are now ubicated in Ukraine (Clavreul, 2009f).

Russia also wants to increase its wheat exports to Asia, and to that end, encourages wheat production in Siberia where land occupation is low. In so doing, Russia will compete with Canada, the United States and Australia. Europeans, on their side, are concerned by Russian exports to the Mediterranean basin, and particularly to Egypt, which is the world leading importer (Clavreul, 2009f).

Africa

In Africa, about 210 million hectares are being cultivated, while more than 1 billion hectares could be ploughed, including 400 million hectares of good lands. But Arvalis' experts do not expect Africa to contribute to the world's increase in food production from 2008 to 2015, but probably during the following decade (Clavreul, 2008c).

African soils are vulnerable and their fertility is generally low. As mentioned previously, the key limiting factors to agricultural production are the poor access to inputs, training, loans, storage facilities and urban markets (because of the lack of good roads). For instance, if rice production increases significantly, it would not be easy to transport the surplus to the consumption areas because of the poor road network, and the farmers run the risk to keep part of their harvest at the farm gate (Clavreul, 2008c).

Asia and Australia

There is little potential for yield increase in Australia, unless drought-tolerant crop species and varieties are bred and cultivated on a large scale. Water scarcity is also a serious issue in China and India, where urbanization encroaches on agricultural land. But it is also in Asia where yields have increased most, particularly in India since the "green revolution". Intensification would be difficult, as several crops are grown on the same piece of land during the year (Clavreul, 2008c).

Conclusions

Some argue that a second "green revolution" will be harder to achieve than the first. But as Lennart Bage, head of the International Fund for Agricultural Development (IFAD), pointed out, the only thing known for sure was that there had been an enormous fall in agricultural investment over 30 years. It seems too early to rule out in advance the possible benefits of reversing that decline.

Funding is crucial in this respect. While the United Nations' secretary-general wanted US$15 billion - 20 billion a year for a second "green revolution", the World Bank and the Asian and Latin American Development Banks had only provided US$1.2 billion and US$500 million respectively by mid-2008. IFAD is also a prospective lender (*The Economist*, 2008f). See also Clavreul and Tricornot (2009).

In order to produce more and quickly, OECD and FAO believe more in productivity gains than in the extension of arable lands. The use of fertilizers should be increased in most developing countries, and farmers should be assisted to buy them. On the other hand, intensification of agriculture has caused environmental damage, which is well diagnosed; a new "green revolution" should therefore be more environment-friendly, without losing much on the productivity side.

Priority to food crops and subsistence agriculture

It has repeatedly been pointed out that one of the major causes of the global food crisis is the dire situation of small and family farms which not only provide food to the farmers themselves but also to local markets. Wrong agricultural development policies have promoted, in Africa for instance, cash crops geared towards export products (e.g. groundnuts, coffee, cocoa, cotton, rubber, etc.); they have been supported by investors or by short-sighted cooperation policies, as well as by local governments. On the other hand, locally produced food crops have suffered from dumping prices of foodstuffs and commodities imported from countries where agriculture is heavily subsidized; consequently local farmers have no incentives to produce more because they are losing markets. Finally changes in food-consumption habits, e.g. wheat has become a staple food in African urban areas, have sidelined local cereals such as sorghum and millet.

To set up a sustainable food security, it is urgent and necessary to support family agriculture, based on the cultivation of traditional crops. To that end, there a few prerequisites: the local market should be well analyzed and monitored; the producer should have access to seeds, fertilizers, and to microcredit eventually; farmers should be trained to adopt techniques that preserve soil fertility and other natural resources, and to well manage their production units; commercialization of agricultural produce should be well organized and the added value must be fairly distributed through the whole production and marketing chain. This approach is that of Agrisud – a non-governmental organization working in ten countries of Africa and Asia over 20 years - and other NGOs. Agrisud's results are promising: 19,500 small enterprises that have been created, had a 85% survival rate after five years (Hessel and Lion, 2008). See also Brunel (2009).

To rebuild a sustainable subsistence agriculture, Agrisud draws the attention of States and donors to the following issues:

- devote a great part of the aid to the promotion of small agricultural enterprises that aim to meet local food demand;
- set up the training of farmers in enterprise management and in good agricultural and environmental practices;
- carry out a technical follow-up over several years;
- train local teams (public services and NGOs) that are able to manage the whole entrepreneurial scheme (Hessel and Lion, 2008).

Advantages of potatoes over grains

Grains like wheat, maize and rice have long been staples of diets in most of the world and the main currency of the food aid. Now, a number of scientists, nutritionists and food-aid specialists are increasingly convinced that potato should be playing a much larger role to ensure a steady supply of food in the developing world, particularly at the level of family agriculture. Even before soaring food prices in 2007-2008, governments in countries from China to Peru to Malawi had began urging both potato growing and eating, as a way to ensure food security and create rural income (Rosenthal, 2008).

The United Nations announced in 2007 that 2008 will be the Year of Potato, and the official inauguration took place at the United Nations headquarters in New York on 18 October 2007.

Potato (*Solanum tuberosum*) originated in the Andes; it was transported and disseminated by the Spanish colonizers in Europe at the beginning of the 17th century. In France, Augustin Antoine Parmentier (1737-1813) made it a widely consumed vegetable. It saved from famine poor rural areas of northern and eastern Europe. Until the early 1990s, potato has been consumed mainly in North America, Europe and USSR. But in 2005, for the first time, production in developing countries (about 161.5 million tons) was higher than in developed ones (155.9 million tons). In 2006, the main producers were: China (70.8 million tons), Russia (38.6), India (23.9), United States (19.7), Ukraine (19.5), Germany (10), Poland (9), Bielorussia (8.3), Netherlands (6.5), and France (6.4) [*Le Monde*, 26 February 2008, p. V]. As the fourth crop in the world, potato is being cultivated on 195,000 km^2 and total world production amounted to over 315 million tons in 2006 (Géné, 2008a).

Annual per capita consumption in 2006 was: Bielorussia (835.6 kg), Netherlands (415.1), Ukraine (414.8), Denmark (291.1), Latvia (286), Poland (271.5), Belgium (267.4), Lithuania (261.2), Russia (259) and Kirghizstan (219.4 kg) [*Le Monde*, 26 February 2008, p. V].

In Lima, Peru, considered as the world capital of potato, the day of papa is celebrated on 30 May. Potato was born on the banks of lake Titicaca, when the first Inca, Manco Capac, requested his spouse Mama Ocllo to "grow maize in the lowlands and potatoes in the highlands". Nowadays, more than 5,000 varieties are stored in the world's largest potato bank at the International Potato Center (CIP, Lima). For the last 25 years, CIP

scientists have been travelling through the Altiplano and Latin America to collect more than 15,000 samples of wild or cultivated potato. They have been analyzed and compared with existing samples, and have been classified as 4,383 unique morphological types. They are stored *in vitro* as tubers, seeds in test tubes or liquid nitrogen in the CIP division of genetic resources (Géné, 2008a).

These varieties or types have all kinds of shapes, colours and sizes. Their local names are also quite picturesque: illa pilpintu (radiant butterfly), puma chaqui (puma's paw), munya tuta (midnight passion), paq'ariyt'ika (morning flower), kusisong'o (cheerful heart). In addition to the difficulty of peeling them because of the number of "eyes" deeply carved into their skin, these Andean potatoes are floury, generally have a uniform taste and do not well withstand cooking in water; they can be fried as chips, but cannot be sauteed. Jacques Benoît, director of Lima's school of Cordon Bleu, has selected 52 varieties that are interesting for cooking, out of 2,000. After many attempts, he remains skeptical about the prospects of Andean potato (papa andina) on the local market or for export. However, cultivated and consumed for centuries by the Quechuas and Aymaras, it is considered a staple food for poor people, while it is shunned by people living along the coasts of Peru who prefer to eat rice and pasta (Géné, 2008a).

Peruvians consume an average 80 kg of potatoes per capita per year, the highest figure in Latin America. In the Altiplano (highlands between 3,500 and 4,000 meters), potato is consumed as chuno blanco, which the Quechuas call "moroya" and Aymaras "tunta". This preparation was mentioned by the conquistadores in the 16th century. They noted that Andean potatoes could be divided into two categories: the sweet ones – the majority – are consumed after being harvested, and the bitter ones which should be processed into chuno blanco to be edible. The process lasts 45 days. After being collected bitter potatoes are frozen at the open air during 45 nights (in June-July, temperature can go down to -10°C at more than 3,000 meters). Thereafter they are dipped in the river to wash away bitter compounds for 30 days. After being taken out of the water, they are frozen again for a last night, then mashed under the feet in order to eliminate water and the skin. For about 10-15 days, they are spread over pebbles along the river and sundried. Once dehydrated, the percentage of humidity is 14% and they have lost three-quarters of their weight. They are rubbed for the last time to take away the last impurities and they acquire the typical chalky white color of chuno blanco. They could be stored for years in this form. Before consumption, they are soaked for one or two hours before cooking, like dry mushrooms. One ton of Andean potatoes yields 140-150 kg of chuno blanco (Géné, 2008a).

Carlos M. Ochoa, an agronomist and world authority on potato, has been roaming the Altiplano for 40 years, from Venezuela to Chile, and has discovered 85 new varieties, some of which bearing his name (*Solanum ochoanum, S. ochoae, S. cochoae*). He has confirmed that the south of Peru and the north of Bolivia around lake Titicaca were the areas of greatest diversity of wild and cultivated Andean potatoes. He stated that "forty years ago, in the caves along the river Chilca, south of Lima, traces of cultivated potato had been discovered, dating back to 7,000 years using C-14 tests". This discovery indicated that potato had been grown in Peru before the Inca civilization (Géné, 2008a).

In France, Olivier de Serres grew potatoes in 1600 in the region of Ardèche (south-east of France), but it was used as feed for pigs. Antoine Augustin Parmentier (1737-1813), a young military chemist who was emprisoned by the Prussians during the Seven Year war, discovered "Hannover roots" during his captivity. After being freed, he showed great interest in the tuber and delivered to the Academy of Besançon a publication titled *Chemical Analysis of Potato* (*Examen chimique de la pomme de terre*), because the academy made a call for studies on "food that could lessen the catastrophic implications of famine". Potato was already common in northern Europe and in eastern France, but the court of Louis XVI had to be convinced about the advantages of this crop. Parmentier grew the tuber in the Sablons plain (Neuilly, north-west of Paris) and the plots were protected by the army. But Parmentier took the initiative to cancel night surveillance by the army, thinking that "every robbery would make a new proselyte of the crop". He was right and he offered a flowered twig of the plant to the king, who pinned the flower on his hat as well a on the upper part of the queen's dress. The overall result was that the aristocrats grew potatoes on their lands and clergymen in their gardens. In 1793, 35,000 hectares of potatoes existed in France; in 1815, the area was ten times larger (Géné, 2008a).

Potato production in China rose 50% from 2005 to 2007 and the government has called potatoes "a way out of poverty". Peru's president has led a campaign to promote potato eating in towns. Schools, prisons and army canteens are serving papapan, bread made with potatoes, helping to increase potato consumption by 20% in 2008. "Increasingly, the potato is being seen as a vital food-security crop and a substitute for costly grain imports", stated Nebambi Lutaladio, an FAO expert on roots and tubers. "Potato consumption is strongly expanding in developing countries, where it is an increasingly important source of food, employment and income". Although the prices of grains have receded from historic highs by the fall of 2008, they were still far more expensive than they

were in 2006, and FAO continues to strongly encourage countries to diversity into potato production (Rosenthal, 2008).

Many international scientists, including Pamela K. Anderson, director of CIP, have met at Neiker Tecnalia, in the heart of the Basque country, a 200-year-old potato research centre, to discuss advances in potato farming, like the development of pest- and drought-resistant strains that could be grown in poorer countries. Potatoes are a good source of protein, starch, vitamins and micronutrients like zinc and iron. As a crop, they require less energy and water to grow than wheat, taking just two months from planting to harvest. Since they are heavy and do not transport well, they are not generally traded on world markets, making their price less vulnerable to speculation. They are not used to make agrofuels. When grain prices skyrocketed, potato prices remained stable (Rosenthal, 2008).

Potato yields could vary from 6 tons per hectare to 60 tons per hectare. This wide variation is partly due to the use of non-certified seeds. In poor countries, potato yields are still relatively low, less than 15% the yield in the developed world. Many teams from publicly and privately funded research are working worldwide on pathogens and parasites of potato. For instance, potato producers in northern France invested more than 40% of their maintenance budget in research in 2008; they support a research network that involves universities, the National Scientific Research Centre (CNRS), National Agricultural Research Institute (INRA) and the National Federation of Producers of Potato Plants (FNPPT) [Begue, 2008].

From the perspective of traditional food-aid programmes – which buy or receive food from where it can be produced cheaply and efficiently, and send it where it is needed – potatoes have limitations. Because they spoil easily and are heavy to ship, food-aid institutions (i.e. the World Food Programme) avoid them. By weight, they contain less protein than wheat, although potato is considered the most nutritious crop per day and per square meter of land, and also with regard to water consumption (Begue, 2008).

Potato extension and consumption have nevertheless markedly increased in African countries since 2003, although potatoes were introduced only about 100 years ago. In Rwanda, potatoes have become the second most important source of calories, after cassava. Potato production and consumption are also expanding rapidly in Nigeria and Egypt, according to FAO. Another sign of this extension is that the world's largest potato processing company, McCain Foods Limited, has opened factories in

China and India in 2006-2007. The yield at a number of farms in India doubled during that period after McCain gave better seeds to small farmers who were supplying its new factory. In Chile, where about 50% of production is generated by small farmers, government projects to provide better seeds have increased yields by 25% during the past decades (Rosenthal, 2008).

In poor countries, farmers seed new potatoes using leftovers from the previous year crop, which are often infected with pests and pathogens. International agricultural companies grow and export germ-free "clean seed" potatoes that are much more productive, but they are more expensive. The International Potato Center (CIP, Lima) helps poor countries to produce their own "clean seed" potato lines (Rosenthal, 2008).

Potato cultivation and industry in China

Potato has been introduced in China 400 years ago through two possible routes. According to the first hypothesis, it was brought by sea from Europe by the Dutch and grown in the north of the country that includes the regions of Beijing and Tianjin. According to the second hypothesis, potato was brought to Taiwan by the Dutch from South-East Asia, and thereafter to the coastal regions in the provinces of Fujian and Guangdong. Nowadays, potato is the fourth-biggest food crop in China after rice, maize and wheat (Giordanengo et al., 2008).

There are four main potato-producing regions: in the north, where the crop is grown from August to October; two successive crop cycles (May-July and October-January in the centre and south-west); and the south-east where potato is grown from October to March. The north-eastern and north-western regions make up 44% of the total acreage devoted to potato; plantation is made during spring and the harvest takes place in the fall. The south-western region where 43% of total potato acreage is found includes the Yunnan-Guizhou plateau, as well as the west of Hunan and Hubei provinces. The region is mountainous, landscapes are varied and climate changes with altitude, so that one potato harvest can be made in the cold highlands and two harvests in the hills and in the river basin. The central region includes the plain of northern China and provinces along the Yangzi Jiang river; 8% to 10% of total potato acreage is found in the central region. As summer is very warm there, potatoes are usually grown in the spring and autumn. In the south, because the non-freezing period lasts more than 300 days and frost is even absent in some regions, potato is usually grown after rice during spring and in the winter. Although this region represents only 5% of total potato acreage,

it is foreseen that this proportion will increase in the future, thanks to the cultivation of large areas of land left idle during the winter (Giordanengo et al., 2008).

Over the period 1991-2005, potato acreage in China has increased from 2.879 million hectares up to 4.881 million hectares, and production rose from 31.565 million tons to 70.865 million tons, the average yield having climbed from 11 tons to 14.5 tons per hectare. Since 1993, China has been the world's biggest potato producer both in terms of total acreage and output. However, the average yield is a third of that obtained in the Netherlands or New Zealand. In China, about 80% is used as such for human food and animal feed and only 10% is processed. Average annual per capita consumption is about 14 kg – a figure that is comparable to that found in other Asian and developing countries, but only half of the world average and less than one-fifth of the consumption in developed countries (Giordanengo et al., 2008).

Potato selection started in the 1940s. Initial efforts aimed at introducing and selecting potato varieties imported from overseas. Some varieties introduced in China, particularly Katahdin, Houma, Epoka, Mita, Aquila and Anémone, have been widely cultivated. New varieties were created in 1947 and cross-breeding during the 1950s and 1960s also led to new varieties. In 1985, 83 varieties had been registered. There was a need to widen the genetic basis of the germplasm used for breeding, mainly derived from *Solanum tuberosum* (Giordanengo et al., 2008).

By the early 1980s, *Solanum andigena* had been introduced in China from Canada and the International Potato Center. Four to six recurrent selections were carried out to produce new genitors with good traits and combination capacity. The resulting varieties had high yields, high starch concentration and a strong resistance to fungal pathogens. In order to still widen the genetic basis, potato breeders had to use new breeding techniques such as self-crossing, retrocrossing and mutation of somatic cells; in addition, biotechnologies also helped to improve germplasm and potato ploidy. Thus, the new variety Gannong potato 1 was derived from a mutated genitor of the Russet-Burbank variety. During that period, breeding mainly aimed to increase yields so that most varieties produced were used as staple food (Giordanengo et al., 2008).

With regard to disease resistance, genetic resources used to control fungal diseases were not only *Solanum andigena*, but also *S. demissum*. By the early 1990s, other genetic resources and crosses were used in order to increase potato virus resistance. From 1995 to presently, potato

breeding in China has grown rapidly and a total of 115 varieties had been selected. Genetic pool has been widened: the diploid species *Solanum phureja* as well as indigenous species like *Solanum chacoense* and *S. hjerting* have been used in combination with *S. tuberosum* and *S. neo-tuberosum*. The latter has given rise to 20 varieties. Selection techniques have been improved, resistance to bacterial, fungal and viral pathogens has been increased in the new potato varieties, as well as their processing quality. Traits of indigenous species and genetically closer varieties have been transferred to modern potato cultivars, thus widening the gene pool. Also transgenesis has been instrumental in improving the processing quality, e.g. the genes for amylase synthase, invertase, an invertase inhibitor, a subunit of ADP-glucose pyrophosphorylase, a polyphenol oxidase and antibacterial peptides have been identified and transferred. Marker-assisted selection (MAS) has also been carried out to improve various traits such as the resistance to bacterial wilt and fungal pathogens, as well as the storage conservation among those varieties used for processing (Giordanengo et al., 2008).

During the 1950s, viruses and viroids have been recognized as the main causes of potato degenerescence. Consequently, the setting up of a system of seed potatoes is crucial for the conservation of traits of a potato variety and for obtaining a high and stable yield. In China, the production of seed potatoes started in 1940 when the varieties were multiplied in highlands that were free of viruses (they are located at over 1,200 meters above sea level and are protected against the aphids which transport the viruses). During the 1970s, the Chinese Academy of Sciences and other institutes have carried out research on the culture of meristems in order to produce virus-free potatoes. The first healthy plants were grown in a seed farm in internal Mongolia in 1976. In 1982, the Chinese government issued the first regulation concerning the production of potatoes from healthy seeds; this was a 6-8-year programme that included first level seeds (healthy plantlets, minitubers in greenhouses, small-size tubers produced under cover), second level seeds (tubers grown and multiplied in the seed farm) and third level seeds (founding seed I, II and III). Presently, less than 20% of potato seed is virus free and is supplied by the private sector, due to the length of the multiplication cycle, a low propagation rate and a poor system of quality control (Giordanengo et al., 2008).

In addition to the improvement of the production of microtubers *in vitro* and of minitubers under cover, large-scale production techniques have been used for the production of minitubers in the case of potato seeds, and a four-year production system has been set up in the Hubei and Guizhou provinces, initially by China's Potato Research Centre by

the early 1990s, and then extended to other areas of the south-west. About 200,000 microtubers could be obtained per square meter of growth chamber; these microtubers were used to produce minitubers under cover the first year, and minitubers are thereafter propagated in isolated plots at higher altitudes, so as to produce standard tubers (seed) at commercial scale. Such shortened cycle based on an efficient multiplication of micro- and minitubers can produce high quality potato seed tubers (Giordanengo et al., 2008).

It is foreseen that the area of potato cultivation in China will increase, along with a rise in consumption of processed potatoes. This consumption also explains the increase in potato imports. In 2003, China imported 100,000 tons of frozen potato and starch for a value estimated at US$6 million. FAO statistical data indicate that between 2000 and 2006, China exported 532,000 tons of potatoes and imported 856,000 tons. In 2006, this situation changed when for the first time exports have been higher than imports. While the United States, Canada, the Netherlands and Germany were China's suppliers, exports are targeted towards South-East Asia and neighbouring markets. China has a competitive export advantage because of its very long coastline and of a low cost of transport by sea to its neighbours (Giordanengo et al., 2008).

In 2010, potato will be grown on 6.5 million hectares in China, particularly in the semi-arid and arid regions of the north-west and also in paddy fields left idle in the south. It is also foreseen that China will increasingly rely on advanced large-scale techniques for micro- and minituber production, and on their adaptation to each main zone of production, with a view to setting up a good quality control system and to rise the proportion of clean seed from 20% to 55%, and to achieve a 10% yield increase. The sector of potato processing should be improved thanks to the use of potato varieties that are easy to process. In addition, during the 11th five-year plan, various national research programs will support potato breeding, marker-assisted selection, functional genomics and genetic transformation, and the improvement of germplasm, the final objective being to increase by 20% the processing rate of potatoes (Giordanengo et al., 2008).

Control of potato diseases

The Irish potato famine of the 1840s has been the result of the havoc caused by the fungus *Phytophthora infestans* (potato blight) which destroyed the potato harvest. To find the origin of the pathogen, Jean Beagle Ristaino, professor of plant pathology at North Carolina State

University, led a team that examined genetic sequences of nearly 100 pathogen samples from South America, Central America, North America and Europe. In particular, they looked at mitochondrial DNA. This genetic research, whose results were published in the *Proceedings of the National Academy of Sciences* (*PNAS*, USA), clearly point the finger at an Andean origin for the disease that devastated potato crops in Ireland, the Scottish Highlands and northern continental Europe in the 1840s. Using techniques similar to tracing genealogical family trees, the scientists tracked the migration patterns of different strains of *P. infestans*. According to the data, most of the early mutations in the DNA of the strains examined occurred in Peru and Ecuador (Nowikowski, 2008).

Some of the 19th century scientists believed that *P. infestans* came from South America, but in the following century the focus shifted to Mexico, specifically the city of Toluca – the highest town in the country. Early in the 20th century, Toluca became a centre for plant-breeding studies, as scientists collected potato seeds from all over the world and tested their resistance to *P. infestans.* But commercial production of potatoes did not exist in Mexico in the 1840s, stated J. Beagle Ristaino. During most of the 19th century, potatoes and potato seeds for North and Central America and Europe came from South American countries mainly Peru (Nowikowski, 2008).

In more than ten years of tracking the plant pathogen back over centuries, including examining shipping records and trade patterns, J. Ristaino unraveled how potato blight reached Europe. Diseased potatoes and potato seeds were shipped, for instance, from South America to the United States, Bermudas or Nova Scotia, and then onto to Europe. Potatoes were not just cargo, but also formed part of ship stores to feed sailors. In 2001, J. Ristaino questioned the then-prevailing belief that of the four strains of the pathogen – Ia, Ib, IIa, IIb – it was the Ib haplotype that caused the Irish potato famine. In 2004, she published in *Nature* her findings implicating the Ia strain (Nowikowski, 2008).

The Irish potato famine led to mass migration from the island to, principally, North America. Irish nationalists have tried to place culpability on Britain, which ruled Ireland at that time, pointing to forced agricultural exports from Irish ports to England, while people in Ireland were starving. But contemporary newspaper accounts relate a different story. There was much concern in England for the Irish plight and many organizations were set up to send aid to Ireland. In early September 1845 the disease was first detected in Ireland, and in early November Robert Peel, the British prime minister, ordered 100,000 pounds of maize to be purchased from

the United States for distribution in Ireland. Similarly conspiracy theories, claiming that the English deliberately sent blighted potato seed to Ireland are contradicted by the fact the Irish famine was part of a larger disaster that affected other European countries (Nowikowski, 2008).

In 1846, the Irish potato crop was down by 88%. But in the previous year potato yields had declined 80% in Belgium, over 70% in the Netherlands, 55% in Wurtemberg and 50% in Denmark. Ireland was particularly hard hit because potatoes formed a far larger proportion of the diet than in the other countries. Over 30% of the population was entirely dependent on potatoes. The 1845 and 1846 Irish potato crop failure were significant only in their vastness. There were 24 failures, of varying severity, going back to 1728, according to the 1851 Census of Ireland Commissioners. The crop was "entirely destroyed" in 1739 and 1740. The crop largely failed in 1770 and in 1800 there was another general failure. Half the crop was lost in 1807. Deaths from famine in the 1840s were equally high, if not higher, in continental Europe: up to 50,000 dead in Belgium and 42,000 in Prussia (Nowikowski, 2008).

Famine undermined fertility and natality in large areas. In Ireland, births fell by a third; in Flanders by 20% to 30%; in the Netherlands by 10% to 20%; and in Prussia about 12%. The Irish and to a lesser extent Scots from the Highlands, escaped even greater famine-related deaths by mass migration. They came to England as manual labourers, in the United States they became soldiers and policemen and in Argentina they became landed aristocracy (Nowikowski, 2008).

Pectinolytic bacteria belonging to the species *Pectobacterium astrosepticum* and *Pectobacterium carotovorum* (*Erwinia carotovora*) cause heavy damage during the cultivation and storage of potato tubers (soft rot). These diseases affect all the stages of the potato production chain: production and certification of potato plants, be it for direct consumption or for food and industrial processing. The environmental factors that promote the speed of the diseases are a humid and confined atmosphere, excess of rainfall and wounds which facilitate the penetration of bacteria. *P. astrosepticun* generally prevails in temperate-climate zones, while *P. carotovorum* is found in subtropical and tropical zones, i.e. under warm climates. Pectobacteria first multiply and thereafter secrete a wide range of enzymes, proteases, cellulases and various pectinolytic enzymes (pectin and pectate lyases, pectate hydrolases and pectin methylesterases) [Latour et al.,2008].

Regarding the genetic resistance to these pathogenic bacteria, it seems that the few regions that could play a role in the resistance to *P. atrosepticum* are dispersed over the 12 chromosomes of potato; that may explain why there are few *Solanum* species showing traits of resistance to *Pectobacterium* spp. There have been some attempts to transfer via genetic engineering some genes that could help build resistance to the pathogens, e.g. a gene coding for a lysozyme that degrades the bacterial cell wall. Another way is to stimulate the multiplication of antagonistic bacteria, such as fluorescent *Pseudomonas* spp., in the rhizosphere of potato plants. These bacteria inhibit the growth of *Pectobacteria*. These methods of disease control have been tested in laboratory conditions and show some effectiveness, but they need to be tested in environmental conditions and to become part of an integrated control approach (Latour et al., 2008).

Transgenic potatoes

In Ireland, work is being carried out on the creation of a transgenic potato resistant to *Phytophthora infestans*, as it has been observed that the risks of potato blight have become more serious since 2007. Irish researchers have isolated a very aggressive strain of the fungal pathogen which migrated towards the west of Europe, then was found in the United Kingdom and Ireland in 2008. This strain produces spores that can survive in the soil for four years; it may infect potato plants before they emerge. Irish potato producers have to fumigate up to 12 times a year, while researchers consider a resistant transgenic variety would need only four fumigations a year. Transgenic potato varieties that would be developed by Ewen Mullins and his colleagues of Teagasc – the Irish authority for the development of agriculture and food – in collaboration with Queen's University in Belfast, would not be cultivated on commercial scale, due to opposition of European countries to transgenic crops. But it is a way of testing whether it is possible to develop a transgenic variety resistant to potato blight in the most efficient way.

The German agrochemical company BASF developed the transgenic potato variety Amflora which is to be used in the paper, glue, textile industries, and as animal feed. It contains almost 100% of amylopectin, which is very suitable for making glossy paper, while conventional potato varieties generally contain 80% amylopectin and 20% amylase in their starch. BASF worked jointly to develop Amflora with the European starch industry that was seeking to improve its competitiveness. The license fees for the potato eventually could earn BASF up to €30 million or US$44 million annually, if allowed onto the European market, stated a spokesman for

the company. BASF included the marker gene for antibiotic resistance during the development of the new potato as a way of identifying plant cells and tissues that successfully produced the desired starch polymer (Kanter, 2008).

Officials at the European Commission recommended putting Amflora onto the market after the European Food Safety Authority (EFSA), an agency in Parma, Italy, that reports to the European Commission on food safety issues, stated that the marker gene for antibiotic resistance had no significant effect on human or animal health. On 15 February 2008, Mireille Thom, a European Commission spokeswoman, reiterated that "Amflora does not pose any problem to human or animal health or to the environment". But some scientists, like Patrice Courvalin, the head of the Antibacterial Agents Unit at the Institut Pasteur in Paris, and Greenpeace stated that the European Commission and EFSA were out of step with other health bodies. P. Courvalin said he was concerned that if the marker gene passed to bacteria in the environment or in the gut of animals that ate the potato and it then evolved, antibiotic-resistant bacterial strains could appear with the potential to have a negative effect on human and animal health. He added that it had not yet been proven that such genes from genetically modified organisms could be transferred to human bacteria, but he stressed that lack of evidence did not mean it would not happen (Kanter, 2008).

EFSA gave a favourable advice concerning the cultivation of Amflora in the European Union. This advice was transmitted to the committee of experts of 27 EU member States, and then to the council of agriculture ministers, where the authorization request was approved twice, but without the required qualified majority of member States. For instance, France abstained. According to the current regulation, it is up to the European Commission, to make the final decision, on the basis of EFSA's advice. The European Commissioner for Environment, Stavros Dimas, was not very enthusiastic about pushing through the decision. In July 2008, BASF decided to sue the European Commission before the European Court of Justice, considering that a decision has not been made after 12 years of dispute (Géné, 2008b).

BASF's behaviour and anger were not only due to the length and delays of making a decision, but also to the fact that the company expected to request another authorization for cultivation in the European Union of a transgenic potato variety, to be consumed by humans. The variety is resistant to a devastating fungal disease (it has been dubbed mildew-resistant 2015), because it contains a gene transferred from a wild Mexican

potato species, *Solanum bulbocastanum*. France refused that field trials be carried out on its territory; these trials have been conducted for several years in the Czech Republic, Sweden, Germany, the Netherlands and the United Kingdom. Commercialization was foreseen for 2015 at the earliest. If the cultivation of Amflora is approved, it will help that of the disease-resistant potato variety (Géné, 2008b).

Researchers at the International Potato Center (CIP, Lima) have developed a potato variety that is resistant to an insect pest, *Tecia solanivora* (in Spanish *polilla guatemalteca*), but opponents to transgenic crops in Peru have requested public authorities not to authorize its cultivation or even field trials, because it may threaten the biological diversity of Andean potatoes.

In 1998, the Plant Biotechnology group of both the Corporación para Investigaciones Biológicas (CIB, Biological Research Corporation) and the National University of Colombia-Medellin (UNALMED) started its research on the development of transgenic potato lines (*Bt*) resistant to *Tecia solanivora*. In 2004, the first *Bt* potato lines were obtained and at the beginning of 2005, the project funded by CEVIPAPA and entitled "Molecular and biological evaluation of transgenic potato lines containing *Bacillus thuringiensis* genes *cryAb* and *cryAc* and resistant to *Tecia solanivora*, has been finalized. As a result 36 transgenic potato lines of the varieties Diacol Capiro (11), Pardo Pastusa (8) and Pan de Azúcar (17) were obtained and tested in laboratory trials in order to evaluate their resistance to the pest. It was observed that the mortality of *T. solanivora* larvae was high and conclusion was drawn that the transformation by the *Bt* genes was effective.

A national programme funded by Colombia's agriculture and rural development ministry and entitled "Non-conventional improvement of potato (*Solanum tuberosum*) seeds via the development of varieties resistant to *Tecia solanivora*", aimed at coordinating four research projects dealing with the rational and environmentally-safe use of transgenic potato varieties. This programme involves : the Plant Biotechnology group UNALMED-CIB; the group on plant genetic engineering of the National University of Colombia, Bogotá; scientists of the Tibaitatá Research Centre and the Biotechnology and Bioindustry Centre (CBB) of CORPOICA; the International Potato Center (CIP, Lima); the Colombian Federation of Potato Producers (FEDEPAPA) and the Agriculture Secretariat of Antioquia. It was estimated that the cultivation of a *Bt* potato resistant to *Tecia solanivora* would save the equivalent cost of five insecticide applications per year and of the necessary manpower.

Colombian researchers are also working on transgenic cassava, banana, chickpea, sugar-cane and blue rose. On 24 November 2008, a meeting was held at the ministry of environment and development on the status of research on genetically modified living organisms in the country. Colombia is considered one of the countries of Latin America that is making remarkable progress in the development of transgenic crop species and their cultivation on commercial scale (maize, cotton, blue or purple carnation).

Sweet potato

Sweet potato is the staple food of hundreds of millions of people in the tropics, and like potato, is the produce of small family agriculture. There are many local varieties and this germplasm can help breed more nutritious varieties, for instance enriched in beta-carotene (provitamin A). Sweet potato is one of the target crop species of the HarvestPlus programme – an interdisciplinary alliance of institutions and scientists working to improve the nutritional status of the undernourished people through biofortifying staple food crops with micronutrients. HarvestPlus coordinates more than 60 institutions across the world. The magnitude of global malnutrition is illustrated by the following figures : more than 4 million preschool age children suffer from eye damage due to vitamin A deficiency and many of them will become blind because of xerophthalmia; more than 2 billion people suffer from iron deficiency that causes mental impairment in children and compromises working ability among adults; billions are at risk from zinc deficiency – children are stunted and are at greater risk from infections and disease.

HarvestPlus is a Challenge Program of the Consultative Group on International Agricultural Research (CGIAR), and is coordinated by the International Center for Tropical Agriculture (CIAT, Cali, Colombia) and the International Food Policy Research Institute (IFPRI, Washington, D.C.). It is supported by the Asian Development Bank, the Bill and Melinda Gates Foundation, Department of International Development (DFID, United Kingdom), Danish International Development Agency (DANIDA), Swedish International Development Agency (SIDA), the United States Agency for International Development (USAID) and the World Bank. In addition to sweet potato, the target crops of the programme are cassava, beans, cowpeas, lentils, groundnuts, pigeon peas, yams, banana/plantains, potatoes, sorghum, millet, maize, rice and wheat.

Plant breeders screen germplasm for iron, zinc and provitamin A carotenoids. Promising lines are then breed to develop micronutrient-rich

crops. These new varieties must first be extensively tested in experimental stations and farmers' fields in target countries over wide geographical areas and different farming and management systems. Breeders strive for high and stable expression of micronutrient content in the new biofortified varieties. Plant biotechnology can support conventional crop breeding where the latter does not work properly and cannot lead to high micronutrient content.

Nutritionists work with plant breeders to set up micronutrient targets for the newly bred crop varieties. These targets are based on the food intake of the population concerned, nutrient losses during storage and processing, and the bioavailability of nutrients from staple foods consumed by these populations. HarvestPlus nutrition teams evaluate the effects of storage, processing and cooking methods on nutrient retention within biofortified crops and determine optimal practices to minimize nutrient loss. Nutritionists also determine the efficiency of nutrient absorption and effect on nutritional status, so as to guide crop breeders in refining their breeding objectives.

Under HarvestPlus, "Reaching End Users" is the part of the programme that studies current extension systems and develop methods to strengthen these systems. Researchers are also trying to better understand markets and consumer preferences in order to effectively promote biofortified crops among producers and consumers. HarvestPlus behavioural change specialists work closely with local governments, organizations and communities to design strategies aimed at promoting the consumption of novel biofortified foodstuffs.
To sum up, the HarvestPlus overall strategy consists of the following stages :

1. identify malnourished populations that can benefit from biofortification; determine appropriate nutrient target levels for selected populations; screen crop varieties and germplasm for breeding;
2. breed new biofortified varieties of staple food crops with higher micronutrient concentrations; test the performance of these varieties in the field; measure retention of micronutrients in crops and foods; evaluate the capacity of human body to absorb and use micronutrients from biofortified crops;
3. develop strategies to distribute biofortified crop seeds to producers; promote marketing and consumption of biofortified crop-derived foodstuffs in order to improve nutritional status.

In most cases, family and subsistence agriculture is primarily targeted by biofortification projects, as it is very often the main supplier of foods to developing countries' populations. For instance, in Brazil, smallholders provide 60% of foodstuffs.

In the case of sweet potato (*Ipomaea batatas*), the International Potato Centre (CIP) had launched by the late 1990s a project in Mozambique with a view to introducing orange sweet potato varieties among the crops grown in this country of southern Africa. In 2008, about 1 million farmers were involved in this €2.5 million project. Another dozen African countries are following the example of Mozambique within a programme titled "Vitamin A for Africa".

In Mozambique, around 70% of children between six months and five years of age have a vitamin-A deficiency and many of them become blind. Orange sweet potato contains much more beta-carotene than the usual yellow varieties. The government of Mozambique agreed with CIP to expand the cultivation of the orange sweet potato, rather than distribute vitamin-A capsules to children every six months.

In 2002, following catastrophic floods in Mozambique, one thousand small farmers were offered 250 sweet potato plants each, and after three seasons this crop species became widely cultivated. Mothers had also to be convinced to include this non-traditional food in the daily diet. CIP's communication strategy in the villages had a key role in publicizing the crop through posters and advertisements on trucks, caps and even women's traditional costume. Radio and theater shows emphasized the slogan: "sweetness that brings health", with a view to convincing the population to eat this tuber that is sweeter than potato and to improve thereby their nutritional status. CIP's representative in sub-Saharan Africa claimed that over 18 months there has been a 15% decrease in the number of persons suffering from vitamin-A deficiency. The tuber has been processed into biscuits, cookies, donuts, fruit juices and even bread. Some bakeries are producing bread that contains sweet potato, has a golden colour and a heavier texture than white bread. Homemade jams are also appreciated by children (*Le Monde*, 24 December 2008, p.4).

Sweet potato is vulnerable to drought that strikes Mozambique during three to six months every year. At the agricultural research center of Umbelizi, 30 km north-west of Maputo – Mozambique's capital – drought-tolerant varieties are being selected and new varieties would become available in 2009-2010 (*Le Monde*, 24 December 2008, p.4).

Like sweet potato, cowpea or niébé (*Vigna sinensis*) is a food crop species targeted by the HarvestPlus programme. In Niger, for instance, people are eating more cowpea than rice or millet, and the production of this grain legume has almost trebled in six years, increasing from 250,000 tons in 2000 to 700,000 tons in 2006. Since 2002, the government had distributed 363 tons of seeds to farmers living in regions that suffered from a deficit in rainfall. Cowpea is now being grown in all regions of Niger, except in the desert region of Agadez, and 4 million hectares are devoted to the crop. Cowpea is tolerant to drought and has a short growth cycle (70 days for the early varieties); it is an atmospheric nitrogen-fixing plant and thus contributes to soil fertility; while seeds are consumed by humans, leaves are used as fodder (*Spore*, April 2008, no.134, p.6).

In a country where meat and fish are unaffordable for most consumers, people eat this legume that is less costly than rice or millet and is very nutritious (proteins, vitamin B, starch, iron, zinc and calcium). Niger exported about 300,000 tons of cowpea in 2007 to Nigeria and Ghana (*Spore*, April 2008, no.134, p.6).

A double green revolution: produce more and better

The green revolution

The development and cultivation of hybrid maize in the United States has been the first application of modern crop-breeding research. Between 1940 and 2000, the use of improved hybrid seeds and fertilizers, as well as weed control, led to a fourfold increase in yields. Chemical fertilizers became a key agricultural input to efficient production; in 2000, for instance, more than 80 million tons of nitrogen were consumed and Vaclav Smil, of the University of Manitoba, Canada, estimated that 40% of the world population (6.2 billion at the time of his estimates) were fed thanks to the Haber-Bosch process of ammonia synthesis and the use of nitrogen fertilizers (Borlaug and Dowswell, 2008).

The phrase green revolution was coined by William Gaud, the United States Agency for International Development (USAID) administrator, to describe the rapid spread of new wheat and rice varieties in Asia :
“These and other developments in the field of agriculture contain the makings of a new revolution. It is not a violent Red Revolution like that of the Soviets or the White Revolution in Iran…Rather, I call it a Green Revolution based on the application of science and technology” (Gaud, 1968).

Advances in crop breeding were openly published and shared, as well as the exchange of germplasm through international networks supported by the institutes of the Consultative Group on International Agricultural Research (CGIAR), e.g. the International Rice Research Institute (IRRI, Los Baos, Philippines), and the Maize and Wheat Improvement International Center (CIMMYT, El Batan, Mexico). New higher-yielding semi-dwarf wheat and rice varieties were the major outputs of this green revolution, but progress was also made in the genetic improvement of maize, sorghum, barley and various grain legumes (Borlaug and Dowswell, 2008).

These varieties gave higher yields only when they were grown with fertilizers and with enough water, as well as with biocides to control weeds and pests. Therefore, irrigated areas planted with these new varieties expanded, e.g. in Asian developing countries it rose from 86 million to 176 million hectares between 1961 and 2000. Fertilizer use soared from 2 million to 70 million tons, while the number of tractors in use increased from 200,000 to 4.8 million units, and hundreds of thousands of mechanical threshers were introduced (Borlaug and Dowswell, 2008).

The green revolution was not spared from a wave of criticism. Some critics underlined that it could not solve social and economic problems that prevailed in rural areas; that the new varieties replaced lower-yielding land races and consequently reduced biological diversity. It is true that advanced crop breeding cannot be the solution to rural development issues. It is also true that higher-yielding cereal varieties that were planted across Asia matured much earlier than traditional races, thus permitting double and triple cropping; this had a positive impact on the demand for labour and on the activities of many rural enterprises and services. Smallholder Asian farmers were quick to respond to the green revolution and adopted the new varieties that trebled cereal production. However, as many as 250 million farmers remained food-insecure, as did another 250 million landless rural dwellers and urban poor. Those food-insecure farmers, mostly living in vulnerable areas or on marginal lands for agriculture, were bypassed in the green revolution that prevailed in Asia in the late 1960s, during the 1970s and 1980s (Borlaug and Dowswell, 2008).

But, although world population doubled, the transformation of low-yielding agricultural systems has kept per capita global food supplies ahead of population growth. Major improvements have taken place in East and South-East Asia, while the number of food-insecure people has more than doubled in sub-Saharan Africa and increased in South Asia, despite the adoption of higher-yielding cereal varieties. But, according to

Norman E. Borlaug, considered as the father of the green revolution, and Peace Nobel Laureate for his major contribution in this regard, had the global cereal yields of 1950 still prevailed in 2000, the world would have needed nearly 1.8 billion hectares of land of the same quality – instead of the 660 million hectares of land that were used – to produce the 2000 harvest. Obviously, such a surplus of land was not available, and certainly not in Asia, where the population has increased from 1.2 to 3.8 billion over that period (Borlaug and Dowswell, 2008).

Why do we need another green revolution?

At the World Food Summit (WFS) in 1996, it was agreed to take all the necessary measures to halve the number of underfed and hungry people – to 400 million – by 2015. This goal was reasserted in September 2000 at the Millennium Summit by 139 heads of State. This goal will not probably be reached. As mentioned earlier, the food crisis that struck the world in 2007-2008, followed by a deep financial and economic meltdown, revealed that the number of underfed, malnourished and starving people has markedly increased: in addition to the chronically hungry, tens of millions of people cannot buy food, either because prices have soared or because they have lost their main source of income; another face of hunger has appeared. More than 963 million people worldwide need food.

Over half of the world's most food-insecure people are poor smallholder farmers in low-income countries who cultivate marginal lands. Most must produce the food they need themselves. Indeed about 1 billion farmers are very poor and unable to adopt productivity-enhancing methods; they also have no access to markets in order to be involved in commercial agriculture. That is why a top priority given to agriculture and rural development should address the needs of these poor smallholder farmers and help them to produce more to feed themselves and neighbouring communities, and to move out of extreme poverty.

For a number of years, during the 1980s and 1990s, when global harvests were good and food prices rather low, and stockpiles of grains could cover global needs, the debate on food security revolved around the assumption that there was enough production to feed the Earth population, and the problem was that of distribution. This meant that if world food output were distributed equally to the inhabitants of the planet on the basis of a satisfactory daily diet, there would be no starvation or hunger. Such even distribution is impossible to reach at global scale and it is unrealistic to think that one could prevent overeating in countries and regions to bring food to places that suffer from food deficiency. It

is true, however, as demonstrated by Amartya Sen, famines are less severe or even disappear when a democratic system is in place that ensures more solidarity among the citizens and takes care of the most vulnerable among them; the state can distribute food and regulate prices. Consequently, at local and national level, if agricultural output is sufficient, a fair distribution system of staple foodstuffs could help ensure food security. But globally it is not that easy; the World Food Programme provides food aid, but the needs are far from being met. In addition, if distribution were to be effective it should rely on the regular supply of agricultural commodities by exporting countries. The 2007-2008 global food crisis has shown that these countries banned or drastically reduced their exports in order to ensure full food security at home; and rice-importing countries, for instance, were particularly hit and requested a curb on these export bans, as their stockpiles melted down and hunger riots could jeopardize their political stability. The conclusion is therefore to produce more food and, of course, to make all efforts towards a fair distribution of that food at local, national and regional level.

A more recent debate on food security has highlighted the issue of the huge quantities of wasted food and agricultural produce. In its report devoted to the food crisis and published on 17 February 2009 in Nairobi during its annual meeting, the United Nations Environment Programme (UNEP) strongly advocated the need to recycle the millions of tons of food, lost or wasted nowadays, as a means to feed the world population in 2050, along with a greater efficiency of the food chain. UNEP stated: "this approach has been explored to a very small extent, while it would have had the additional advantage to reduce the pressure on fertile lands and deforestation" (Caramel, 2009).

UNEP's report quotes many examples which are not new in their majority, but illustrate the weaknesses of agriculture in developing countries that suffers from crop pests, poor storage infrastructures, lack of adequate transportation. The report also emphasizes the huge wastage of food in wealthy societies. In the United Kingdom one third of the food purchased was not consumed, and in the United States losses at the level of the various distribution systems were estimated at about US$100 billion per year. In contrast, the World Food Programme's needs for 2008 amounted to US$3.5 billion (Caramel, 2009).

Globally, according to UNEP, almost half of food production is lost or put aside because it does not fit the market standards, or wasted during the consumption processes. For instance, 30 million tons of fish are thrown

back to sea every year. This amount would be sufficient, according to UNEP, to meet half the supplementary needs of fisheries till 2050 and thus maintain the current per capita consumption of fish. In addition, UNEP suggests that recycled food be used to feed livestock, so that less cereals are devoted to that purpose. One-third of cereals produced globally is currently used as feedstuffs and the forecast for 2050 is to use half of the output, if current consumption trends are maintained. Recycling could also be geared towards the production of agrofuels, in order to mitigate the potential competition between the production of food and that of fuels (Caramel, 2009).

There is no doubt that food is wasted, first and above all after harvests due to poor storage and deterioration by insects and rodents; thereafter, on the markets and during commercialization due to the lack of a cold chain that is indispensable to preserve perishable produce such as vegetables and fruits. It is also true that consumerism in many industrialized countries is almost synonymous of wastage and of wastage of food in particular.

Remedies to this situation are, on the one hand, part of the improvement of agricultural production (quality and quantity) and of rural infrastructures particularly for poor smallholder farmers. Post-harvest technologies cannot be dissociated from the efforts aimed at increasing and improving food production. Regarding the food habits and wastage in wealthy societies, what is needed is more education and a real cultural revolution aimed at reducing superfluous consumption of goods and services and at finally decreasing humankind's ecological footprint. It takes time but there are several signs of progress in the right direction.

Once again, like in the debate on production versus distribution, it does not seem feasible in the short term to "recycle" all the losses or wastes into edible food. This has to take place along the process of producing more food and better. To feed 200,000 new mouths every day worldwide and to be able to cater for the food needs of 9.2 billion people in 2050 (compared with 6.7 billion in 2009), there is no other alternative than increasing agrifood output by 50% over next forty years.

Borlaug and Dowswell (2008) estimated that 80% of food demand must be supplied through yield increases (intensification) on lands already in production, although agricultural areas were expected to expand in tropical regions in South America (Brazil's cerrados) and sub-Saharan Africa, and to a smaller extent in temperate zones, mainly in North America. Large yield gaps exist between actual and potential crop yields in developing countries, particularly in family and subsistence agriculture.

Cereal crops and grain legumes or pulses will make up more than 95% of the world food supply at least in the foreseeable future. However, the rapidly increasing demand for meat, eggs and dairy products will become an important part of the whole food demand.

This is also true of fish and seafood. Although the latter account for about 2% of the calories contained in the world food supply, they contribute 16% of animal protein, as well as fats and minerals. Overfishing has become a major problem, as by 2000 three-quarters of ocean fish stocks had been overfished, depleted or exploited to their maximum sustainable yield. Marine catch reached a top level of 85 million tons a year during 1990s, but aquaculture has grown rapidly and accounted for more than one-quarter for the 125 million tons of the world fish and seafood production in the early 2000s. According to FAO, by 2030 world annual fish and seafood production would likely rise to 160 million tons and aquaculture would account for almost all of this increase, with most of that production taking place in Asia and China – the world leader. Nearly 40% of all fish and seafood production is currently internationally traded, with developing (Asian) countries playing an ever-increasing role; earnings are exceeding by far revenues from cash crop exports such as coffee, cocoa, bananas or rubber (Borlaug and Dowswell, 2008)

Africa : the great challenge

Nowadays and on the continent average, Africa imports food products. Demographic studies indicate that its total population would double (or even more) during the next 40 years, from 800 million people in 2007-2008 up to 1.8 billion in 2050. Urban population would double in only 20 years. Agricultural deficit cannot continue to grow and Africa should count on its agricultural potential in order to mitigate recurrent or endemic famines. Local supply, particularly of African towns, should rely on local, national and regional markets. But to what extent Africa's rural areas and agriculture would meet an increasing demand for food?

Since the late 1980s and for 17 years or so, Norman E. Borlaug has been engaged in a smallholder agricultural development programme in sub-Saharan Africa known as Sasakawa-Global 2000. It was initiated by the late Ryoichi Sasakawa and carried out by his son, Yohei Sasakawa, with financial support from the Nippon Foundation of Japan. A key partner has been former US president Jimmy Carter and his Global 2000 team from the Carter Center. The work has been carried out with agriculture ministries in fourteen countries and with hundreds of thousands of small-scale farmers (SSA), who were able to treble yields of their basic staple

food crops. However, widespread productivity impacts have not yet been achieved (Borlaug and Dowswell, 2008).

SSA indeed had very little irrigated agriculture, and water stress is a frequent and widespread limiting factor. SSA had a much less developed rural infrastructure, especially in transport systems, compared with Asia in the 1960s during the "green revolution" and later on. Also, because of trypanosomiasis and East Coast fever, relatively few SSA farmers have had access to animal traction compared with their Asian counterparts. Also human diseases, such as malaria and more recently HIV/AIDS, had a negative impact on African agricultural workers' productivity. All these factors made the agricultural value added in SSA at around US$400 per worker, the lowest in the world (Borlaug and Dowswell, 2008).

One of the urgent actions in SSA would be to treble or quadruple fertilizer use over the very low levels currently prevailing : Asia uses 20-25 times more fertilizers per hectare of arable land, and Latin America ten times more. However, for many smallholder farmers in SSA, fertilizer is costly, sometimes two to three times more than in other parts of the developing world. However, there should be more proactive policies aimed at promoting the increased use of chemical fertilizers. In addition, other techniques improving soil fertility must be used, such as nitrogen biofertilizers (inoculants of symbiotic nitrogen-fixing bacteria). As soil fertility is restored, higher-yielding, early-maturing, disease- and insect-resistant crop varieties should be introduced, and in fact these varieties are available from national and international agricultural research institutions, especially for rice, maize, wheat, millet, sorghum, cassava and several grain legumes such as cowpea and pigeon pea. In addition, minimum tillage systems can help reduce soil erosion, conserve moisture and reduce the hard work of weeding and land preparation (Borlaug and Dowswell, 2008).

The Alliance for a Green Revolution in Africa (AGRA), funded by the Rockefeller and Bill and Melinda Gates foundations, and chaired by the former United Nations' secretary-general Kofi Annan, aims at boosting the production of small-scale farmers through the promotion and transfer of more efficient agricultural technology. It takes its name from earlier green revolutions in Latin America and Asia, where the introduction of new crop varieties, chemical fertilizers and irrigation has been credited with rescuing hundreds of millions from starvation. AGRA is helping scientists to work on new seeds, bankrolling the breeders that produce them, and assisting wholesalers expand their inventory. Most importantly, it is enlisting small farmers as free-market agriculture extension officers,

training them in the proper use of seeds and chemical fertilizers. "The farmer will leave the shop with the product, and who the knowledge of how to use it", stated Esborne Baraza, coordinator of the AGRA's activities in western Kenya (Faris/Yala, 2009).

The model is the village of Sauri in western Kenya, where seeds and fertilizers supplied by Columbia University's Millennium Promise has allowed farmers to reclaim soils that were depleted and weed-infested, expanding cultivated land by 50% and quadrupling maize production. Growers, who struggled to feed their families, have succeeded to have surpluses. Within three years, most of them could afford to buy the inputs themselves (Faris/Yala, 2009).

AGRA also has its critics who support the use of organic practices that can be just as productive, but more sustainable than farming based on technology inputs. At the St. Jude Family project in southern Uganda, double-decker animal pens open onto maize, cabbage, banana and green beans plots. Soils are contourned to reduce run-off and erosion. Legumes fix atmospheric nitrogen to the soil. Cow manure produces biogas for the farmer stove. The project has introduced organic techniques to 180,000 Ugandan farmers. In the tea-growing region of central Kenya, farmers trained in simple organic techniques are substituting labour for costly inputs such as fertilizers, e.g. raising beds, drilling deep pits for water collection, producing compost, intercropping maize and beans. It is a lot of work, and even if the yields are steady, they will still be ahead thanks to lower costs (Faris/Yala, 2009).

A strong case has been made for organic farming: a 22-year study led by David Pimentel, professor of ecology and agriculture at Cornell University, Ithaca, New York, that was published in 2005, showed that organic farming produced as much maize and soybeans as conventional farming. While it required more labour, the cost was more than offset by savings in commercial nitrogen fertilizers, insecticides and herbicides. In Africa, where labour is cheap and capital scarce, the benefits would be amplified. Those in favour of organic farming argue that current conventional farming makes growers vulnerable to shocks: sudden rises in the cost of inputs (as it occurred in 2007-2008), drops in produce prices (like in 2009), unexpected climate shifts. Artificial fertilizers change the chemistry of the biologically impoverished soils, making the farmers dependent on their continual application (Faris/Yala, 2009).

AGRA replies that it has learnt the lessons of Africa's experience. Africa's farmlands are divided into small, impoverished plots and scattered across

diverse ecosystems. Rather than try to impose a transition to large-scale, industrialized agriculture, AGRA is providing smallholders with a variety of products for use in traditional planting. The goal, states Joe Devries, director of AGRA's seed program, is not to supplant existing practices but to supplement them. Devries asserted that organic farming could be part of the solution, but would not be enough on its own. In the United States, about 41 kg of fertilizers per acre per year are used on a farm, and overutilization of fertilizers has become a serious environmental problem. But in Africa, only 1.4 kg of fertilizer is used per acre per year and underutilization of fertilizers is therefore the problem. For some farmers, like those in western Kenya, commercial solutions will be the best way forward. Others might be better served by organic techniques. Each grower should be able to make a comparison in the appropriate ecological and socio-economic environment. It seems that AGRA, more organized and well supported, is the group passing its message out (Faris/Yala, 2009).

While in Africa around 400 million people were living on less than US$1 a day in 2008, 75% was the proportion of Africans employed in agriculture; the per capita food production since 1960 decreased by 10% (while global per-capita production grew by 25%) [Faris/Yala, 2009]. Most experts agree that African agriculture must grow at 5% to 6% per year, at least if it is to become a major force in alleviating poverty. Nevertheless, it should be recognized that agriculture alone cannot employ all rural Africans. Despite the HIV/AIDS pandemic and catastrophic implications, rural population was projected to increase to 616 million by 2030, even as the share would fall to 50%. Rural employment (off-farm) must therefore be expanded to alleviate poverty and slow down migration to urban slums (Borlaug and Dowswell, 2008).

In July 2002, Africa's heads of State adopted the New Partnership for Africa's Development (NEPAD) with three guiding principles :

- rethinking the development process in Africa to provide strategic direction for interventions based on increased measures of collective self-reliance, in the framework of the African Union;
- retaking ownership of the development process;
- regaining the leadership of the development process.

African heads of State selected agriculture as one of the top priorities for immediate implementation. NEPAD has a plan, called Comprehensive Africa Agriculture Development Plan (CAADP), built around four areas of action: land and water reclamation and management; infrastructure and markets; food production and reduction of hunger; and institutions,

especially for research and extension. More than 30 CAADP programmes have been prepared for resource mobilization. In addition, African governments have pledged to increase national contributions to the overall agriculture development budgets by 50% (Borlaug and Dowswell, 2008).

Jacques Diouf, director-general of the Food and Agriculture Organization of the United Nations (FAO), and Jean Michel Severino, director-general of the French Agency for Development, consider that Africa's agriculture has a strong development potential, and a comparative advantage with respect to other regions. Despite important geographic disparities, Africa possesses plenty of water resources that are not well exploited; there is still land available for agriculture and labour in abundance. In addition, the potential of increasing yields and productivity is high, because currently African agriculture uses low amounts of fertilizers and is not much modernized. Both executives made a strong plea to the international community in order to support African agriculture through the supply of inputs such as fertilizers and improved seeds, and through enabling farmers to have access to local markets. That was the purpose of the initiative launched by FAO in December 2007 against soaring prices. Food and subsistence agriculture should be the primary target of aid and support, using all available means: inputs, access to markets, specific systems of credit and insurance (Diouf and Severino, 2008).

Adrien de Tricornot (2008) has shown some optimism with respect to the capability of West Africa to meet its population's food needs. He quoted a study on *The Agricultural Potential of West Africa* carried out by the Foundation for Agriculture and Rurality in the World (FARM, *Fondation pour l'agriculture et la ruralité dans le monde*), and presented on 25 February 2008 at the Paris Farm Fair. The study revealed that agricultural production had a growth rate higher than that of regional population from 1980 to 2005; during that period population doubled. Quantities of exported cash crop products (coffee, cocoa, fruit) doubled and those of food crops, particularly roots and tubers, trebled. Farmers were therefore able to meet the demand, the dependence on imports being around 10%-15% of consumed calories. However, this was mainly the result of an extension of arable land and not due to an increase in yields and productivity (intensification). This was substantiated by the fact that only an average 9 kg of fertilizers were used per hectare (compared with the world average of 101 kg/ha), that there was one tractor for 5,300 hectares and less than 2% of surface water was used (Tricornot, 2008).

West Africa's population would grow up to 450 million people in 2030 from 300 million in 2007-2008. FARM's study concluded that the model of agricultural growth should change because the current one would lead to a collapse of land productivity and to an accelerated degradation of natural resources. However, the study showed that whenever there have been incentives such as the introduction of more efficient production techniques, the maintenance of good prices for agricultural produce and the availability of markets, agricultural production has shown good performance. In addition to technical tools aimed at increasing productivity, FARM has recommended to put in place a regional integration strategy, a tariff union with a trade policy that includes an effective regulation of internal markets (Tricornot, 2008).

A sign of hope: cotton cultivation

Africa contributes only 5% of global cotton production, but it is among the main exporters. There are in this continent good opportunities for producing high-quality cotton and to add value to this cash crop, which can provide an income that improves the purchase of food and the nutritional status of the populations concerned. African cotton is often grown with little fertilizer and is hand-picked. See Zachary (2007).

In 2008-2009, the estimates of world production were: China, 8.025 million tons; India, 5.2 million tons; United States, 2.964 million tons; Pakistan, 1.9 million tons; Brazil, 1.269 million tons; Uzbekistan, 1.090 million tons; Turkey, 500,000 tons; Turkmenistan, 290,000 tons; Australia, 272,000 tons; Greece, 225,000 tons; Syria, 220,000 tons; Burkina Faso, 182,000 tons. Global production was estimated at 24.14 million tons, including 1.215 million tons for Africa (Clavreul, 2009a).

Mali has been for many years the cotton-producing leader in Africa with 600,000 tons per annum. Since 2000, cotton production has been weakened by world low prices and it fell down to 120,000 tons in 2008. Climate conditions that have been favourable, were not the culprit; cotton producers who were not often paid on time by the Malian Company for Textile Development (CMDT) and who were therefore indebted, preferred to grow crops to feed themselves or cereals whose soaring prices provided more income. However, cotton cultivation with some 3 million jobs, direct or not, allows one-fourth of total population to make a living. Privatization of CMDT, that replaced the French Company for Textile Development in 1974, is to be carried out, as requested by the World Bank and done in neighbouring countries. The company will focus on its basic work, i.e. cotton harvesting, processing and marketing. Cottonseed oil production, that has

been privatized, has almost disappeared. Among producers, privatization of CMDT is controversial and one wonders whether it could improve the price of cotton. If prices fall down, what would be the behaviour of a private producer, who used to be assisted by the state? It was foreseen that the new CMDT's equity would be shared by the producers (20%) and the state (17%) [Marot, 2007; Clavreul, 2009a].

Burkina Faso is currently the African leading producer with an estimated annual production of 182,000 tons in 2007-2008, compared with 118,000 tons for Egypt, 112,000 tons for Tanzania, 100,000 tons for Zimbabwe, 97,000 tons for Benin and 92,000 tons for Nigeria. While cotton cultivation and its revenue provide a living for about 10 million people in sub-Saharan Africa, the global economic crisis has worsened the situation of cotton growers. Consequently, they try to decrease their production costs to remain competitive, and to provide training in economics, marketing strategy and management skills to leaders, in order to better defend their interests at regional and world level (Clavreul, 2009a).

Thus, Burkina Faso has authorized the cultivation of transgenic cotton. At the cotton university, which gathered executives and technicians of cotton trade-unions from 13 Western and Central African countries from 12 to 16 January 2009, in Segou, Mali, following a week-long meeting in 2008 in Burkina Faso, several participants highlighted the advantages offered by genetically modified crops, without underestimating controversial issues, economic dependence that may result from their use, as well as their environmental impact. In Mali, the national assembly had authorized the cultivation of GMOs in the fall of 2008, but the application decrees had not yet been published by early 2009. Omar Sampo Ceesay of Gambia underlined the need to solve the issue of delivering cotton on the markets in a sustainable way before adopting GMOs. In particular, he stated that "Ghana also wished to grow transgenic cotton, but importers should buy it". In 2007, transgenic cotton contributed 43% of total cotton production (Clavreul, 2009a).

Regarding the training of producers and trade-union technicians, the African Association of Cotton Producers (APROCA), which is composed of national unions of cotton producers, took the initiative to organize a training session at the cotton university in Segou, Mali, from 12 to 16 January 2009, with the financial support of the Foundation for Agriculture and Rurality in the World (FARM). The goal was to offer this training to two other groups of 40 persons, and thereafter to let African trainers to carry out the activity. The initial training was carried out by two specialists of strategy and leadership from the French Higher School of Commercial Studies (HEC, Paris) [Clavreul, 2009a].

On the other hand, African cotton producers had been very active at the World Trade Organization's negotiations in Cancun (Mexico) in 2003 and in Hong Kong in 2005, where they drew the attention of the attendants to the unfairness of world trade and the difficulties faced by African farmers. François Traoré from Burkina Faso played a key role in defending the interests of African cotton producers, and in advocating the cultivation of transgenic cotton. See Zachary (2007).

Soil fertility mapping and rehabilitation: the case of Africa

In order to feed their populations estimated at 1.8 billion people in 2050, African countries should know the status of their soils and how to better use them for agriculture. On 13 January 2009, the Center for Tropical Agriculture (CIAT, Cali, Colombia) announced in Nairobi that a new project, African Soil Information Service (ASIS), aimed to carry out a complete digital map of the continent in four years. This project should integrate already existing data and those supplied by field teams. In about 60 sites distributed throughout the arable lands of Africa (less than half of total area) infrared spectroscopy will be used and its results will be combined with satellite images to design a map of soils, showing the level of their degradation (Rémy, 2009).

ASIS will therefore map the fertility status of African soils, particularly of arable soils. Soils are considered "healthy" when they can bear ecosystems, produce harvests, store atmospheric carbon and hold rainfall. Overexploitation is the greatest threat to soil fertility and sustainability. In Africa, the lack of fertilizers (too costly and poorly available) leads to the exhaustion of farmlands beyond their regeneration capacity and to the non-replacement of their nutrients that are leached out. African farmers use an average 8 kg of fertilizers per hectare per year, compared with 200 kg in China, according to Nteranya Sanginga, director of the CIAT Institute of Tropical Soil Biology and Fertility. Millions of hectares of agricultural lands are degraded in Africa. This causes an annual loss of about €30 billion (Rémy, 2009).

In Kenya, on 12 January 2009, the government has declared a state of urgency because 10 million people were threatened by starvation in a country where agricultural produce amounted to 64% of exports. Like Malawi, Kenya (and Mali and Tanzania as well) has ecided to heavily subsidize farmers to buy fertilizers in order to foster food production. But one should not forget that the massive use of fertilizers in Asia since the 1960s, which allowed the continent to move from a situation of food dependency to that of a commodity exporter, had devastating environmental effects.

Forty years later, there is a consensus on the need to use a well-balanced mixture of fertilizers, organic and chemical, and to adapt it to each region; this implies a good knowledge of soil fertility (Rémy, 2009).

In this respect, an FAO study showed that African soils were losing about 48 kg of nutrients per hectare per year, i.e., an average equivalent of 100 kg of fertilizers per year. As compensation, they just receive 8-10 kg of inorganic fertilizers per year, compared with an average 90 kg worldwide. In the Caribbean countries, soil productivity is limited by the low natural fertility and depth, as well as by erosion due to the stiff slopes and bad drainage, and by salinization. The reduction or even disappearance of fallow in the most populated regions, the intensive felling of trees and woodlands, overgrazing and contamination are the main factors of soil degradation. This results in the deterioration of soil chemical and physical properties, the decrease in organic matter content and biological activity and in the concentration of the main nutrients (nitrogen, phosphorus and potassium) [*Spore,* February 2009, no. 139, pp. 8-10].

The decrease in crop productivity results in the farming of soils that are not prone to agriculture; these soils produce less. Consequently, the farmers whose income decreases buy less fertilizers. Overall agricultural production falls down and cannot cope with an increasing population. That is why large-scale programmes have been launched to rehabilitate African soils, such as Terrafrica – a partnership between the main agencies of the United Nations, the NEPAD, the European Union and many international and regional organizations – and the Alliance for a Green Revolution in Africa (AGRA), whose objective is to rehabilitate 6.3 million hectares of agricultural lands (*Spore,* February 2009, no. 139, pp. 8-10).

There has been a long standing opposition between those who support the massive use of inorganic fertilizers and those who prefer to rely on organic or sustainable agriculture. There is now a consensus on an integrated approach to the management of soil fertility, and adapted to the local environment. Inorganic fertilizers are generally necessary to achieve a significant increase of production. But in Africa their use by small landholders is often restricted to cash crops. They are not much used for food crops that are less income-yielding. Inorganic fertilizers are now commercialized by private companies and are not available everywhere; their cost, which rose sharply during the global food crisis, limits their use by small and poor farmers.

For instance, in northern Burundi, high population density has led to the disappearance of fallow land and farmers who cannot buy costly fertilizers use rice bran to fertilize their lands. In western Cameroon, where the

price of fertilizers trebled between November 2007 and May 2008, soils that are impoverished by the burning of grasses, need fertilizers; manure is rare and this scarcity has been worsened by porcine and avian plagues, and farmers are not yet fully accustomed to use compost and to plant green manure shrubs such as *Calliandra* and *Pygeum africana* (*Spore*, February 2009, no. 139, pp. 8-10).

The global food crisis and the higher cost of fertilizers have led to applying soil conservation and rehabilitation techniques that have been known for a long time and not sufficiently disseminated. For instance, recent archeological discoveries revealed that Amazon Indians used to improve soil fertility with a mixture of compost and charcoal. Charcoal improves the soil capacity to absorb nutrients and therefore to better meet the needs of crops. In Belize, a project launched by the Taiwanese Mission of Agriculture of the Cayo district consists of alternating layers of charcoal and of compost in order to grow vegetable crops, as used to do the Indians hundreds of years ago. Another method consists of adding charcoal to paddy and fish-farming wastes, or to a compost derived from organic food wastes. These techniques can be applied on a large scale only if forest resources are available and managed in a sustainable way to produce charcoal (*Spore*, February 2009, no. 139, pp. 8-10).

S. Apiiga, a researcher at Ghana's food and agriculture ministry, stated that fertilizers alone cannot restore soil fertility and that farmers should learn and apply good agricultural practices such as the association of cereals with legumes (beans, groundnuts and pigeon peas), and use manure, crop wastes and compost to fertilize their plots. The basic principles of conservation agriculture are well known. The first one is to try to maintain a permanent cover of the soil, e.g. crop wastes, straw, compost, wood waste are left on the ground to protect the soil from wind and rain erosion. Secondly, soil surface should not be disturbed by deep ploughing; hoeing is sufficient. Thirdly, crops should rotate, e.g. alternate legumes which enrich the soil through fixing atmospheric nitrogen and cereals which need more nitrogen. Soil conserved in these ways can be improved by manure and compost and inorganic fertilizers. That was done by farmers belonging to the association Nangabo, near Kampala in Uganda, who have increased the productivity of banana trees thanks to the rotation of crops and the use of mulch to cover soils. Others use no-tillage farming: in Madagascar, about 10,000 farmers in the center and south of the island have almost trebled rice yields (from 1.5 to 4 tons per hectare), using plants that cover the soil and serve as green manure. In Cook and Solomon islands, Niue, Samoa, Tonga and Vanuatu, *Mucuna* and *Dolichos lablab* are used as cover plants, as well as multipurpose trees like *Gliricidia sepium;* soil fertility has

been improved in one year and cassava production has been increased, while farmers reduced the quantities of fertilizers they used to buy (*Spore*, February 2009, no. 139, pp. 8-10).

Cultivation of crops lined between fertilizing trees improves soil structure and fertility. It is practised in humid regions and has been successful in Kenya. In dry areas, trees will not grow adequately and will absorb part of the water needed for crops. In the Sudan-Sahelian zone, it is generally advised to add organic matter to the soils and spread fertilizers.

When fertilizers are added, their composition should suit soil chemical properties, crop nutrient needs and correspond to the expected yields. Farmers need fertilizer formulas that are adapted to their soils. Bulk blending is a very interesting technique for many Africa-Caribbean-Pacific countries. It consists of producing cheap mixtures of fertilizers, using locally produced raw materials and fertilizers available on the international market at the lowest cost. Thus, phosphorites that exist in many countries are an excellent and cheap source of phosphorus fertilizers. Microdosage is another convenient technique that consists of applying low quantities of fertilizers when the crop is sown. This technique has been developed by the International Crop Research Institute in the Semi-Arid Tropics (ICRISAT, Patancheru, Andhra Pradesh, India). A small quantity of fertilizer is placed in the soil with the seed, or within three weeks after sowing. The efficiency of the technique has been demonstrated in Zimbabwe where cereal yields rose 30% to 40%, as well as in West Africa where they rose between 44% and 120% for millet and sorghum. ICRISAT has convinced fertilizer producers to distribute small bags of fertilizers in the villages with simple notes about how to use them (*Spore*, February 2009, no. 139, pp. 8-10). See also FAO (2003, www.fao.org/DOCREP/006/x9681F/x9681/Foo.HTM); *The Global Fertiliser Crisis and Africa* (www.future.agricultures.org/pdf files/brieffertilizercrisis.pdf)

Water : managing an increasingly scarce resource

Global hydrological cycle and water availability

Every year, thousands of cubic kilometers (km^3) of freshwater fall as rain or snow or come from melting ice. According to a study, in 2007, most nations outside the Gulf were using a fifth or less of the water they receive – at least in 2000, the only year for which figures were available. The global average withdrawal of freshwater was 9% of the amount that flowed through the world hydrological cycle. Both Latin America and Africa used less that 6%:

	Withdrawals			
	Renewable resources (km^3/year)	Total (km^3/year)	% of renewable resources	Per person (m^3)
North America	6,653	1,525	8.4	1,664
Asia	13,927	2,404	18.1	644
Europe	6,603	418	6.4	574
Latin America & the Caribbean	13,750	265	2.0	507
Africa	3,936	217	5.6	265
World	43,659	3,829	8.8	626

Source: UN World Water Development Report (2000). (The Economist, 2009a*)*

There is evidence that given current patterns of use and abuse of water, the amount now being withdrawn from the hydrological cycle are moving close to the limits of safety – and in some places beyond it. An alarming number of the world's large rivers no longer reach the sea. They include the Indus, Rio Grande, Colorado, Murray-Darling and Yellow rivers. These flow through the main grain-growing areas of the world (*The Economist,* 2009a).

According to the World Wide Fund for Nature (WWF), fish stocks in lakes and rivers have fallen approximately 30% since 1970. This is a bigger population decrease than that registered for animals in equatorial and temperate forests, savannas and any other large ecosystem. Half of the global wetlands have been drained, damaged or destroyed during the 20th century, mainly because, as the volume of freshwater in rivers falls, salt water invades the delta changing the balance between fresh and salt water. On this evidence, there may be systemic water problems, as well as local disruptions (*The Economist,* 2009a).

Two global trends have an increasing incidence on the availability of water, and both are likely to accelerate over coming decades. The first is population growth: as it rose from 3 billion to 6.5 billion over the past fifty years, water use roughly trebled; on current estimates, the population is likely to rise by a further two billion by 2025 and by three billions by 2050, and the demand for water will increase accordingly. It is not the absolute number of people that makes the biggest difference to water use but changing habits and diets. Diet matters more than any single factor because agriculture uses about 70%-75% of global water and even more in some developing countries. Different foodstuffs require radically different amounts of water. The meaty diet of Americans and Europeans

requires around 5,000 liters of water a day to produce, whereas the vegetarian diets of Africa and Asia use about 2,000 liters a day (*The Economist,* 2009a).

On the other hand, almost all the 2 billion people who will be added to the world population between 2009 and 2030 will be third-world city dwellers – and city people use more water than rural people. FAO reckoned that, without changes in efficiency, the world will need as much as 60% more water for agriculture to feed those 2 billion extra mouths. That is roughly 1,500 km^3 of water – i.e. as much as is currently used for all purposes in the world outside Asia (*The Economist,* 2009a).

The other trend affecting water availability is climate change. There is growing evidence that global warming is speeding up the hydrological cycle, i.e. the rate at which water evaporates and falls again as rain or snow. This higher rate seems to make wet regions more humid and arid ones drier. It brings longer droughts between more intense periods of rainfall. Climate change has three major implications for water use. First, it changes the way plants grow. Trees, for instance, react to downpours with a spurt of growth; during the longer dry periods that follow, the extra biomass then dries up so that if lightening strikes, forests burn more spectacularly. Similarly, crops grow too fast, then wilt. Secondly, climate change increases problems of water management: unusually larger floods overwhelm existing control; reservoirs do not store enough water to meet the needs of people and crops during longer droughts; global warming melts glaciers and causes snow to fall as rain. Consequently, dams have been making a comeback, especially in African countries with plenty of water but no storage capacity; the number of large dams (more than 15 meters high) has been increasing. Thirdly, climate change has persuaded governments to produce agrofuels. Currently, about 2% of irrigation water is used to grow energy crops, or 44 km^3. But, according to the United Nations, an extra 180 km^3 may be required in the future if all national plans are implemented. Though small compared with the increase in water required to feed the additional 2 billion people, the additional amount for agrofuel production is still substantial (*The Economist,* 2009a).

In short, two-thirds of the world population is projected to face water scarcity by 2025-2030, according to the United Nations. Recurrent droughts are striking an increasing number of countries, e.g. around the Mediterranean, in the Middle East, some regions of Latin America (an exceptional drought struck Argentina in 2009), Australia, while floods of unprecedented violence are causing the wastage of huge volumes of water.

According to the third *World Report on Water Resources*, published in March 2009 by the United Nations (six agencies led by the United Nations Educational, Scientific and Cultural Organization-UNESCO) just before the World Water Forum (Istanbul, 16-22 March 2009), 76% of the world population is using an average of 5,000m³ of water per person per year, whereas 25% is consuming only less than 2,000 m³ per person per year. Regional situations are very contrasted: while South America has 25% of available freshwater in the world, but has only 6% of world population, 60% of the world population lives in Asia, which has only 30% of the available freshwater (Dupont, 2009b).

Economic and social issues

The economic and social impact of water deficiency and/or floods is high. For instance, in Kenya, the losses due to drought and floods that occurred between 1997 and 2000 have been estimated at US$4.8 billion, i.e. 16% of gross domestic product (GDP). Losses in Africa caused by the lack of water infrastructures have been evaluated at US$28.4 billion per year. Those in the Middle East and North Africa have been estimated at US$9 billion per year (Dupont, 2009b).

Water is rarely priced in ways that reflect supply, and demand. Usually, water pricing simply means that city-dwellers pay for the cost of the pipes that transport it and the sewage plants that clean it. Basic information about who uses how much water is lacking. Rainfall and river flows can be measured with more accuracy, but the amount pumped out of lakes and how much is taken from underground aquifers is not known accurately. Until recently, few poor countries treated water as a scarce resource, nor did they think about how it would affect their development projects. In addition, the decision-making process often involves numerous overlapping authorities responsible for watersheds, sanitation plants and irrigation, in both developed and developing countries (*The Economist,* 2009a).

Investment in water has been patchy and neglected. Aid to developing countries for water was flat in real terms between 1990 and 2005. Within that period, there was a major shift from irrigation to drinking water and sanitation, but this meant that less aid was going to the main users of water, farmers in poor countries. Aid for irrigation projects in 2002-2005 was less than half what it had been in 1978-1981. Angel Gurria, the head of the Organisation for Economic Cooperation and Development (OECD), has stated that there was “a crisis in water financing” (*The Economist,* 2009a).

Improving the efficiency of water use

In a world that has been and is using too much water, the answer to this global problem is to improve the efficiency with which water is used. Industrial users have done it, cutting the amount of water needed to make each ton of steel and each extra unit of GDP in most rich countries. Merely by using water-saving practices, e.g. gradually eliminating flood irrigation and replacing it by drip irrigation, needs could be met for decades. Still, industry consumes less than a fifth of the world water and the major issue is how to induce farmers who use 70% -80%, to follow suit. It takes at least three times as much water to grow maize in India, for instance, as it does in the United States or China :

rice	1,500 m^3/ton	in the United States
	1,300 m^3/ton	in China
	2,800 m^3/ton	in India
wheat	900 m^3/ton	in the United States
	750 m^3/ton	in China
	1,600 m^3/ton	in India
	1,600 m^3/ton	in Brazil
soybeans	1,900 m^3/ton	in the United States
	2,700 m^3/ton	in China
	4,100 m^3/ton	in India
	1,000 m^3/ton	in Brazil
maize	500 m^3/ton	in the United States
	800 m^3/ton	in China
	2,000 m^3/ton	in India
	1,200 m^3/ton	in Brazil

Changing irrigation practices can improve water efficiency by 30%, stated Chandra Madramootoo of the International Commission on Irrigation and Drainage (*The Economist,* 2009a).

In addition to better management practices, there is a growing trend to track “water footprints” as an indicator of how much water is used to produce any commodity or food ingredient or beverage. This concept is modeled partly on carbon footprinting, a widely used measurement of carbon-dioxide emissions.

The water-footprint concept was presented in 2002 by Arjen Hoekstra, professor of water management at University of Twente in the Netherlands. Using data from FAO, A. Hoekstra and others measured the

water volumes for making various products and applied those statistics to people's consumption patterns in order to obtain a rough water footprint for average individuals and nations (Alter, 2009).

A new wave of research on "virtual", or embedded, water has given companies and governments tools to track not just the water they consume directly, but also the volumes embedded in a dish-washing detergent, Argentine beef and cotton grown in Pakistan. Thus, it takes roughly 135 liters of water to make a cup of coffee, some 2,660 liters to produce a cotton T-shirt, 2,400 liters to produce a typical hamburger, i.e. more than three times the amount the average American uses every day for drinking, bathing, washing dishes and flushing toilets; the major part of this volume is used to grow cereals for cattle feed (Alter, 2009).

Almost all the water that is used for growing crops and producing food is returned to the water cycle, either as evaporated water or in the form of polluted runoff. But it is temporarily unavailable for other uses, and may not be returned to the same aquifer, lake or river if it comes back as precipitation in another region. That raises supply difficulties in water-scarce areas (Alter, 2009).

Some experts question the accuracy and relevance of water footprints, which vary depending on where and how products are made. For instance, oranges from Brazil may have a higher water footprint than oranges from Spain, but the Brazilian ones may be a better choice because of the country's rainy climate. According to Peter Gleick, director and co-founder of the Pacific Institute, an Oakland, California-based environmental think-tank, water footprints are hard to calculate. Some companies measure just water used in factory operations; others count the liters used to grow ingredients in their supply chains, and still others take stock of water that consumers use to wash clothes or dishes with their products. For instance, Coca-Cola Co.'s bottling factories use about 4 liters of water to make a two-liter bottle of soda. But that figure surges to as high as 500 liters of water per two-liter bottle of soda if one adds the water used to grow ingredients such as sugar-cane, according to an estimate provided to the company by the World Wide Fund for Nature (WWF). A Coca-Cola Co.'s spokeswoman stated this figure was preliminary and might change as the methodology used to calculate it evolves (Alter, 2009).

For many food and beverage companies, calculating water footprint is not just an attempt to be environment-friendly, but it is also about self-interest. A Coca-Cola Co.'s bottling plant was shuttered in South India in 2004 after residents claimed it depleted and polluted local water

supplies. SABMiller plc – a big beer-producing company – invested in water-purification technology for its factory in Dar es Salam, Tanzania, where overuse of groundwater by industries has caused fresh aquifers to become increasingly salty. SABMiller's executives started to worry about the company's water footprint in August 2007. The World Business Council for Sustainable Development released its on-line "global water tool" in 2009; this tool let companies enter the GPS coordinates of their factory sites to identify hot spots where water scarcity overlapped with operations or agricultural supply chains. SABMiller's results were alarming: about 30 sites, including factories in South Africa, India and Peru, were shown as vulnerable to future water shortages, according to Andy Wales, SABMiller's director of sustainable development (Alter, 2009).

The company therefore decided to deal with its water footprint in South Africa – a water-scarce country where more than 5 million people lack access to safe drinking water – with hopes of replicating the project elsewhere. South Africa's breweries produce 17% of SABMiller's beer. The company hired the environmental consultancy URS Corp. to trace how much water was used in steps from growing hops to rinsing bottles, and made the World Wide Fund for Nature (WWF) an independent adviser. The findings led SABMiller to focus on water-scarce regions, including Gouritz – a coastal area where its suppliers grow hops, barley and other ingredients and where water resources are decreasing. SABMiller is considering more efficient irrigation technology for sugar and barley farms there (Alter, 2009).

Despite the controversy about water footprint, the latter is poised to increase. By 2050, there will be 3 billion more inhabitants in the world than in 2009, and we shall have to use the same amount of water we use nowadays, as stated by Stuart Orr, manager of the WWF Freshwater Footprint Project. Consequently, heavy users of water are trying to decrease their impact on water resources by funding water sanitation and conservation work. For instance, Unilever plc., which owns 400 food and household brands, has estimated it saved about US$26 million by reducing water waste in factories from 2001 to 2007. The company also started to reduce water used to produce ingredients for its Lipton Tea and Ragu tomato sauce by using drip irrigation to grow black tea in Tanzania and tomatoes in California. Such endeavours could have a significant impact, as Unilever buys 7% of tomatoes harvested in the world and 12% of all commercial black tea (Alter, 2009). PepsiCo piloted a programme to help rice farmers cultivating 1,600 hectares in India switch from flood irrigation to direct seedling, a planting method that requires less water and makes crops more drought-resilient (Alter, 2009).

The Nature Conservancy, an environmental non-governmental organization, is working on a certification plan which aims to give companies and businesses seals of approval (like to some extent the Fair-trade symbol) according how efficiently they use water. The plan is supposed to be initiated in 2010 (*The Economist*, 2009a).

The political and economic world is increasingly interested in trying to find solutions to the global water crisis. At the World Economic Forum held in Davos from 28 January to 1 February 2009, where 1,600 executives, 40 heads of state and government and 300 researchers, university leaders and NGO representatives attended the meetings, a report on water was released for the first time and its tone was alarming: "the scarcity of water during the next decades will have implications for economic development, human security, environment and political stability". In addition to highlighting the issues relating to the growing demand for water in agrifood production, energy generation and a wide range of industrial items, the Davos report underlined the need of waste-water treatment as well as the advantages of desalination of sea-water for the production of drinking water (Dupont, 2009a).

The Davos report highlighted the opportunities for investors in a sector that becomes more attractive: infrastructures needed for the management of water resources as well as for the treatment and recycling of water correspond to a world market estimated at US$400 billion a year. The desalination market was expected to grow by 20% annually until 2015 in China, India, Australia and the United States. Water transfer at regional and subregional level from one country to a neighbouring one or from one basin to another in the same country could be a solution that is not free of polemics. The Davos report also mentioned that some countries are buying or leasing land overseas to farm them and thus ensure food security at home (Dupont, 2009a).

Decreasing agricultural inputs : a European agriculture using less pesticides

On 25 and 26 November 2008 in Paris the French presidency of the European Union organized a seminar that aimed to answer the following question : will European farmers be able to feed the Union's populations while reducing the use of synthetic pesticides? The meeting was organized before the adoption of a new European regulation on the use of pesticides that was expected to upheave agricultural practices. The French agriculture minister, Michel Barnier, stated that "farmers will have to face the great challenge of the new European agricultural model in a

difficult context, as food demand was expected to duplicate, and climate and health hazards were increasing" (Dupont, 2008).

It is true that the European Union is the world's biggest consumer of pesticides. Some 300 products used to eradicate or treat crop diseases and parasites were registered in 2008. Every year pesticide residues are detected at very low doses in almost all foodstuffs that are tested. In approximately 5% of the cases, the concentration is above the allowed ceiling (Dupont, 2008).

Europe's rules on pesticides are based on risk. Risk is something one measures in the real world; it depends not just on how toxic a chemical is, but how much of it is used and how often it is used. The new legislation will shift the basis of the law towards an assessment of hazard, i.e. something one measures in a laboratory by finding out how much of a substance one needs to kill or injure an experimental animal (*The Economist*, 2008h).

Several scientific studies have revealed the relationship between the exposure to pesticides and the development of cancers, the alteration of fertility, particularly among farmers. For instance, "follicular" lymphoma is one of the most frequent cancers and one of the main causes of mortality caused by cancer. About 17,000 new cases of lymphoid cancer are detected annually in France. This cancer is caused by a breach on chromosome 18, of which a part is translocated on chromosome 14. In most people, this translocation is found in one cell out of one million, but among some groups of people and particularly among farmers exposed to pesticides which can cause this kind of chromosomal breach, translocation between chromosomes 18 and 14 is one thousand times more frequent. The lymphocytes that are affected are very similar to the precancerous cells of "follicular" lymphoma. These results were presented on 7 November 2008 by Bertrand Nadel and Sandrine Roulland of the Immunology Centre of Marseille-Luminy, at a symposium on malignant haemopathies, organized by the canceropole of the region Provence-Alpes-Côte d'Azur (Benkimoun, in *Le Monde*, 28 November 2008, p.4).

In an article published on line on 18 November 2008 in *Occupational and Environmental Medicine*, Jacqueline Clavel and her team of the National Institute for Health and Medical Research (INSERM U754) indicated that the repeated exposure to pesticides could be a predominant cause of several malignant haemopathies, including multiple myeloma and Hodgkin's disease. Their work established a relationship between Hodgkin's lymphoma and the exposure to triazol fungicides and herbicides derived from urea as well as between the so-called "tricholeucocyte"

leukaemia and exposure to organochloride insecticides and various herbicides. Conversely there was no significant relationship in the case of non-Hodgkinian lymphomas (Benkimoun, in *Le Monde*, 28 November 2008, p.4)

The European regulation to be adopted in 2009 by the European parliament includes several aspects. One of them – the most debated – makes the criteria required for the authorization of pesticides tougher. For the fist time, those of proved toxicity will not be authorized; these are carcinogenic and mutagenic compounds and substances that are toxic for reproduction. However, some exceptions could be made for a period of five years (or more), when important sectors of agricultural production are threatened by their withdrawal. Compounds that disturb the hormonal system will also be banned. The European parliament wanted to make regulation even tougher by eliminating neurotoxic and immunotoxic compounds, as well as substances that are harmful for bees. Negotiations were being held between the parliament, the European Commission and the Council of the European Union. According to the European Commission, only 2% to 4% of substances would be banned, while the agrochemical companies mentioned the figure of 40% and considered the European parliament's demands "unacceptable" (Dupont, 2008).

Another innovation of the European framework directive on the sustainable use of pesticides, which completes the reform of the homologation procedures, foresees the generalization, from 2008 to 2014, of the methods of "integrated protection of crops". The objective is to prevent crop diseases and to use pesticides at the right time and as a last recourse (Dupont, 2008).

This is a great challenge for farmers. But it is part of a new agriculture paradigm, which is to have an agriculture that uses less water, fertilizers and biocides, and is more environment-friendly. It is possible to reduce the use of pesticides in a very significant way and to keep high yields, if farming systems, which are nowadays based on the specialization of productions and the preventive reliance on chemicals, are thoroughly rethought. In fact, a whole range of measures could be applied, such as diversification of crop rotations, use of disease-resistant varieties, lowering the density of planting, improvement of monitoring and warning systems in case of pest attacks, use of pesticides derived from natural substances. It is advisable to rely on the know-how of farmers, as stressed by Guy Paillotin, in charge of the design of the French programme of reduction of pesticide use. Some of these farmers are already using half of the quantities of pesticides currently consumed by others (Dupont, 2008).

The European Union's symposium highlighted a number of future trends and issues: farming activities, with fewer chemicals, will become more complex and economically risky; training and advice will be indispensable to the generalization of new practices; regulation imposed without the participation of the farming communities and the involvement of any production chain has little chance to be respected. And the questioning of habits adopted over 50 years, under the stimulus of public authorities, cannot be done in one day (Dupont, 2008).

Many agricultural scientists argue that the change will have widespread, alarming consequences for farming and will lead to further increases in food prices. ADAS, a British environmental and rural consultancy, has produced a report which stated even the lowest-impact proposals would reduce food production by a quarter. In January 2008, an Italian report published similar figures (*The Economist*, 2008h).

John Atkin, the head of the crop-protection division of Syngenta, the Swiss agrichemical and seed company, stated the foreseen changes were wrong: "Current regulations were tough and we have already reached a point where some useful compounds, particularly for minor crops (leeks, green beans and flower bulbs), have been lost, to the detriment of agricultural productivity". He added that even under existing rules some 700 substances have disappeared from the market, out of an original total of around 1,150. Ian Dewhurst, the principal toxicologist at the British government's Pesticide Safety Directorate, pointed out that by failing to think about real world risks, the European Commission might end up acting against the wrong pesticides. Ian Denholm, head of plant and invertebrate ecology at Rothamsted Research Station, concurred, and judged that the present system founded on science-based risk assessment, is a "rigorous gold standard" (*The Economist*, 2008h).

The counter-argument is that the existing legislation, which was drafted in the late 1980s, is not working. Elliott Cannel, a spokesman for the Pesticide Action Network, an environmental group based in London, reckoned the average European probably ate food contaminated with pesticides at least once a fortnight. Vyvyan Howard, a toxicologist at the University of Ulster and a supporter of the reform, also reckoned that the existing system was not as good as it claimed to be. The new system, according to V. Howard, is based on science, but with pragmatism. The goal is to reduce the overall toxicity of the entire range of pesticides. The new criteria would remove the most hazardous products from the food chain altogether (*The Economist*, 2008h).

In response to the sceptics' concerns, the European Union's agriculture ministers met on 23 June 2008 to work out a compromise that would allow any country that thinks it cannot replace a particular pesticide to ask permission to continue to use it. This has angered environmental groups and it has pleased neither agricultural scientists nor the British government. To obtain exemption was too bureaucratic and could involve as much as two years of consultation (*The Economist*, 2008h).

A number of lessons can be drawn from the European Union's debates and new regulation on the use of pesticides. Firstly, cheap, pesticide-free food is probably an achievable objective. The second lesson, however, is that science cannot always give clear-cut answers. Hazard assessment is not often relevant to real risk. On the other hand, a true risk assessment is impossible, since not all of the variables can be identified, let alone measured and modeled. Nevertheless, the experiment should be tried and conclusions drawn. That will be the case of the new legislation: experience and scientific studies will tell if it would last or be changed (*The Economist*, 2008h).

Livestock husbandry: reducing its environmental impact

Grazing lands cover about 30% of the world surface and more than 40% of the harvested cereals feed livestock. As the demand for meat, eggs and milk products is growing, forests and woodlands are converted into pastures.
For instance, in June 2008, in an unprecedented move against illegal cattle ranchers in the Amazon forest, the Brazilian government has seized 3,100 head of cattle that it said were being raised on an ecological reserve in the State of Pará; that operation intended to serve as a warning to other ranchers grazing an estimated 60,000 head of cattle on illegally deforested land in the Amazon, stated the environment minister, Carlos Minc (Downie, 2008).

C. Minc stated the cattle would be auctioned in two weeks, with the proceeds going to the government's food programme for the poor, Fome Zero, as well as to health programmes for indigenous people and to fund cattle-removal operations. He also announced that Ibama, the government agency, had begun legal proceedings to seize an additional 10,000 cattle grazing on illegally deforested land in Rondônia State. Finally the minister stated that thanks to operations like those announced by early June 2008, ranchers with cattle in protected areas like indigenous and forestry reserves were starting to move their herds for fear of having their livestock confiscated (Downie, 2008).

A report by the environmental group Friends of the Earth stated that Brazil's growing dominance on the global beef market was in large part due to the expansion into the Amazon where land is cheap. Brazil indeed surpassed Australia and the United States to become the world's biggest beef exporter in 2004, and has more than 200 million head of cattle. The report stated that a third of Brazil's fresh beef exports in 2007 came from the Amazon, and three of every four head of cattle added to Brazil's herds since 2002 were in the Amazon. Fears have been growing over the future of the world's biggest rainforest. Although annual deforestation figures fell to a 16-year low of 11,222 square kilometers in 2007 – from a 9-year high of 27,379 square kilometers in 2004 – government agencies reported in 2008 that deforestation was on the rise again, and cattle herders were blamed for much of the increase (Downie, 2008).

The move of the government against illegal ranching has been lauded by environmental advocates, but they warned that the efforts should be pursued to stem deforestation."This can be a good way of at least showing the government is concerned about the contribution of ranching to the problem of deforestation", stated Peter May, associate director of Friends of the Earth Brazil. "It is an important strategy, but if they do it just once and then never do it again, it will be seen as a media event" (Downie, 2008).

On the other hand, livestock husbandry and related industries are very polluting: the billions of tons of wastes generated by them contaminate river and water tables with nitrogenous compounds; livestock husbandry alone is responsible for 18% of the global emissions of greenhouse-effect gases – higher than that of transportation with respect to global warming. It is estimated that livestock husbandry generates 65% of global emissions of nitrous oxide (mainly from manure) and 37% of methane (Clavreul, 2007d).

In addition, livestock husbandry consumes large volumes of freshwater, i.e. has a large water-footprint : production of 1 kg of pork needs 4,600 liters of water, while 1 kg of beef needs up to 13,500 liters, according to some estimates, whereas 1,000 liters of water are consumed to produce 1 kg of wheat (4 kg of cereals are consumed to produce 1 kg of chicken meat, and 6 kg of grains to produce 1 kg of pork) [Clavreul, 2007d].

All forecasts indicate the increase of global consumption of meat and products of animal origin. In all countries, throughout human history, the rise of income has been accompanied by that of meat consumption,

and that will be the case in the so-called emergent countries, where strong population growth will occur. According to the joint forecasts by FAO and OECD, between 2007 and 2016, world meat production would increase by 9.7% for beef, 18.5% for pork, and 15.3% for chicken, mainly in Brazil, China and India. By 2050, meat production may be duplicated, from 229 million tons at the beginning of the 2000s, to 465 million tons. Milk production would follow the same trend. The main reasons are of course population growth and increase in needs and consumption by younger, urbanized and wealthier societies, as well as diet changes (Clavreul, 2007d).

Geographic distribution of this increase in meat consumption will be as follows: decrease in consumption in rich countries where it is presently high or excessive, and increase in middle and low-income countries, where there is a deficit. According to the British medical journal *The Lancet*, dated 13 September 2007, the global average consumption of meat is 100 g per capita per day, but it amounts to between 200 g and 250 g per capita per day in industrialized countries, and only to 20 g to 25 g in low-income countries. The authors of the study published in *The Lancet* stated that "if global population is to increase by 40% from now to 2050, and if no major reduction in the emissions of greenhouse-effect gases by livestock does not occur, meat consumption should be lowered to an average of 90 g per capita per day, in order to stabilize the emissions of this sector". Consumers of rich countries should already be aware of the disastrous implications of excessive meat consumption. At the global level, the issue is not to produce less, but differently, in order to lessen the negative impact of livestock husbandry (Clavreul, 2007d).

FAO's advice is to halve the environmental costs per animal production unit, only in order not to worsen the situation, for instance, by including the environmental cost in meat prices, privileging chicken meat consumption, which has a lesser negative impact on the environment, improving livestock husbandry practices. One expectation is to know better the genomes of livestock species (sequencing of these genomes is proceeding rapidly, and the cow genome was published in 2009) and to select breeds that are both resistant to diseases and sturdy, and productive. Other research work focuses on developing less wasteful feeding rations, and on the digestive system of ruminants, in order to master methane production (methane is 23 times more active than carbon dioxide on global warming). For instance, at the French National Agricultural Research Institute (INRA), the use of food additives derived from vegetable oil, or of more cereal feedstuffs has led to a rapid growth of young bulls and to a lower production of methane. But livestock husbandry being a

complex system, environmental advantages could be accompanied by economic shortcomings (a larger consumption of cereals). Consequently, an integrated approach may lead to sustainable husbandry with the participation of agronomists, zootechnicians, nutritionists, economists and social scientists. A working group along this line has been setup at INRA. The new goal is to combine higher production with an ecologically sound approach (Clavreul, 2007d).

Advanced crop breeding and management

In his Nobel lecture in 1970, Norman E. Borlaug (Peace Laureate) stated that the green revolution won a temporary success in humankind's struggle against hunger, which if fully implemented could provide sufficient food for the planet's inhabitants through the end of the 20th century. The green revolution also showed that Thomas Malthus' dire predictions were wrong. But N.E. Borlaug also warned about the need to curb human population growth, otherwise the success of the green revolution would be only ephemeral (Borlaug and Dowswell, 2008).

In the 21st century, over the next 40 years, agrifood production will have to be duplicated in 2050, and consequently continued genetic improvement of food crop species and varieties is needed to shift the yield frontier higher and to increase stability of yield. Research breakthroughs are needed, especially in plant and crop genomics and biotechnology.

It is also important to recognize that conventional breeding will continue to make significant contribution to increased agrifood production and improved nutritional properties of crops. The "good" agronomy or rational agriculture is another important tool to face the challenge of duplication of agrifood production: improvement of the efficiency of water use and irrigation systems, particularly for smallholder farmers in water-deficient areas; no- or minimum tillage agriculture, and crop rotations; organic fertilization of soils and use of biofertilizers; reduction of pesticides and integrated biological and chemical control of pests, use of biopesticides; agroforestry.

Experts consider that we have the tools to duplicate yields of food crops worldwide and improve the standard of living of 5 million families of smallholder and poor farmers in 2020, while reducing by 30% the quantities of farm inputs.

Management of rice crops

Rejecting the modern reliance on genetic engineering, Norman T. Uphoff of Cornell University, Ithaca, an emeritus professor of government and international agriculture, has advocated a revolutionary method for managing rice crops. According to him, harvests typically double if farmers plant early, give seedlings more room to grow and stop flooding fields. That cuts water and seed costs while promoting root and leaf growth. The method, called the System of Rice Intensification, or SRI, emphasizes the quality of individual plants over the quantity. In a decade, this method has evolved into a global trend and encountered great resistance from rice scientists. Yet, a million rice farmers have adopted SRI, according to N.T. Uphoff, who predicted this number would increase to 10 million (Broad, 2008).

The International Rice Research Institute (IRRI, Los Baños, Philippines), which helped start the green revolution in the 1960s and works on improving rice breeding, was critical of N.T. Uphoff's predictions. "The claims are grossly exaggerated", stated Achim Dobermann of IRRI; he declared fewer farmers used SRI than advertised because old practices often were counted as part of the trend and the method was not followed completely. But Vernon W. Ruttan, an agricultural economist at the University of Minnesota and a long-time member of the US National Academy of Sciences, once worked for IRRI and doubted the SRI prospects. He now stated that the method was already reshaping rice cultivation. "I doubt it will be as great as the green revolution", he stated," but in some areas it is already having a substantial impact" (Broad, 2008).

In Tamil Nadu, a State in southern India, Veerapandi S. Arumugam, the agriculture minister, hailed SRI as "revolutionizing" paddy farming, while spreading to "a staggering" 400,000 hectares. In Laos, an agriculture official stated SRI had doubled the size of rice crops in three provinces and would spread to the whole country because it provided higher yields with fewer resources (Broad, 2008).

In 1990, Charles F. Feeney, a Cornell University alumnus and philanthropist who made billions of dollars in duty-free shops, gave Cornell US$15 million to initiate a programme on world hunger. N.T. Uphoff was director of that programme for 15 years and he traveled to Madagascar in late 1993; slash-and-burn rice farming was destroying the forests and N.T. Uphoff sought alternatives. He heard that a French Jesuit priest Father Henri de Laulanié, had developed a higher-yielding rice cultivation method in Madagascar that he called the System of Rice Intensification. Rice farmers typically harvested 2 tons per hectare, while with the new method the

yield could rise to 5 to 15 tons per hectare. N.T. Uphoff oversaw field trials for three years, and the farmers harvested an average of 8 tons per hectare. Impressed, he featured SRI on the cover of his annual reports for 1996 and 1997, and in 1998 he began promoting it beyond Madagascar. Slowly, it caught on, but it was criticized by skeptics. In 2006, three of N.T. Uphoff's colleagues at Cornell University wrote an analysis based on global data. They stated: "we find no evidence that SRI fundamentally changes the physiological yield potential of rice". N.T. Uphoff still believed that he had pioneered an efficient system to increase rice yields (Broad, 2008).

Perennial wheat and crops

In cereal agriculture, erosion is a big problem. Scientists estimate that an average of 26 tons of soil is lost per hectare per year to water erosion, and high winds can take 110 tons of top soil from a hectare of bare wheat field in just 24 hours. Henceforth, the quest around the world to perennialize sorghum, wheat, and even chickpeas and sunflowers. This has taken a new urgency for a variety of reasons, like climate change and soil loss. For instance, the Land Institute in Salina, Kansas, USA, is in the process of breeding a mix of perennial crops, such as wheat, sunflowers and sorghum (Robbins, 2007).

The search for perennial wheat began in 1997 at Washington State University by Stephen Jones, a geneticist with a major question: what are the genetics which govern a plant's annual nature? He replied that "it is only a single gene that convinces a plant not to die". A successful perennial wheat not only has to live, but it has also to enter a dormant cycle in the fall and then return to life in the spring; it has to look like annual wheat, have a satisfactory yield and thresh cleanly. S. Jones and his graduate students overrode the "death" gene in the late 1990s through old-fashioned breeding techniques that crossed wheat with wild grass – not genetic engineering –, but it takes several years (Robbins, 2007).

In Australia, researchers carry out a well-financed project to breed a perennial wheat to reduce salinity in annual wheat fields. In Texas and Oklahoma, breeders are working on perennial wheat as a crop and for grazing cattle. In countries where farming is terraced, farmers want perennial wheat to control erosion. Because it also needs less plowing and planting, farmers in eastern Washington State estimated it would lower their fuel costs by 75%. Seed costs would also fall. Annual wheat needs help from herbicides to ward off weeds, because it cannot compete with them, and is less naturally pest resistant (Robbins, 2007).

In eastern Washington State, thanks to the soil accumulated since the large-scale outburst flooding from Glacial Lake Missoula, about 12,000 years ago, and cool nights, Whitman county is the richest wheat region in the United States, but the soil (loess) is disappearing. Crops on the ground throughout the year would fix the soil and would also bank substantially more carbon than a field that is plowed every year round. Researchers at the Land Institute, Kansas, estimated annual crops caused the loss of about 40% of the total carbon in the soil. Perennial plants with bigger roots that can absorb water from depth are also more able to survive warmer climates. But researchers are still years away from replacing annual crops with perennial ones, because of the slow nature of such breeding programs. However, research is promising in this important area (Robbins, 2007).

Genetic improvement of crops : a new method of selection

A new tool for the genetic improvement of crops is the Targeting Induced Local Lesions IN Genomes or tilling, a method of reverse genetics that help identify point mutations induced by chemical mutagenesis or naturally existing in the germoplasm (ecotilling). This method of selection is applied to mutations induced by ethylmethane sulfonate (EMS), a mutagenic compound that can alter a single nucleotide. A. Bendahmane (2008) has been able to select populations of EMS mutants for melon, pea and tomato. For each plant species, agronomic traits are selected, such as fruit quality, higher biomass, disease resistance or modification of sexual organs so as to facilitate hybridization (e.g. creation of hermaphrodite melons).

This research work is being carried out at the French National Agricultural Research Institute (INRA) unit of plant genomics research, headed by A. Bendahmane. Research focused on the cloning of loci that control the tolerance or resistance to biotic and abiotic stresses, as well as the development stages of the plants studied. Thus, the Vat locus in melon confers resistance to *Aphis gossypii* and plants that express the transgene of this locus are not attracted by this insect. The Pmv locus, also in melon, induces resistance to the fungus *Sphaerotheca fulginea*. The Pmv locus is allelic to Vat, the proteins encoded by Pmv and Vat differing by a single deletion and three substitutions of amino-acids.

Male-sterility in radish is due to an altered mitochondrial gene (*Orf 138*) which prevents pollen production without altering female fertility. Nuclear gene *Rfo* restores male fertility through modifying the expression of

gene *Orf 138*. The expression of *Rfo* through transgenesis in male-sterile radishes confers male fertility.

In peppers, locus pvr2 confers a recessive resistance to potyviruses (family of potato Y virus). Resistance is due to two point mutations that prevent the interaction between the viruses and the plant.

In melon, sexual expression depends on two genes A and G. Both A and G loci have been cloned and the analyses of their sequences would lead to a better understanding of how allele combinations determine the sex of the plant (Bendahmane, 2008).

Raising maximum yield potential

In rice, maize and wheat, research on plant architecture, hybridization and wider genetic resource utilization is being pursued to increase maximum yield potential. New types of "super rice" with fewer, but highly productive, tillers are being developed in Asia. The International Rice Research Institute (IRRI, Los Banos Philippines) claimed that this new plant type, in association with direct seeding, could increase rice yield potential by 20% to 25%. Similar new wheat plant, with fewer tillers, larger heads, more grains, could lead to an increase in yield potential of 10% to 15% above the best current varieties (Borlaug and Dowswell, 2008).

The success of hybrid rice in China (now covering over 60% of the irrigated area) has led to renewed interest in hybrid wheat. Improvements in chemical hybridizing agents, advances in plant biotechnology and the development of new wheat plant type made a reassessment of hybrids worthwhile. With better heterosis and increased grain filling, the yield frontier of wheat could be raised by 25% to 30% (Borlaug and Dowswell, 2008).

In Malaysia, one of the new corporations stepping into hybrid rice production is the conglomerate Sime Darby. While it is traditionally focused on oil-palm plantations, Sime Darby set up a Malaysian joint venture with the global supermarket company Tesco and was seeking vertically integrated contract farming schemes to supply Tesco in Malaysia and beyond. The Malaysian government entrusted Sime Darby with the task to design an economic development "master plan" for the northern part of the country. This plan included a multimillion-dollar seed centre, partly financed by the government, that would be under

the company's control. The centre was expected to focus on developing higher-yielding varieties for ten cash crops, including rice. In line with this latter aspect, Sime Darby signed a research-and-development agreement with the Chinese Academy of Agricultural Sciences for the transfer of germplasm and their biotechnology know-how. Nestlé was also involved in the plans, through a joint venture to develop and grow red rice in the Malaysian northern State of Kedah (*Seedling*, April 2008, p. 29).

In maize, most of the yield gains have been obtained by breeding plants that can withstand higher plant densities, and by shifting to single-cross hybrids. However, in most regions, large gaps exist between experimental and smallholder farmer yields throughout the developing world, especially in Africa (Borlaug and Dowswell, 2008).

Transgenic crops (1996-2008): a biotechnology approach to double food, feed and fiber production by 2050

In 2008, Wen Jiabao, China's prime minister, stated that "to solve the food problem we have to rely on big science and technology measures, rely on biotechnology, rely on genetically modified crops." Also in 2008, W. Rutto, Kenya's agriculture minister, declared: "biotechnology offers Africa an opportunity to increase food security" (James, 2008).

These statements meant that conventional crop improvement alone could not double agrifood production by 2050. While recognizing that biotechnology and genetically modified crops are not a panacea, they can offer another approach to double this production sustainably by 2050 on 1.5 billion hectares of cropland worldwide. Indeed, a successful strategy to reach that goal should rely on agronomy, improved food systems, the recognition of key priority to agriculture on the political national agendas, and crop improvement that integrates the best of conventional methods and biotechnology to optimize productivity and contribute to food, feed and fiber security.

Extension and global impact

In 2008, 25 countries have adopted genetically modified crops; the global area was 125.0 million hectares, representing an increase of 9.4% over 2007, equivalent of 10.7 million hectares**.** The United States grew these crops on 62.5 million hectares, Argentina on 21.0 million hectares, Brazil on 15.8 million hectares, India on 7.6 million hectares, Canada on 7.6 million hectares, China on 3.8 million hectares, Paraguay on 2.7 million hectares, South Africa on 1.8 million hectares, Uruguay on 0.7 million

hectares, Bolivia on 0.6 million hectares, Philippines on 400,000 hectares, Australia on 200,000 hectares, Mexico on 100,000 hectares and Spain on 100,000 hectares (James, 2008).

In 2008, three new countries cultivated these crops: Burkina Faso, Egypt and Bolivia. About 13.3 million farmers grew these crops, including 12.3 million (90%) smallholder and resource-poor farmers. In ten countries, 27 million hectares were planted with crop species having stacked traits, i.e. herbicide-tolerance and pest-resistance traits, and root-worm resistance (in the case of maize). A new genetically sugar-beet variety (tolerant to glyphosate or Roundup Ready sugar-beet) was grown in Canada and the United States (James, 2009).

In 2009, Mexico's president signed a decree that authorized experimental cultivation of transgenic maize (except in agrobiodiversity-rich areas of this crop species). This would pave the ground to large-scale farming of herbicide-tolerant and pest-resistant maize in a country that imports about 10 million tons of maize from the United States (part of it being transgenic).

The global impact of genetically modified (GM) crops has been in 2007-2008:
- an increase in food, feed and fiber production, estimated at 32 million tons;
- economic benefits evaluated at US$10 billion (US$6 billion in developing and US$4 billion in industrial countries); farm income gains of US$44 billion from 1996 to 2007 were distributed as follows: 56% was due to cost reduction and 44% was due to production gains of 141 million tons;
- reduction need for external inputs, saving of 359,000 tons of pesticides;
- conservation of soil and water through no- or minimum tillage associated with transgenic seeds; and saving 14 billion kg of CO_2;
- protection of forests and biological diversity, because the production gains of 141 million tons for the period 1996-2007 would have required (at 2007 average yields) an additional 43 million hectares had GM crops not been grown (James, 2008).

Brookes and Barfoot (2008), researchers at PG Economics Ltd, United Kingdom, have published a detailed study on the socio-economic and environmental impact of genetically modified (GM) crops in rich and poor countries over the period 1996-2006. Their main conclusions were that :

- the cultivation of the four crops (maize, soybeans, canola and cotton) resulted in a supplementry income of US$6,941 million in 2006 for

farmers and in an additional US$33,770 million over 11 years; that corresponded in 2006 to 6.2% of the whole income provided by the cultivation of the four crops and to 3.8% of total income of the farmers concerned;
- glyphosate-tolerant soybeans was the first crop, folowed by pest-resistant cotton;
- the three countries that benefited most were the United States, Argentina and China, followed by Brazil, India and Canada; in the United States, according to the Economic Research Service of the Department of Agriculture (USDA), in 2009, the rates of adoption by farmers of GM soybeans, cotton and maize were 91%, 88% and 85%, respectively;
- the developing countries benefited a little more from the cultivation of GM crops than developed ones in 2006 : US$3,713 million compared with US$3,228 million;
- the cultivation of the four GM crops altogether have resulted in the use of less biocides (insecticides and herbicides) – 285,700 tons less over the 11 years, which corresponded to -15.4% in weight and -7.9% of active compounds of total pesticides used on equivalent areas;
- the environmental impact quotient (EIQ) has been lowered markedly by the cultivation of GM crops (the environmental impact has been mainly studied in the case of soybeans because of the wide cropping areas, and in that of cotton because of the heavy use of insecticides needed by this crop);
- the lesser use of biocides over 11 years has been higher in developing countries (52%) than in developed ones;
- the cultivation of the four GM crops has reduced the annual production of greenhouse-effect gases (equivalent to the emissions of 6.56 million cars over the same period); these gases include cabon dioxide produced by less numerous tractors due to the lower mumber of pesticide spraying and to no-tillage farming along with the use of glyphosate.

Forecasts

During the period 2007-2015, the forecasts are the following :
- more crops and traits are to be used by more farmers and countries;
- transgenic rice will become the main genetically modified crop as it concerns 255 million rice households;
- drought tolerance will be the focus of research and advanced breeding, varieties of drought-tolerant maize being available commercially as of 2012;
- quality traits will also be transferred, such as in “golden” rice

(containing beta-carotene or provitamin A), "golden" potato, or cereals enriched with essential amino-acids (high-lysine), oilseeds and vegetable oils enriched with unsaturated fatty acids (soybean and palm oils) and omega-3 fatty acids;
- more transgenic crops will be developed by countries from the South (India has developed and cultivated its own transgenic cotton varieties in 2008-2009) and there will be more South-South cooperation;
- marker-assisted selection (MAS), combined with transgenesis in crops, will "speed the breeding", in order to provide a faster response to more severe and rapid changes in climate change (James, 2008).

Clive James (2009) forecasts that in 2015 the number of countries growing genetically modified crops would rise to about 40 (compared with 22 in 2006); the number of farmers cultivating them would increase to reach 20 million or more (compared with 10 million in 2006); and the global area of these crops would amount to about 250 million hectares (compared with 100 million hectares in 2006).

According to the OECD report, *The Bioeconomy to 2030. Designing a policy agenda*, published in 2009 after a meeting of experts from 18 countries was held in 2008, "in 2015, about half of the global production of agricultural foodstuffs would be derived from plant varieties developed through biotechnology". The authors of the report consider that it would help overcome the current debate on the prohibition of GMOs, and would lead to a new approach to legal regulation, intellectual property rights and to setting up political priorities at global level. The report highlights two specific characteristics of the biotechnological sector : on the one hand, the strict administrative control of the main agricultural biotechnological applications, that permits to have a reliable perception of market evolution in the next five to seven years; on the other, the fact that biotechnologies are being used in the production of a wide range of products such as plastics, fuels or seeds, means that future innovative research has a solid base.

Biotechnology would contribute a 50% to agricultural harvests. This result will be added to the inputs of biotechnology to health and industry, and would end up in 2030 in a 2.7% share of the OECD's GDP. Such a percentage could be higher in those developing countries which are not members of the OECD and whose economy depends, to a large extent, on agriculture.

Acceptance and regulatory issues

Acceptance issues relating to genetically modified crops are:

- food safety (despite claims by environmental groups, it has not been proved by independent assessment bodies that foodstuffs derived from transgenic crops are unsafe for human and animal health; any transgenic crop is submitted to a risk-assessment process, including safety tests for health, before being grown commercially);
- environmental impact (risk assessment of transgenic crops, particularly in field trials, include the study of gene flow and the impact on biological diversity, the effect on non-target organisms, the coexistence with non-transgenic or conventional crops, the monitoring of fields cultivated with genetically modified crops during the period of authorization, generally 10 years); this is done through a case-by-case approach, and up to now adventitious genetic combination has been shown for some crops, like oilseed-rape, and measures have been recommended to avoid pollen recombination between transgenic crops and conventional ones and/or wild relatives; the durability of pest resistance acquired through the transfer of genes encoding *Bacillus thuringiensis (Bt)* enterotoxins is a challenge and research is being carried out to counter it, if it appears despite the current measures being applied in the field;
- ownership of the technology (dominance of the private sector, although the public sector plays an important role, e.g. in India in developing local transgenic cotton varieties); the very high cost of developing a transgenic variety and of winning its approval by regulatory bodies makes it difficult for the public sector, especially in developing countries, to play a dominant role; that is why many experts call for less overregulation; the public sector, e.g. national agricultural research systems have played and are playing an important role in basic research and in the development stages at laboratory and greenhouse level, and in developing new technologies;
- ethical aspects (the right to food, especially for the poor, should be taken into consideration when deciding about who should pay royalties to the companies owning patents or rights concerning transgenic crops; as it was decided for anti-HIV/AIDS drugs delivered to poor countries, royalties should be waived for smallholder poor-resource farmers, e.g. "golden" rice seeds would be sold to poor farmers at a lower price, when their annual income is under a threshold of about US$10,000);
- impact on international trade (Sasson, 2006, 2008; James, 2008).

In February 2009, when the report of the International Service for the Acquisition of Agri-Biotech Applications (ISAAA) and authored by Clive

James was published, the environmental association Friends of the Earth questioned the validity of the figures relating to the increase in the area of the transgenic crops in Europe. Instead of a 21% increase in 2008 compared with 2007, the association underlined that the ISAAA report excluded France from its calculation; the moratorium adopted by France in 2008 regarding the cultivation of transgenic maize variety MON 810 (produced by Monsanto corporation) had reduced the area of transgenic crops in Europe by 50,000 hectares approximately; therefore, instead of 21% increase in 2008, the area decreased by 2%. In addition, Friends of the Earth stated that in 2008, the area of transgenic crops in India had been overestimated by about 400,000 hectares. The global increase of 9.4% in 2008 is less than that of 2007 (12%), and 2006 (13%), or 2001 (19%). Friends of the Earth published a report *Who benefits from GM crops?*, in which it estimated that 80% of transgenic crops were grown in three countries, the United States, Argentina and Brazil (Kempf, 2009).

Such controversy on figures and growth rates cannot hide the fact that genetically modified crops are a reality, that an increasing number of countries and farmers will adopt them, following a very rigorous regulation, and that the ISAAA is promoting a pro-choice approach, i.e. that countries can choose this technology or not, but should understand all the pros and cons, and particularly the implications of not choosing it for their agrifood production.

Regarding the issue that the majority of transgenic crops are devoted to fiber and textile production (cotton), feed (maize and soybeans), or industry, it should be underlined that in India, for instance, the doubling of the cotton harvest provides an income to farmers who can buy food and spend less time in the cotton fields, thus devoting part of their time to other productive tasks. On the other hand, it is true that transgenic seeds are more costly than conventional ones**,** but as the yields are higher and inputs of biocides are lesser, the overall income is positive. For instance, in Spain which is the European country that cultivates the largest area of transgenic maize (100,000 hectares), seeds cost between €30 and €35 per hectare, but the yield is 700 kg to 1,000 kg higher; the farmers' overall income is therefore higher (Benito, 2009).

In Australia, the agriculture minister of the State of New South Wales, Ian Macdonald, stated that the adoption of genetically modified crops had reduced the countries' dependence on pesticide use. The use of transgenic cotton within an integrated pest control strategy has resulted in a 90% reduction of endosulfan in cotton cultivation in Australia. This pesticide

is considered as highly toxic; for instance, New Zealand prohibited its use in December 2008 and 50 other countries did the same, due to the possible relationship between endosulfan and the occurrence of breast cancer and disturbances of the central nervous system (Benito, 2009).

The reduction in the use of pesticides not only prevents health hazards but also makes cultivation less costly, as is also the case of the decrease in fertilizer use. For instance, in the United States harvests have rised 70% in 12 years, but this did not entail a 30% increase in the use of nitrogen fertilizers, which can contaminate water tables and underground water (Benito, 2009).

With respect to regulation of transgenic crops and their coexistence with conventional ones, measures are taken to separate them, taking account of the distances travelled by pollen grains and the persistence of their fertility power, or to change the periods of sowing. These measures are generally very effective, but should evolve with the knowledge base. Organic farmers argue about the threshold of adventitious contamination of their crops that may lose their "bio" label; on the other hand, a close to 0% contamination is quite impossible to reach. In Spain, for instance, of the 3,000 legal disputes that are processed annually by the chambers of agriculture there was none about transgenic maize impact on conventional crops (Benito, 2009).

Scientists from the Institute for Agri-Food Research and Technology (IRTA, Barcelona) have concluded that *Bt* maize, resistant to the stem-borer, showed an average increase in production of 7.3%, equivalent to 1,055 kg per hectare. In four trials conducted in 2004 and 2005 in the regions of Lleida and Girona, when the stem-borer causes serious losses, significant differences in yields were observed between conventional and *Bt* maize varieties. In addition, *Bt* maize varieties contained less mycotoxins (-83%) than conventional ones.

In natural cultivation conditions, IRTA researchers concluded that a distance of between 15 and 20 meters (a zone cultivated with non-transgenic maize varieties) was sufficient to prevent the presence of GM0s (under 0.9% – the threshold fixed by the European Commission) in the adjacent conventional fields. IRTA researchers are also pursuing their investigations on crop coexistence, so as to better control gene flow through the reduction of flowering coincidence of GM and non-GM plants. Although provisional results show that a three-week difference in sowing seeds early results in a flowering lag of three days, while in the case of late sowing the lag is of 10 days, sufficient to minimize gene flow.

Regulation processes are not less rigorous in developing countries than in industrial ones, contrary to some critics of transgenic crops. The latter should be tested and their risks assessed in the country where they are to be used (unlike medicines that could be submitted to clinical trials in one country and once approved, they can be used in all countries). For instance, in 2009, Monsanto was testing a soybean variety that is resistant to an insect pest because this is a tropical insect. Regulation in Brazil is even tougher than that of the United States, and to commercialize the seeds of the transgenic insect-resistant variety, not only one country should approve it, but also others. In that case, China, Taiwan and South Korea should do so. In these countries, regulation bodies are independent, and this is important because exporters need to know where they can sell their products (Benito 2009).

Controversy about regulation of transgenic crops in Europe

The European Union's member States are generally opposed to the consumption of foodstuffs derived from genetically modified crops and consequently these crops are not cultivated or on small areas (with the exception of Spain which cultivates a transgenic *Bt* maize variety for feed on about 100,000 hectares). Nevertheless, the European Commission has authorized the cultivation of GM crops after the approval delivered by the Parma-based European Food Safety Agency (EFSA). Member States should follow the decision of the European Commission except when they consider that the approved GM crop could threaten human health or pose serious risks for the environment. The current system of approval of GM crops by the European Commission – generally considered favourable to the cultivation of these crops – has been criticized. On 4 December 2008, the European council of environment ministers has requested a thorough revision of this system. The council underlined the need of a "detailed evaluation of the long-term impacts of GM crops on the environment" and has also stressed that "member States and the Commission should make sure that potential risks (…) are examined through systematic and independent investigation" (Le Hir, 2009a).

An illustration of this controversial situation is the non-approval by some member States of the *Bt* maize variety MON 810, the cultivation of which was nevertheless approved by the European Commission. In April 2009, after Austria, Hungary, France, Greece and Luxembourg, Germany was the sixth member State of the European Union to suspend the cultivation of MON 810 on its territory (4,000 hectares had been cultivated in 2008). On Tuesday 14 April 2009, the German agriculture minister, Ilse Aigner, argued that this GM maize variety might be dangerous for the

environment in order to justify her decision. Wolfgang Köhler, in charge of biotechnology in the agriculture ministry, cited "two new studies" that showed the negative impact of this maize variety on non-target insects such as certain species of butterflies and ladybugs. Other experts argued that these studies were not relevant because ladybugs are Coleopteran insects that are not sensitive to the *Bt* toxin produced by MON 810. In addition, former studies on monarch butterflies have shown that in natural conditions their larvae are not in contact with *Bt* maize in the United States and feed on milkweed (while in laboratory conditions they were fed with *Bt* maize pollen). In February 2009, Stephen Rauschen of Aachen University and in charge of testing for the ministry of education and research whether *Bt* maize varieties were safe, stated he was against the intention of the agriculture minister to prohibit MON 810. On 20 February 2009, in an open letter to the minister, S. Rauschen wrote that "nothing in our research work indicates the GM maize variety MON 810 carries a risk for the environment higher than, or different from, that of conventional varieties. By contrast, the cultivation of MON 810 has a lesser environmental impact than chemical insecticides used to control parasitic caterpillars of maize (Mennessier, 2009).

"The same scenario occured in France in 2008 with the report by Le Maho", stated Jean Bizet, a French senator who supports agricultural biotechnology. In Austria, a study on the impact of transgenic maize on the reproduction of mice has been invalidated by experts. The French senator made a strong plea for a more rigorous scientific approach when approving or not the cultivation of GM crops (Mennessier, 2009). See also Le Hir (2009b).

That is the purpose of the new French High Council for Biotechnologies, that was created by the 25 June 2008 law on GM0s and which started its work on 12 May 2009. It is chaired for five years by Catherine Bréchignac, president of the National Scientific Research Center (CNRS). The High Council is composed of 63 members (selected among 75 persons who applied for the job, with a view to achieving a wide multidisciplinarity) distributed in two committees. The scientific committee, chaired by Jean-Christophe Pagès, a molecular biologist and biochemist, comprises 34 specialists in genetics, molecular biology, microbiology, human and animal heath, agronomy, environment, statistics, law, economics and sociology. The economic, ethical and social committee chaired by Christine Noiville, a law specialist, comprises 26 representatives of associations for environment protection, consumers' associations, agricultural professional associations, agrifood, seed and pharmaceutical industries, trade-unions of these enterprises, as well as well as parliamentarians and

locally elected persons. The High Council has a budget of €1 million devoted to studies and running costs (Le Hir 2009b).

The High Council's chairperson underlined that the synergy between both committees of the council, i.e. between scientists and representatives of the social and economic arena, will be a very innovative approach. Christine Noiville went even further: "scientific evaluation of GMOs is indispensible, but is not sufficient. A risk should be put in its context, in order to see if it is worth taking it or not. Some risks are worth it, others, even minimal, are not". The minister of sustainable development, who qualified the High Council as unique in Europe on 22 April 2009, when he presented it to the public underlined that "it will work in total independence versus scientific groups, laboratories, governments or industrial companies". C. Bréchignac added that "we shall make sure that we are not submitted to the lobbying pressure of biotechnology industries, but that we shall not hinder them" (Le Hir, 2009b).

The High Council is placed under the aegis of the ministers of sustainable development (and ecology), agriculture, research and economy. It can receive and study requests from parliamentarians, associations and professional groups, but it can also decide to review specific topics. Its field of competence includes not only GMOs, but also veterinary medicines and gene therapy assays. The first subject to be treated by the High Council is that of the freedom to produce and consume GMOs or not. This subject is considered urgent by the network of associations for environment protection within "France Nature Environment" (Le Hir, 2009b).

The minister of sustainable development also wished that the High Council for Biotechnologies could make proposals to the European Commission regarding the changes that, in his view, were needed in the European system of approval of genetically modified crops (Le Hir, 2009a,b).

European agrochemical and seed companies, and genetically modified crops

Of the world's top six seed companies, four are European. Syngenta, based in Switzerland, and Bayer CropSciences, based in Germany, both major agrochemical firms, have been involved with genetically modified (GM) crops for almost as long as Monsanto and Dupont, the United States-based agrochemical corporations that dominate GM seed markets. These European companies are the Americans' main competitors (and also allies)

in the countries growing GM crops on a large scale (Argentina, Brazil, Canada and the United States) and together they work for opening GM markets to their seeds (*Seedling*, April 2008, p. 12).

France's Vilmorin and Germany's KWS, the other European seed corporations among the global top six, also sell GM seeds in the major markets through their joint venture, Ag Reliant. These firms have yet to commercialize their own GM traits, choosing instead to license the patented transgenes of the bigger agrochemical companies for incorporating them into their lines. They try to catch up with the giant agrochemical companies that control the first generation of GM crops (*Seedling*, April 2008, p. 12).

Vilmorin, which is controlled by the Limagrain Group – a seed cooperative founded in France (Puy-de-Dôme) – invested heavily in the 1990s and early 21st century in various European biotechnology programmes and companies, i.e. Biogemma, a firm in which Limagrain has a 55% equity. But, frustrated by what they see as an unhospitable environment for GM crops, both Limagrain and Vilmorin are shifting more and more their GM research and field trials outside Europe. Thus, while a new law on GMOs was adopted by the French parliament on 22 May 2008 and aimed at translating in France the 2001 European directive, Limagrain announced that it did not intend to implement field trials on transgenic maize in 2008 in France. Limagrain's director-general, Daniel Chéron, stated : "To work correctly, we ought to be convinced that our field trials will not be destroyed, that the authorizations will be delivered on time and that the commitments on our side will be acceptable" … "Today, we are not confident". The French agriculture ministry did underline that there was no intention on the part of the government to stop research, including field trials, and indicated that a temporary committee was created on 21 March 2008 to authorize these trials for 2008 (it was to be replaced by the High Council for Biotechnologies). According to the data provided by the agriculture ministry, about a dozen field trials had been authorized for 2008.

Limagrain has pursued its research work; in particular Biogemma is carrying out trials in Israel, and above all in the United States, as stated by its director-general, Pascual Perez. Daniel Chéron commented that France and Europe were lagging behind in biotechnologies. As an example, Limagrain's first GM maize variety would not be available before another five years, and several years will be needed to obtain the necessary anthorizations for marketing it. While Monsanto has based its market predominance on herbicide (Roundup) tolerance and insect

resistance of GM crops, Limagrain has focused on drought tolerance and yield improvement.

Vilmorin's long-term planning is now oriented towards Asia, where the company expects more market potential for GM crops. In 2006, with the French food corporation Danone, it signed a deal with the Indian biotechnology firm Avesthagen, giving Vilmorin 4.3% of the shares of the company and setting up two holding companies in India to make acquisitions. Shortly after, the Avesthagen joint venture purchased two Indian seed companies: Swagasth, which focuses on cereals, and Ceekay, a vegetable seed company. In November 2007, the companies announced they were in the final stages of negotiations to take one of India's top private seed companies for US$4-5 million (*Seedling*, April 2008, p. 12).

Vilmorin was equally active in China. In June 2007, it struck a deal to take a 46.5% stake in Yuan Longping High-tech Agriculture, a leading Chinese hybrid rice and vegetable seed company. This followed another deal struck by Vilmorin's Dutch joint venture, KeyGene, with the Shanghai Institute for Biological Sciences to set up a joint Lab for Plant Molecular breeding. This deal occurred at the same time as others made by various European seed companies in China, including Bayer's two joint hybrid rice seed ventures and Syngenta's purchase of a 49% stake in Sanbei, reportedly the 12th-biggest seed company in China, as well as its signing of a five-year research collaboration with the Institute of Genetics and Developmental Biology in Beijing. Also BASF, another major European seed and pesticide firm, signed a collaboration agreement with China's National Institute of Biological Sciences in 2008. Hans Kast, president of BASF Plant Science, stated : "Asia is emerging as a key player in plant biotechnology in both research and cultivation, and we are striving to intensify partnerships in this dynamic region. Europe, on the contrary, is losing its competitivness due to slow and contradictory political decisions" (*Seedling*, April 2008, p. 12).

This opinion was also shared by Alain Veil, adviser at the French Centre for International Cooperation on Agricultural Research (CIRAD), who stated : "When there are less private partners, the whole research is suffering"… "France is losing ground in the area of plant innovation". In addition, French expertise may be less present or relevant when it would be necessary to authorize or not the cultivation of GM crop varieties developed in the United States.

Progress in genetic transformation of crops

Genetic traits transferred

In 1996, for the first time, a gene was transferred to a maize plant, in order to make it tolerant to a herbicide (e.g. glyphosate) or resistant to an insect pest (the gene encodes the synthesis of one of several entomotoxic proteins of the soil ubiquitous *Bacillus thuringiensis* or *Bt*). In 2008, three genes could be transferred to the same plant in order to confer herbicide tolerance, insect pest and rootworm disease resistance. By mid-2009, Monsanto and Dow Chemical received the authorization to cultivate the transgenic maize variety SmartStax in 2010, from the US Environment Protection Agency (EPA) and Canada's Food inspection Agency. This maize variety contains eight transferred genes that make the plant tolerant to herbicides (Roundup Ready 2 and Liberty Link technologies), resistant to insect pests (technologies Herculex I and VT-PRO, the latter protecting against two Lepidopteran insects), and to pests living in the soil (technologies Yield GardVT Rootworm/RR2 and Herculex RW). SmartStax was expected to raise the yield of maize by 3% to 6% thanks to the reduction of refuge areas, i.e. areas planted with non-transgenic maize in order to trap insect pests and lower the likelihood of development of resistance among these pests). An additional incremental yield of 2% to 4% will be obtained thanks to a better control of rootworms and other pests.

A longer-term objective is to transfer 20 genes into the same maize plant. Traits to be transferred into crops include agronomic ones, such as resistance to viral, bacterial and fungal diseases, as well as to insect pests, tolerance to heavy metals and to a wider range of herbicides, and above all to drought. Crops that can tolerate drought and water stress (and also salinization of soils) are the focus of priority research carried out by both public and private institutions. For the first time, a drought-tolerant transgenic maize variety will be commercialized in 2012 by Monsanto, thanks to a close cooperation between the US agrochemical corporation, the Bill and Melinda Gates Foundation and the International Maize and Wheat Improvement Center (CIMMYT, Mexico); see below.

In Nigeria, the International Institute of Tropical Agriculture (IITA, Ibadan) has developed in 2008 a new transgenic variety of cassava, named TMS92/0067, that is well adapted to arid zones, resistant to pests and higher-yielding.

By mid-April 2006, DuPont, which owns the seed company Pioneer Hi-Bred International, and the Swiss corporation Syngenta became equal partners in GreenLeaf Genetics – a Syngenta venture that licenses conventional and genetically modified varieties to other seed companies in the United States and Canada. Syngenta will also use an experimental genetic engineering technology developed by Pioneer that allows crops to withstand glyphosate, the herbicide sold by Monsanto as Roundup. With both Pioneer and Syngenta offering that new technology, there was a better chance of competing against Monsanto's popular seed technology, Roundup Ready (Pollack, 2006).

While Monsanto accounts for the vast majority of transgenic crops planted in the world, Pioneer and Syngenta license the Roundup Ready technology to impart glyphosate resistance to their own crop varieties. Developing their own herbicide-resistance technology would not only give them entry into a lucrative market, but also relieve them from paying licensing fees to Monsanto. In fact, Pioneer's executives stated soybean seeds using its new proprietary technology would be ready for sale in 2009. The technology is called optimum GAT, standing for "Glyphosate ALS Tolerant". Crops transformed thanks to Optimum GAT would be even more resistant to glyphosate than Roundup Ready crops, and would also be resistant to another widely used class of weed killers that use the so-called ALS chemistry, i.e. the inhibition of acetolactate synthase, a plant enzyme that the weed killers inhibit (Pollack, 2006).

In return for allowing Syngenta to use Optimum GAT technology, Pioneer obtains a license to insect-resistant genes from Syngenta. It now sells seeds of insect-resistant maize developed in partnership with Dow Chemical. The move marks a departure for Pioneer, which is proud of its long history as a maize breeder and until now has sold seeds under its own name. But Monsanto has been gaining market share in maize seeds at Pioneer's expense, in part by licensing Monsanto's herbicide-tolerance and insect-resistance crop genes to other seed companies. Pioneer's executives stated that they would continue to sell their premium brands under the company's own name, but they also claimed that there were more non-premium varieties just sitting on the shelf that could be licensed to others, allowing Pioneer to expand into 40% of the market that does not purchase premium seeds. Other seed companies would be able to cross lines provided by Pioneer to create new varieties, and seed retailers could sell Pioneer varieties, under their own brands (Pollack, 2006).

Robb Fraley, chief technology officer for Monsanto, stated it was too early to judge the effectiveness of the Optimum GAT technology or the impact

of the new joint venture. “In the end,” he said, “it’s going to come down to who has the best product in the market place” (Pollack, 2006).

Other traits to be transferred into crops aim at making more nutritious foodstuffs derived from them, i.e. crops richer in beta-carotene or provitamin A, essential amino-acids, unsaturated fatty acids, anti-oxidants. This second wave of transgenic crops will hit the world market during the decade 2010-2020.

Finally, food or non-food crops will be used to produce biopharmaceuticals more rapidly and safely, e.g. enzymes, medically active proteins, monoclonal antibodies, vaccine subunits. This third wave of transgenic crops which has already given rise to some products (e.g. a vaccine against Newcastle virus disease, a major threat to poultry, that has been produced in tobacco plants; glucocerebrosidase, an enzyme that is active against a rare monogenic disease, Gaucher disease, also produced in tobacco plants; a gastric lipase, produced in maize plants experimentally, that helps treating children suffering from cystic fibrosis).

The US company Ventria Bioscience announced in May 2006 that it had been able to cultivate a transgenic rice variety that produced lactoferrin and a lysozyme. Both human proteins extracted from the transgenic rice could be used in rehydration solutions to control infant diarrhoea. This new rice has been grown on only 135 hectares in North California, two other US States having refused to welcome the company’s field trials. Ventria Bioscience also mentioned a study carried out in Peru (Lima) on 135 children and showing that the ingestion of lactoferrin and lysozyme could reduce by 30% diarrhoeal episodes as well as the risks of relapse, compared with the usual rehydration solutions, not including maternal milk. US consumers’ associations have voiced their reluctance to accept this nutraceutical rice, because the start-up may not follow the regulations on commercialization that apply to evaluating the benefits and hazards of biologically active compounds.

Scientists at the Plant and Food Research Institute of New Zealand have developed a transgenic tobacco variety with a high content of methylselenocystein (MSC), further to the introduction of the gene encoding the enzyme needed to synthesize MSC. The content of selenium has doubled or even quadrupled, and there was no toxic effect on plant growth. Selenium is suspected to strengthen the immune system and could improve the efficiency of chemotherapy treatments and reduce their toxicity. In laboratory animals, MSC has shown a strong anticarcinogenic effect on cancer cell lines, and it has been the most

effective anticarcinogenic compound based on selenium against breast cancer. Consequently, the increase of MSC in some well chosen plants, such as potato, tomato, egg plant and pepper, may become an efficient way of producing MSC.

Control of viral diseases

The rice yellow mottle virus (RYMV) which causes heavy losses of the rice harvest in Africa, was identified for the first time in 1966 in Kenya. Thereafter its presence has been reported in most rice-growing countries of Africa. The disease is characterized by the appearance of yellow stripes on the leaves, followed by necrosis. The fertility and development of grains are seriously affected. Transmission of RYMV is done by insects or by simple contact between the plants. The only hope to control the disease is through the selection of virus-resistant varieties (Albar et al., 2006).

It has been shown that very few varieties of *Oryza sativa* (Asia) and *O. glaberrima* (Africa) do not present the foliar symptoms of the disease and their yields are unaffected. However, these resistant varieties lack the agronomic traits needed for intensive irrigated rice cultivation or for growth in low-lying areas where the disease causes heavy losses. A gene for resistance to the virus has been located on a fragment of chromosome 4. On the basis of rice genomics, the gene Rymv1 seemed to be the best candidate for resistance. This quality was thereafter demonstrated through genetic engineering: a line of resistant rice has been transformed through the introduction of the sensitive allele of that gene; the offspring of transformed plants are sensitive to the disease and contain the transgene.

The virus has a small genome coding for a few proteins (five in the case of RYMV); it therefore needs host proteins to perform the infectious cycle. One of the proteins needed seems to be that coded by the gene Rymv1, involved in the translation of viral proteins and eventually in other processes such as the movement of the virus within the plant cell. The French researchers at the Research Institute for Development (IRD) have identified mutations of the gene located in the same region and analyzed them in three distinct resistant varieties. It seems that in the latter, the mutation does not alter the role of the protein with regard to its basic functions, but could inhibit its interaction with the virus that is blocked in one of its infectious cycle stages (Albar et al., 2006).

Another strategy for controlling the disease has been developed by the IRD's scientists, i.e. introducing into the plant genome part of the virus

genes, so as to induce resistance to the RYMV. The results showed that transgenic plants had a partial and short-lasting resistance and they could even become more sensitive. It therefore seems that the introduction of a virus gene through transgenesis is not more effective than the use of natural resistance. In fact, IRD's scientists have been able to transfer the Rymv1 gene into agronomically important rice varieties through crosses and the resulting lines have been offered to national research institutions (Côte d'Ivoire, Senegal and Madagascar) or international bodies such as the West Africa Rice Development Association (WARDA, Benin), in order to use them in national breeding programmes (Albar et al., 2006).

At the Donald Danforth Plant Science Center, St Louis, Missouri, researchers have discovered that a genetically modified rice produced proteins that mitigated the infection by the rice tungro virus. This disease is caused by the simultaneous infection of two viruses: the bacilliform and spheric tungro viruses, that are both transmitted by a small insect. This viral disease causes annual losses estimated at US$1.5 billion in South and South-East Asia; the countries most affected by the rice tungro viral disease are the Philippines, Vietnam, Bangladesh, Malaysia, Thailand and India.

In the 22 December 2008 issue of the *Proceedings of the National Academy of Sciences* (*PNAS*, USA), scientists of the Donald Danforth Plant Science Center published an article on the way to control the multiplication of the rice tungro virus. Roger N. Beachy, the Center's director, and Shunhong Dai, researcher at the center, showed that transgenic rice lines that overexpressed one of the two proteins RF2a and RF2b – two transcription factors in rice cells, could tolerate infection by the tungro virus. After laboratory experiments and greenhouse tests, the results were confirmed in tests carried out in a greenhouse of the International Rice Research Institute (IRRI, Los Baños, Philipines). RF2a and RF2b are crucial proteins for plant development and play a role in the regulation of the plant defence mechanisms against viral attacks.

The resistant transgenic rice lines will be tested in field trials (five to ten years), with a view to making the new seeds available in the Philippines and South-East Asia. It should be recalled that up to 2009 no country had approved the commercialization of a genetically modified rice variety, although in China authorizations to cultivate transgenic rice were in an advanced stage.

Mexican researchers from the National Polytechnic Institute (IPN, Mexico City) have sequenced the whole genome of the citrus tristeza virus – a

most destructive disease of citrus trees. Under the leadership of Alberto Mendoza Herrera of the Center for Genomics and Biotechnology, Reynosa, Tamaulipas State, this major achievement could open the way to an improved control of the disease. Also his discovery can help taking phytosanitary measures, and controlling the disease after an early detection.

In 1998, for the first time, transgenic papaya, resistant to the ringspot virus (RSV), was cultivated in Hawaii. Later on, scientists of Malaysia Agricultural Research and Development Institute (MARDI) developed a similar transgenic variety, followed by researchers at the University of Philippines. These new varieties saved the crop, which was severely attacked by the virus. For instance, in Hawaii, the crop collapsed in 1995, and thereafter production caught up, reaching 22,680 tons in 2001, thanks to the cultivation of the transgenic RSV-resistant variety.

In Colombia, common varieties of papaya – tocaimera, maradol and Hawaiian – are grown, and the RSV causes heavy losses. Scientists of Medellin National University have been working on the development of RSV-resistant varieties through conventional breeding. A variety named U.N. Cotové, resulting from the crossings between regional papaya varieties and others originating from the Atlantic Coast, Hawaii, Florida and Cuba, was tolerant to the virus and could give 40 fruits per plant. Colombian researchers are also working on transgenic RSV-resistant papaya.

Control of fungal diseases

Botrytis cinerea, also designated as grey rot, causes heavy losses in horticultural and agricultural crops: some 200 crop species and varieties are affected, such as potato, tomato and capsicum. This fungus secretes powerful phytotoxins, such as botridial toxin and botcinic acid. The only way to control the fungus is to spray fungicides on the plants, a costly process that may also harm human health and environment. Scientists of Brown University in the United States, Cadix University in Spain and the French National Agricultural Research Institute (INRA), have discovered the pathway of biosynthesis of the deadly fungal toxin and the way to denaturate it. Led by Muriel Viaud and David Cane, the researchers have identified a cluster of five genes that coded for the synthesis of botridial toxin. The Introduction of a mutant gene that inhibits the enzyme (sesquiterpene cyclase), which controls the production of botridial toxin, makes the fungus innocuous. This

discovery, when applied on a large scale, could change the current way of controlling the fungal disease and eventually eliminate the use of fungicides.

The Institute for Improvement of Sugar Cane at Coimbatore, India –SBI– is one of the oldest research centres in the world working on improving sugar-cane varieties. Created in 1912, it has developed some 2,800 sugar-cane clones that were used in 30 countries, including Australia and the United States, as well as in its own breeding programmes.

The SBI, in collaboration with the National Research Institute on Plant Biotechnology, New Delhi (NRPB), is trying to produce sugar-cane varieties resistant to the red rot, a fungal disease, causing major losses. The objective is to transfer to sugar-cane antifungal genes from alfalfa (glucanase), from rice (chitinase) and chrysantemum (antimicrobial peptides). SBI researchers could introduce these genes in a high-yielding (sugar) cane; they also developed borer-resistant sugar-cane varieties, following the introduction of *Bt* genes. The scientists developed the transgenic varieties by bombarding with a particle gun cells of sugar-cane variety CoC-671, well known for its very high sucrose yield.

Brazilian and Australian scientists are carrying out similar work, with a view to increasing sucrose content and/or to eliminating pests and diseases, which are claiming 15% and 10%-12% crop losses. India's goal is to enhance productivity, up to 100 tons per hectare by the year 2020, compared with the present 65-70 tons per hectare, in addition to increasing sugar recovery.

In September-October 2009, when sowing soybeans starts in the centre-east of Brazil (Mato Grosso), a soybean variety resistant to the fungus causing the Asiatic rust will be introduced on commercial scale for the first time. The area sown with this new variety is estimated at 150,000 hectares and it will reach up to 6 million hectares in 2010-2011. This variety was developed by the MT Foundation, based in the State of Mato Grosso, which has been working on it for about three years and was able to introduce a gene that confers resistance to the fungus and originates from a resistant line. The new variety was named Inox.

Asian rust is a fungal disease that is rather widespread in the centre-east of Brazil where the climatic conditions are optimal for its development. Soybean producers control the disease through fumigation of the crop, applied four or five times during the growing season. In the absence of fumigation, 80% of a soybean field could be wiped out in a few weeks. In

addition, it has been observed that the fungus has become increasingly resistant to conventional fungicides. It has been estimated that soybean producers had spent over US$10 billion in eight years, to control the disease since it appeared in the country.

According to the MT Foundation, the new variety will reduce the number of fumigations applied during the growing season to 1.4-1.6 (average), compared with 2.6 in the case of non-resistant varieties. This would result in a significant reduction of production costs, as well as in a decrease of the use of fungicides (that in turn will reduce the occurrence of resistance).

Bt cotton varieties

After twelve years of research and field trials, the Indian Council for Agricultural Research (ICAR) has been able to make available to Indian farmers a locally produced transgenic *Bt* cotton variety. This variety, called Bikaneri Nerma (BN-Bt), is the result of joint research carried out by the Central Institute for Cotton Research (CICR), Nagpur, the University of Agricultural Sciences (UAS), Dharwad, and the National Research Center for Plant Biotechnology (NRCPB) in New Delhi. It was not easy for ICAR to obtain this result. Despite the fact that the Genetic Engineering Approval Committee (GEAC) had authorized the commercial cultivation of this variety on 2 May 2008, field trials were prohibited for a few months. Finally, ICAR granted its approval and made it clear that it was willing to license or transfer the technology to both public and private seed companies. The director of the Central Institute for Cotton Research (CICR) stated that the new variety and its derived products will be made available to farmers at a reasonable price through the CICR, State Agricultural Universities (SAUs), Agricultural Technology Information Centres (ATICs), as well as through public and private seed corporations.

The new transgenic cotton variety has become available in March 2009 and was particularly interesting for farmers practising dryland agriculture and not using irrigation, such as in Vidarbha. This may lead to a "cotton revolution" in the near future. See pp. 235-236

Aluminium toxicity

Scientists of the US Agricultural Research Service (US ARS) and Brazil's Agricultural and Livestock Research Organization (EMBRAPA) have identified a gene that plays a key role in protecting sorghum against aluminium toxicity. Aluminium concentration is high in tropical acid

soils and resource-poor farmers have to survive on crops grown on these soils. Leon Kochian, a plant physiologist of US ARS, and Jurandir V. Magalhaes of EMBRAPA, have identified a gene in sorghum that controls the production of citric acid, which is excreted in the soil and combines with aluminium , thus, inhibiting its toxicity. This mechanism is different from that discovered in wheat, where it is malic acid that is excreted through the roots and combines with aluminium. US ARS and EMBRAPA are working jointly to develop sorghum varieties having the capacity to produce citric acid and are thus better adapted to African soils containing high amounts of aluminium (*Nature Genetics*, 2008, see: http://www.ars.usda.gov/is/AR/archive/nov08/gene1108.htm).

Breeding more nutritious crops

Regarding traits relating to enhancing nutritious properties of crops, "golden" rice has been the first example of a crop species genetically modified in order to synthesize beta-carotene (provitamin A) in the endosperm of its seeds; the latter acquires therefore a yellow color (henceforth the adjective golden), due to the transfer of three new genes involved in the biosynthesis of beta-carotene and derived from daffodil. "Golden" rice is also an example of a transformed crop species that offers advantages not only for farmers but also for consumers (the content of provitamin A protects them, especially children, against xerophthalmia – a major cause of blindness). Research that led to "golden" rice is considered a very fruitful model of cooperation between the public and the private sector in order to provide a product that contributes to human health; in addition, the researchers-discoverers decided to abandon their intellectual property rights, in order to make "golden" rice more easily available to resource-poor farmers. "Golden" rice is expected to be commercialized in 2011, more than ten years after its development by Ingo Potrykus and colleagues. See Sasson (2006). "Golden" rice will also contribute to the necessary increase in rice production worldwide. The International Rice Research Institute (IRRI, Los Baños, Philippines) has estimated that in 2025 rice production should rise from 520 million to 880 million tons to meet the world demand.

In May 2008, researchers of Washington University and IBM have launched the project Nutritious Rice for the World that aimed at mobilizing the power of one million computers, interconnected in a calculation grid, in order to study over two years the structure of rice proteins. The objective of that project is to develop through hybridization higher productive and more nutritious rice varieties.

A team of researchers of the University of Lleida, Spain, led by the US plant molecular biologist and geneticist Paul Christou, are carrying out a research project that received a €2.5 million grant from the European Research Council and of which the objective is to develop more nutritious cereal varieties. In addition, these varieties will be genetically modified to become resistant to insect pests and to need less fertilizers. According to P. Christou, the aim of the project is "to achieve that maize and rice – staple foods for the populations of developing countries that have not access to meat or fish – contain amounts of iron, zinc, calcium, vitamin K and other micronutrients which would convert them into complete foodstuffs". It was expected that the first seeds of these highly nutritious cereal varieties be obtained in five years, thanks to the funds provided by the European Research Council. Once the genetically modified seeds have been obtained, the intention of the researchers is to distribute them in developing countries, free of charge, in particular to resource-poor farmers in Africa, Central America and South East Asia.

In addition to the assistance provided by the European Research Council (which has subsidized 78 projects out of the 766 requests received from scientists residing in Europe; Spain received support for five projects including that of the University of Lleida), the research team expected to receive funds from the Rockefeller and Bill and Melinda Gates Foundations, which have shown interest in funding that "humanitarian and philanthropic project". The scientists who are from France, Israel, South Africa, Pakistan, China and Spain made it clear that they were willing to struggle for winning the approval of the genetically modified seeds at the commercial scale, which entails changes in the current regulation of transgenic crop cultivation.

Scientists of Switzerland's Federal Institute of Technology (ETM) in Zurich have developed genetically modified rice plants the grains of which contain six times more iron than conventional crops. Rice contains iron in the seed husk, but dehulled rice which is commercialized contains much less. This biofortification is a major achievement because it could contribute to reducing the prevalence of anaemia caused by iron deficiency, particularly in those countries of Africa and Asia where rice is the staple food. According to the World Health Organization (WHO), more than 2 billion people i.e. almost 30% of global population, suffer from iron deficiency.

The genetically modified rice plants contain two genes encoding the production of the enzyme nicotianamine synthase (which mobilizes iron)

and of the protein ferritin (that stores iron in the plant). According to Wilhelm Gruissem, of the Biology Department of ETM, the agronomic evaluation of GM plants did not reveal any significant changes in the agronomic traits, except a slight tendency to early flowering.

On 28 April 2009, in the *Proceedings of National Academy of Sciences* (*PNAS*,USA, http://www.pnas.org/content/early/2009/04/27/0901412106.abstract), researchers of the University of Lleida Department of Plant Production and Forest Science, in collaboration with the University of Murcia and that of Johann Wolfgang Goethe in Germany, published their first results concerning the development of a transgenic maize containing high contents of vitamins A and C, and folic acid. The bacterial genes encoding the synthesis of these three compounds had been transferred to the maize plants grown in confined rooms. The grains of maize cobs contained more provitamin A than current commercial varieties and fivefold more than in "golden" rice, and had the same colour as carrots. The contents of vitamin C and folic acid were respectively six and two times higher than those in current commercial varieties. Vitamin concentrations remained stable at least till the homozygotic generation T3. Studies will be carried out on rats at the University of Merida Faculty of Medicine in order to test the nutritional effects of the new transgenic variety for two to three years, according to Teresa Capell, a molecular biologist who participated in this research. She underlined that the new variety is not a hybrid one and consequently farmers would be able to use their seeds for the following crop. If approved, the variety, the seeds of which will be distributed free of charge to the farmers, will not give very high yields, but harvests that would meet basic needs, with the advantage of being highly nutritious.

In the September 2008 issue of the *Journal of Experimental Botany*, scientists of Iowa State University published their results concerning the genetic modification of maize varieties aimed at increasing the content of provitamin A in the grain endosperm. Bacterial genes *crtB* and *crtL* were transferred into the plant and the amounts of provitamin A were 34 times higher than those of non-transgenic plants, i.e. 13.6 µg of provitamin A per gram of grain dry weight. These concentrations can meet 50% of a person's daily needs of provitamin A. See http://www.jxb.oxfordjournals.org/cgi/content/full/ern 212v1.

It should be mentioned that a non-transgenic maize containing high amounts of beta-carotene has been developed through another breeding technique, called association genetics. The work carried out by Carlos Harjes, a geneticist at Cornell University, Ithaca, New York, not at Monsanto,

was published in *Science* on Friday 18 January 2008; the co-author is Edward Buckler, who promoted that technique. It consists of finding out, within a plant or crop species, the genes which encode interesting traits, that could be transferred later on through conventional cross breeding to other varieties of the same crop. Some maize lines contain high amounts of beta-carotene (66 µg per gram of seed dry weight), while the majority of them contain small amounts (0.5 to 1.5 µg/g). The first objective of the US researchers was therefore to identify the genes that promote a high production of beta-carotene; they did so through a series of genetic and statistical tests on 288 lines of maize. The precise zone of the gene has been identified, as well as the kinds of genes involved. Thanks to the information collected, markers of the gene involved in higher production of beta-carotene have been developed and will help detecting the lines that possess the relevant gene in maize collections; then the gene will be transferred through conventional breeding. This marker-assisted selection could therefore lead to maize varieties with a higher content of provitamin A, that would be better and more rapidly accepted by farmers than transgenic varieties (Kempf, 2008a).

In 2008, Pioneer Hi-Bred International Inc. was carrying out a project aimed at developing more nutritious sorghum varieties. Researchers have obtained genetically modified seeds containing higher amounts of essential amino-acids (lysine), vitamins A and E, iron and zinc. Paul Anderson, director for research at Pioneer Hi-Bred International Inc., stated that this result could not have been obtained through conventional breeding. This project named Africa Biofortified Sorghum was being carried out with a consortium of nine partners and a budget of US$18.6 million granted by the Gates Foundation. In addition, the leading corporation, Pioneer, was also training and retraining African scientists of the Scientific Council for Industrial Research and the Kenya Agricultural Research Institute (KARI) in order to work in the US laboratories based in Johnston and then transfer knowledge and technology to Africa. Two African scientists were associated with the project: Kenneth Mburu of Kenya and Getu Beyene of Ethiopia. Field trials of genetically modified sorghum varieties have been carried out in the United States and Porto Rico, and are expected to be done in South Africa.

More than 20 years ago, the US National Cancer Institute initiated a "five-a-day" programme to encourage Americans to consume at least five portions of fruit and vegetables daily. But the numbers of Americans achieving this objective declined over the past ten years. Less than one out of four reach the "five-a-day" target. "Most people do not eat five portions of fruit and vegetables a day, but they can get more benefit from

those they do eat, if common fruits and vegs can be developed that are higher in bio-active compounds", stated Cathie Martin from the John Innes Centre, a biotechnology institute in Norwich, eastern England. She made this statement after publishing a study on line on Sunday 26 October 2008 in *Nature Biotechnology*, a journal of the London-based Nature Publishing Group. The publication dealt with the creation of tomatoes containing two genes taken from the snapdragon flower (*Antirhinum majus*) to enable them to express anthocyanins, the purple pigment found in high amounts in fruit such as blackberries and cranberries.

Previous research has found that anthocyanins offer protection against certain cancers, cardiovascular and degenerative diseases (ageing), and may also hinder inflammation, obesity and diabetes. After creating the purple tomatoes in the laboratory, the British researchers tested the products on mice that they had engineered to make them susceptible to cancer. They found that the mice fed with the high anthocyanin tomatoes showed a significant extension of life spans. "This is one of the first examples of metabolic engineering that offers the potential to promote health through diet by reducing the impact of chronic disease, and certainly the first example of a genetically modified organism that really offers a potential benefit for all consumers", stated Cathie Martin. "The next step will be to take the preclinical data forward to human studies with volunteers to see if we can promote health through dietary preventive medicine strategies".

Opponents say food deficiencies are linked to poverty and other social issues that cannot be resolved by gene technology. However, biofortification of staple food crops as shown previously (see pp. 128-129) can help farmers and consumers whatever the technique adopted – genetic engineering or conventional breeding.

Scientists of the Italian Institute of Food Science and Production have been able to develop genetically modified tomatoes that contain high amounts of resveratrol – an anti-oxidant compound that is found in grapes, but also in groundnuts and other nut species, and oysters, whose natural function is to protect fruits against the attacks of pathogens. The transgenic tomatoes contain the gene encoding the grapevine enzyme estilbene-synthase, and they produce high amounts of resveratrol and its derivatives, particularly in the skin of mature tomatoes. The Italian scientists also evaluated the anti-oxidant capacity of the resveratrol produced in transgenic tomatoes and found that extracts had an anti-inflammatory effect higher than that of synthetic resveratrol or the compound extracted

from natural sources (in *Plant Biotechnology Journal*, April 2009; see http://www3.interscience.wiley.com/journal/122328578/abstract).

Plant Science Sweden AB has been authorized to carry out field trials for transgenic canola (*Brassica napus*) lines that have been genetically modified to improve the composition of oil in seeds. The latter contain higher amounts of long-chain polyunsaturated fatty acids after fungal genes coding for desaturase enzymes have been introduced. Also to identify transformed cells in tissue culture a marker gene has been introduced, that for tolerance to immidazolinones. Greenhouse trials have shown that the transgenic lines were not different from the non-transgenic control ones. The field trials have been authorized by early 2009 in the municipal areas of Eslöv, Svalöv, Klippan, Kristianstad and Vaaron, on a total area of 15 hectares.

Flavour and taste, as well as aromas, are also the focus of genetic research and breeding. These are important traits for attracting consumers. For instance, Haim Rabinowitch, former rector of the Hebrew University of Jerusalem and professor of agriculture in the same university, stated "the cherry tomato already existed, but we gave it the flavour it did not have and we increased its shelf-life because it rotted rapidly; genetics is in this regard a powerful tool" (Muñoz, 2009). Israel has become a major exporter of improved seeds (rather than an exporter of agricultural products because of lack of farmland). "Seed exports amounted to €78 million in 2008. More than 25% of cucumbers exported from Spain and sold in Europe originate from Israeli seeds. The seed exported concentrates knowledge in biochemistry, genetics, ecology and nutrition", stated H. Rabinowitch (Muñoz, 2009).

Hypoallergenic food crops and more digestible feed

Transgenesis can also help eliminating harmful plant metabolites, e.g. allergenic compounds. Peggy Ozias-Akins and her colleagues of the University of Georgia, Tifton, are using genetic engineering to grow hypoallergenic peanuts. While the objective of the research project is not to produce peanuts entirely free of allergens, the varieties to be developed could be very helpful in decreasing the number of people suffering from this ailment. The US research team has been able to test groundnut plants that do not produce two proteins considered as major allergens. The results of this ongoing research work has been published in *The Journal of Agricultural and Food Chemistry* (2009); see *Ibercib Boletin mensual de Agro-biotecnología*, 16 January 2009.

Scientists of the Chinese Academy of Agricultural Sciences (CAAS) have developed a GM maize variety the seeds of which contain higher amounts of phytase. This enzyme is a feed additive that helps animals to digest phytates present in maize and soybean feedstuffs. Pigs have not enough phytase in their digestive tract and cannot therefore fully digest phytates, and extract and assimilate the phosphorus they contain. Consequently, enormous quantities of phosphorous are found in their manure, and have a negative environmental impact (e.g. eutrophication of water streams). In order to avoid this kind of impact and also to improve the digestibility of phytates, livestock producers add to feedstuffs phytase produced through fermentation. The development of the new maize variety will therefore avoid environmental problems that are serious in China and improve animal nutrition.

After the approval by the Federal Regulator of Gene Technology, field trials have been carried out in 2008 with about 500 lines of genetically modified fodder plants in Hamilton, west of Victoria, Australia. These trials concerned perennial raygrass (*Lolium perenne*) and other grass species, developed by the Department of Primary Industries' scientists. "These new fodder lines had a reduced content of non-digestible matter, which may result, depending on the outcome of field trials, in the decrease of feedstuffs for the livestock industry", stated Gavin Jennings, minister of innovation. "This would be a major progress for the milk and meat industries that would have less pastures at their disposal due to climate change and prolonged drought". Agriculture minister Joe Helper assured that the field trials were being carried out within the framework of a research on "proof of concept" and that the fodder plants must not be used as feed. See: http://www.greenbio.checkbiotec.org.

Increasing shelf-life of fruit

In 1996, for the first time, a transgenic tomato variety was developed by the US company Calgene, not through gene transfer, but through the inhibition of the expression (silencing) of the gene encoding the synthesis of polygalacturonase, an enzyme that accelerates the softening and overripening of the fruit, in other words reducing its shelf-life. This new tomato variety was sold commercially, including in the form of tomato sauce, but was later on withdrawn from the markets due to the high public non-acceptance of transgenic crops.

Nevertheless, increasing the shelf-life of fruit remains a major objective of crop breeding and genetic engineering. For instance, the technology

can be applied to bananas that travel over long distances to reach their final markets; their fast maturation could be slowed down through the inhibition of ethylene production in the fruit, i.e. the inhibition of the key enzyme of ethylene biosynthesis.

In the case of papaya, in addition to the successful large-scale cultivation of transgenic ring spot virus (RSV)-resistant papaya varieties in several countries, a research team, led by Evelyn Mae Tecson-Mendoza, professor of biochemistry at the Phytoimprovement Institute of the University of the Philippines, Los Baños, is working on increasing the shelf-life of papaya. Generally papaya matures in two days and becomes yellow; it should therefore be consumed on the second or third day, otherwise it is not digestible. The technique used to increase the shelf-life of the fruit up to 14 days consists of inhibiting the expression of the gene encoding the ACC synthase – the key enzyme for ethylene production (antisense RNA). Since 1997, E.M.T. Mendoza has been conducting research relating to molecular techniques used to decrease post-harvest losses of papaya and increasing its storage period. Only in 2007, field trials of the genetically modified variety could be carried out. She also showed that the transgenic variety was nutritionally identical to the conventional one, containing vitamin C and the antinutrient benzylisothiocyanate. See: http://www.agbios.com/main.php?action=ShowNewsItemid=10179.

RNA interference

A new category of transgenic plants, resistant to insect pests, are currently the focus of active research and could be commercialized in the medium term. These plants were described on 4 November 2007 in two articles published in *Nature Biotechnology,* and the technology used to develop them is based on RNA interference. Double-stranded RNA interference can inhibit the expression of genes and has become an important laboratory tool for the silencing of target genes.

The 2006 Nobel Prize of medicine and physiology was attributed to Andrew Z. Fire and Graig C. Mello, who were respectively 47 and 45 years old, for having discovered the molecular bases of RNA interference. Graig C. Mello is professor of molecular medicine at the Medical School of Massachusetts University and is the son of a paleontologist at the Smithsonian Institution. With his co-workers he has been successful in inhibiting the expression of specific genes in the embryo. Andrew Z. Fire is professor at Stanford University; when he was 19 years old, he joined the Massachusetts Institute of Technology and obtained his PhD

at the age of 23. At MIT, he worked with the geneticist Philip Sharp (a Nobel Laureate in medicine and physiology in 1983), before moving to the United Kingdom where he collaborated with one of the pioneers of molecular biology, Sydney Brenner, the 2002 Nobel Laureate in medicine and physiology. He came back to the United States in 2003 (Nau, 2006).

In 1990, Richard Jorgensen, professor at the University of Tucson, Arizona, was working on the molecular mechanisms of pigmentation in plants; he used to introduce into the plant genome genes that interfered with the natural pathways leading to pigmentation. He was able to transform purple petunias into white ones, and later on introduced several copies of the gene controlling the purple coloration, in order to obtain even more purple flowers. Unexpectedly, he obtained white flowers. David Baulcombe was also working in the same area in the United Kingdom. This unexpected result was explained in 1998 by Andrew Fire and Graig Mello who published an article in *Nature* (19 February 1998). Both researchers demonstrated that in the worm *Coenorhabditis elegans*, it was possible to inactivate a gene through the interference with its messenger RNA. This phenomenon was dubbed RNA interference. This was a novel and remarkable experimental tool for studying the function of thousands of genes, when inactivating them totally or partially. This could also have interesting applications in a wide range of fields encompassing medical and agricultural biotechnology. The key idea is to use some targeted RNA molecules that interfere with a physiopathological process. Indeed, many experiments are being carried out in laboratory animals with a view to treating cancers or viral diseases. The administration of interfering RNA can be done very simply, as with drugs, orally or parenterally. In the United States, big pharmaceutical groups and dozens of biotechnology companies are developing this technology and the first clinical trials are being carried out. The Nobel Prize awarded to Graig Mello and Andrew Fire will certainly speed up this process (Nau, 2006).

Two articles published in *Nature Biotechnology* highlighted the fact that this technology could be used in plants. In the first article, a research team of Shanghai's Institute of Biological Sciences led by Xiao-Ya Shen, describes how they were able to hurt caterpillar larvae of *Helicoverpa armigera*, a devastating pest of tomatoes, but also of cotton. This Lepidopteran insect had developed resistance to gossypol, a natural insecticide produced by the plant. The Chinese researchers found the gene encoding that resistance and expressed the corresponding RNA in model transgenic plants. Larvae that were fed on these plants became vulnerable to gossypol, because the resistance gene had been inactivated.

The second article, published by a research team of Monsanto, concerns the cultivation of maize and one of its devastating insect pests, *Diabrotica virgifera*. James Roberts and his colleagues first tested the efficiency of several double-stranded RNAs corresponding to genes that are involved in key physiological functions of the Coleopteran pest; these RNAs were directly fed to the insect. Thereafter, they developed transgenic maize plants that expressed some of these RNAs and noticed that the damage caused to the roots of plants grown in the greenhouse by the Coleopteran's larvae was largely reduced. Monsanto's researchers consider that the control strategy based on interference RNA could complete the current strategy based on the transfer of *Bacillus thuringiensis (Bt)* entomotoxin genes into the crop. *Diabrotica virgifera* is resistant to most of these toxins and consequently another control method should be applied.

Chinese researchers shared Monsanto scientists' concerns and wanted to anticipate any resistance to *Bt* toxins that would appear among insect pests. Interference RNA, which is a very selective "biocide", had been used in the laboratory on nematodes that were fed with bacteria producing these RNAs, according to Hervé Vaucheret, of the Cell Biology Laboratory of the French National Agricultural Research Institute (INRA). The novelty is that the technology can also work in insects that ingest these RNAs. Monsanto's team noted, however, that the cotton weevil, *Anthonomus grandis*, was not receptive to this control method, which may indicate that *all* insects are not susceptible to interference RNA ingested orally.

Regarding the acceptance of these new transgenic plants, the issues are the same as those concerning genetically modified plants obtained through genetic engineering. In other words, one should check that non-targeted insects are not affected by the transgene and that the RNA sequence is not present in other organisms. The environmental impact of the new transgenic plants may therefore lead to similar controversies.

Genomics: impact on advanced crop breeding

In addition to "good agronomy" and crop biotechnology, crop genomics is becoming a major tool to advance crop breeding and select varieties that are better adapted to their environmental conditions, particularly to climate change, and meet the nutritional needs of consumers. It consists of identifying the genes of a whole genome of a plant species or crop variety, of sequencing them and thereafter of discovering their individual function (functional genomics).

On 15 September 2006 and for the first time, the sequence of the genome of a tree species, the poplar (*Populus trichocarpa*), has been published in *Science* by an International team, involving 40 US, Canadian and European laboratories. After *Arabidopsis thaliana* genome had been sequenced in 2001, and that of two rice subspecies (*Oryza sativa* subsp. *indica* and subsp. *japonica*) in 2002, the poplar was chosen because of its small number of genes (45,000). *Arabidopsis* and the poplar tree have diverged 100-120 million years ago; the poplar genome was almost duplicated and after losing some genes during evolution, its genome is 1.6 larger than that of the small Cruciferous.

Some genes for resistance to diseases as well as for the synthesis of cellulose and lignin have been isolated by scientists of the French National Scientific Research Centre (CNRS) and University of Aix-Marseille, in charge of the architecture and function of biological macromolecules. These discoveries may lead to the genetic modification of forest species to achieve industrial and energy-production objectives (wood, pulp and agrofuels).

In fact, the Flemish Institute of Biotechnology (VIB) has been authorized by mid-2009 to carry out field trials of genetically modified poplar trees. In 2002, field trials of GM plants were prohibited due to a moratorium imposed by the European Union. Nevertheless, VIB decided to appeal in court against this decision in order to conduct field trials of genetically modified poplars containing less lignin (-20%) and more cellulose (+17%) than conventional trees. In May 2008, VIB's request was rejected, despite the fact that Belgium's Advisory Committee on Biosafety and the Flemish environment ministry gave a favourable advice. VIB pursued its legal action and finally received the authorization from the Supreme Court. First results of these field trials were expected in 2012. The GM poplars could produce more cellulosic biomass that could be converted into bioethanol. In greenhouse trials, it was shown that these GM trees could produce 50% more bioethanol than conventional trees.

Rice genome contains about 57,000 genes. In order to understand the function of each gene, the knockout technology consists of creating mutants of genes that are thus inactivated, and then to look for the function (morphological, physiological and metabolic) that is impaired. This is the objective of the International Consortium for Rice Functional Genomics, which has produced until early 2009, 200,000 mutant lines, the altered sequences of which are known. These data are made available to researchers in order to accelerate the identification of genes encoding agronomic traits. Some 460,000 mutant lines would be necessary to embrace the whole coding DNA of rice.

As a result of a huge five-year research project, scientists of Yale University have published in 2009 an atlas containing transcriptomes of 40 rice cell types (transcriptome is the total number of messenger RNAs produced in a cell following DNA transcription). The atlas therefore contains information on each one of the 30,000 genes of rice in a cell type. The published transcriptomes enable researchers to compare the activity of any gene in each of the 40 cell types, including those relating to the development of roots, stems and embryos. According to Timothy Nelson, professor at Yale University and leader of the study, the rice atlas will be useful for other crop species, and it might be possible to unravel the network of genes involved in photosynthesis, so as to improve food and biomass production.

Annual rice production (paddy) is about 600 million tons (i.e. 400 million tons of white rice after dehulling) and three-fourths of this production (2006) is consumed in China, India and Indonesia. Experts concur that yields should grow by 1% annually to meet population growth in these countries as well as global needs by 2025. Unfortunately, the global acreage of cropland decreases and the increase in rice yields in irrigated zones (75% of the world crop) cannot meet the foreseen needs, despite the fact that the development of hybrid rice in China has doubled the production of irrigated rice over thirty years. Rainfed rice (4% of the world crop) and submerged rice production in deltaic zones (3% of the world crop) cannot either contribute to meeting the growing needs (Galus, 2006).

Consequently, a fourth type of rice cultivation is being promoted by specialists in inundated lowlands, where acreage could be extended. But rice cannot stand submersion for more than four days, while when floods occur it can remain under the water for two weeks, with the subsequent destruction of 10% of crops, i.e. an average annual loss of a little more than $1 billion (Galus, 2006).

A research team led by Xenong Xu of the department of plant pathology of the University of California and David Mackill of the International Rice Research Institute (IRRI, Los Baños, Philippines) has identified a gene (*Sub1A*) that controls the tolerance to flooding in the subspecies *indica* of rice (*Oryza sativa*), the most widely cultivated crop. They have worked on a variety of O*ryza sativa* subsp. *indica*, FR13A, which naturally can withstand two weeks of flooding. The results were published in *Nature* on 10 August 2006. They also transferred this gene into another variety of *indica* rice called *swarna*, that is sensitive to flooding and is cultivated mainly in India. This transfer, done through conventional breeding and not through transgenesis, resulted in tolerance to flooding for about 15

days. In addition, yields have been increased. Other varieties tolerant to flooding are being developed in Laos, Bangladesh and India. This work would lead to the extension of the cultivation of rice under submersion that is mainly carried out in South and South-East Asia. This kind of cultivation is practised over 54 million hectares worldwide (Galus, 2006).

The identification of the *Sub1A* gene has been possible thanks to the sequencing of the rice genome. This is a powerful tool that enables geneticists and agronomists to seek genes that make rice tolerant or resistant to a wide range of stresses, as stated by Takuji Sasaki of the National Institute of Agrobiological Sciences in Tsukuba, Japan (Galus, 2006).

In **Mexico**, at the National Laboratory of Biodiversity Genomics, Irapuato, Luis Herrera Estrella and his colleagues have been working on sequencing the **genome of a maize** variety called Palomero 1, toluqueño, one of the seven basic lines of this crop species, 4,000 years old or even more. The size of the genome is rather small: a total of 54,132 genes that can potentially encode proteins; 47,100 genes have been validated through transcription and 87 % of the total number of genes are potentially functional.

In the United States, the genome of another maize variety (B73) has been sequenced. The US project, carried out at Washington University, Missouri, for three years, has needed an investment of US$29.5 million. This first sequencing concerned about 95% of maize genome, the rest of genome sequencing being scheduled for the end of 2008. Access to the results of this work is free for all researchers worldwide through the public DNA GenBank and online, as well as on the website: www.maizesequence.org.

Mexican researchers, like their colleagues in the United States and other countries, are focusing their work on identifying and isolating genes that make crop species and varieties tolerant to drought. They are studying two maize lines tolerant to drought, Cajete Criollo and Michoacan 21, and another one that is susceptible to drought (8J-2). They transferred the drought-tolerance genes to rice and tomato varieties. They are now being able to carry out field trials with transgenic drought-tolerant maize lines, further to the approval by Mexico's president of the "Special regime" for maize which authorizes these field trials in some regions of the country. The Center for Research and Advanced Studies, Irapuato, where L. Herrera Estrella and his colleagues are working, focuses its research on drought-resistant maize and on maize lines that require less agrochemicals. The new regulation involves a step-by-step risk assessment and a case-by-case approach so as to identify transgenic crops that are most relevant to

local conditions: it is not an indiscriminate authorization for the cultivation of transgenic crops.

One should recall that over the last 12 years (up to 2009) transgenic cotton could be grown in Mexico in experimental plots. The law of biosafety of genetically modified organisms (GMOs) was published in 2005 and the norms set up in 2008 concerned three stages before the commercialization of biotechnology-derived products: experimental, pre-commercial (pilot) and commercial. In 2009, Monsanto was authorized to conduct pre-commercial trials with genetically modified cotton varieties, BG, RR, BGxRR, for the following sowing season.

In the case of maize, the three States of northern Mexico, Sonora, Sinaloa and Tamaulipas, have requested the Mexican Congress as well as the secretariats of agriculture and economy, to authorize the cultivation of transgenic maize with a view to reducing Mexico's dependence on food imports. The request was announced on 14 July 2006 and its objective was not to lose another cultivation year, at a time when Mexico imported from the United States half of the volume of grains it needed for feeding its population. While maize is grown on half the agricultural acreage of Mexico, the average yields of this crop species are among the world's lowest: 2.3 tons per ha. The president of the Maize Production System commented that, bearing in mind the recent experience of Honduras, the authorization for cultivating maize in northern Mexico would reduce by up to 25% the subsidies in that region, while production would grow by 30%. Such decision would enable Mexico to become self-sufficient in yellow maize production and exporter of white maize.

Sinaloa is the highest maize-producing State with 4.5 million tons, followed by Tamaulipas with 1 million tons, and Chihuahua with 500,000 tons; all this maize is consumed in Mexico and the country imported about 10 million tons in 2007.

By the end of August 2006, the director of the National Service of Agri-food Sanitation, Innocuity and Quality (Senasica) announced that the Maize Master Project, involving 18 transgenic events in seeds patented by Monsanto, Dow and Pioneer, was being examined by the secretariat of environment and natural resources (Semarnat). Once the secretariat approves the feasibility of field trials with these transgenic seeds, the Secretariat for agriculture, livestock husbandry, rural development, fisheries and food (Sagarpa) will authorize them.

Some places seem to be easier than others for conducting such trials. This is the case of Yaqui Valley in the state of Sonora, where no maize is grown, because it is an area devoted to wheat. Conversely, other areas in northern Mexico will be close to regions where non-transgenic maize is cultivated, and there the decision will be more difficult to make.

On 29 May 2006, both Semarnat and Sagarpa sent to the Federal Commission of Regulation Improvement (Cofemer) a draft project on "special protection regime of maize", which was rejected due to the non-compliance with some standards. Such regime was considered the prerequisite step for the approval of field trials of transgenic maize according to the biosafety law, approved in 2005. Thereafter, Semarnat and Sagarpa were of the opinion that this regime was not mandatory, because one was dealing with field trials on 0.25 ha plots with maize that does not produce pollen, in an area monitored by the National Institute for Forestry and Agricultural Research (INIFAP) with forbidden access for foreigners.

In addition to the Maize Master Project, many requests for field trials were made by such companies as Syngenta and Bayer. The approach to be followed was that Semarnat approved the requests (after evaluating the environmental impact and the effects on biological diversity) and thereafter Sagarpa. The latter was under the pressure of farmers who wanted to test transgenic maize varieties and who where promised by Mexico's president that these field trials should have begun before the end of his six-year term (December 2006).

Once the field trials of transgenic maize were authorized in accordance with the provisions of the 2005 law and excluding any "fast track" approach, it was estimated that some 8 million hectares in the States of Sinaloa, Tamaulipas and Sonora could be cultivated commercially with transgenic maize varieties. In these States, the expected results would be more striking, due to the high adoption rate of technology by the farmers. Maize is the main crop of interest for seed producers in Mexico, because of its commercial potential, the cultivated area, the low productivity and therefore the expectations of much higher yields as well as of new businesses derived from other uses of the grains, e.g. bioethanol production as an agrofuel.

In Mexico, the only authorized transgenic crops were cotton and jitomato. In 1996, the first transgenic varieties were introduced on small areas, the total surface reaching 900 hectares. Nowadays, transgenic cotton seeds are sown in the States of Baja California, Sonora, Sinaloa, Chihuahua,

Coahuila and Tamaulipas. Due to the expected development of the market, such large seed-producing companies as Monsanto, Dupont, Adventis, Bayer, BASF, Dow Chemical and Syngenta are speeding up their production of new varieties of maize, wheat, soybeans, canola, and horticultural crops like jitomato.

In 2009, the secretariat of agriculture, livestock husbandry, rural development and food (Sagarpa) published a decree that modified the 2005 biosafety law in order to authorize the experimental cultivation of transgenic maize. Sagarpa is entrusted with the duty to give the cultivation permits and with the monitoring of the cultivated plots so as to make sure that they do not pose any risk. Ariel Alvarez Morales, executive secretary of the Intersectorial Committee for Biosafety of GMOs (Cibiogem), stated that "this technology (crop trangenesis) was most promising, had many possibilities, but also entailed risks, and we should progress in a careful way, but not adopt a no-moving attitude; we need to know better our own maize varieties and how we should manage them". José Manuel Madero, commercial director of Monsanto for Latin America, expressed his satisfaction for this reform, and insisted on the fact that transgenic maize was safe and that this technology had a huge potential.

For instance, according to the article *Fungal and mycotoxin contamination in Bt maize and non-Bt maize grown in Argentina*, published in the international *World Mycotoxin Journal*, the levels of infection by the fungus *Fusarium* and the concentrations of fumonisins (mycotoxins produced by the fungus) were much lower in *Bt* maize varieties than in the conventional ones. Lepidopteran insects, such as the stem borer (*Diatraea saccharalis*), are the main pests of maize in Argentina; their larvae feed on the stalks, leaves and grains, and they leave holes and galleries which can break the plant, inhibit the transfer of nutrients and are the point of entry of *Fusarium*; the fungal toxins are very dangerous for human and animal health. It has been verified worldwide that, in addition to protecting the plant against insect pests, *Bt* entomotoxins indirectly reduce the amounts of mycotoxins present in *Bt* maize. This is the case in Argentina where transgenic *Bt* maize has been cultivated since 1998 and trait is currently found in 70% of hybrid maize varieties commercialized in the country. See: http://www.wageningenacademic.metapress.com/content/cm0741m1k6j400u5.

The US National Science Foundation (NSF) has allocated to the University of California, Davis, a three-year grant of US$6.8 million in order to carry out a genomics project aimed at accelerating the development of higher-yielding **wheat** varieties, more nutritious, resistant to pests and diseases,

and tolerant to climatic stress. This project received the highest grant of the 2009 NSF's Phytogenomics Programme. Jan Dvorak and his colleagues are trying to design the physical map of one of the three genomes that constitute the whole genetic makeup of wheat. This is a titanic task, as each one of the three wheat genomes is bigger than that of rice. Physical maps represent the location of the genes and other markers along the chromosome. These markers are used by geneticists to have an orientation through the genome; for instance, sites of marked sequence (SMS) are DNA sequences that are several hundred nucleotides long, which are encountered in one place of the genome. Instead of designing a physical map of wheat chromosomes directly, the chromosomes of *Aegilops tauschii* will be mapped first, as this is one of wheat ancestors and the origin of its D genome. Thus the objective of the project is to design the physical map of the individual chromosomes of the wheat D genome.

The European programme *Triticae genome* involves 15 public research organisms and two seed companies, with a funding of €7.5 million, in order to sequence the wheat genome. The latter is very complex, with many repeated sequences which make difficult the precise location of genes of agronomic interest. Sequencing will focus in particular on chromosomes bearing genes related with drought, salinity and pest resistance, as well as those involved in yield components. After establishing the physical maps corresponding to these traits, the precise location of the relevant genes will be determined and the molecular markers linked to them will be identified (Chauveau, 2008).

During a meeting held at Ciudad Obregón in Mexico, research work on the fungus Ug 99 that causes heavy losses in wheat has been presented at the beginning of 2009. This fungus is a strain of wheat stem rust that appeared for the first time in Uganda by the end of 1990s. The fungus then spread to Ethiopia, Iran, Yemen, Kenya and Sudan. Some scientists even think that it is progressing towards South Asia where 19% of the world wheat is produced.

Scientists have developed some 60 new wheat varieties that contain various genes that confer a slight resistance to Ug 99. Nevertheless, researchers believe that these genes might become effective in the long term, because they will force the fungus to overcome a wide range of genetic hurdles. These wheat varieties produce 5% to 10% more grain that the usual varieties. In order to foster the breeding of more resistant and higher-yielding varieties, there is a constant exchange of germplasm between the International Maize and Wheat Improvement Center (CIMMYT, Mexico) and the Experimental Station of Njoro in Kenya, where Ug 99 is endemically present. In Kenya, the resistant lines are tested in

field conditions, and they are sent back to Mexico where new traits are added. This improvement scheme dubbed "improvement airlift", takes advantage of two growing seasons in Mexico and Kenya, and has halved the number of years needed to breed and test new resistant wheat varieties. See: http://www.scidev.net/es/news/nuevas-variedades-de-trigo-combatir-u-hongo-destru.html.

On 29 January2009, the journal *Nature* reported the sequencing of the genome of **sorghum**, carried out by a team led by Andrew Patterson of the University of Georgia and Tom Hash of the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT, Patancheru, Andhra Pradesh, India). Not only this achievement will lead to breeding of new sorghum varieties, but could also help in the genomics work on sugar-cane, maize and millet that share with sorghum gene similarities (synteny). Thus, thanks to the data generated by rice and sorghum genomics, molecular markers have been developed and used in genetic studies of pearl millet, another crop species considered a major one by ICRISAT. Once located the genes that enable sorghum to resist to drought, they could be used to develop transgenic lines that are adapted to specific geographic and climatic conditions. Sequencing the genome of sorghum could have an important impact on food production, but also on agrofuel production, because this crop can produce the same volume of ethanol as maize, but using 30% less water.

By the end of 2008, the US Departments of Energy (DOE) and Agriculture (USDA) announced the sequencing of **soybean** (*Glycine max*) genome that will be made available to the international scientific community. Soybeans are a very important crop species, not only because it makes up 70% of edible proteins consumed worldwide, but also because it is a raw material for the production of biodiesel. Soybeans are, after maize, the most exported commodity of the United States. According to Gale A. Buchanan, a USDA scientist, the announcement of the finalization of the sequencing of soybean genome was a great day for agriculture and all the people throughout the world.

The soybean genome has a size of a few billion nucleotides, one-third that of the human genome, with a total of 66,000 genes. The Institute of Genomics of the US Department of Energy has been involved in the genomics of soybeans because of the use of the crop in the production of biodiesel. Soybeans represented 56% of world oilseed production and 80% of the US production of biodiesel in 2007. It is also one of the biggest and most complex plant genome to be sequenced, using the technique

of complete random sequencing. This technique consists of the random breaking of DNA into small fragments that are sequenced later on.

Functional genomics will follow the sequencing phase. Researchers of the University of Missouri have demonstrated the applicability of transposons in order to study the functions of soybean genes. Transposons are genetic elements that can "jump" along the genome and insert in a random manner within the genes, thus causing mutations and altering their functions. Scientists were thus able to detect visible mutations that impair agronomic traits such as root growth or the composition of seeds.

In 2009, a new genetically modified soybean variety containing more oleic acid was expected to be commercialized in the United States. This will permit the use of fats and oils derived from this variety at higher temperatures, without being transformed into transfats that are harmful for health. "This was the first soybean variety developed to meet health criteria and for foodstuff producers", stated Jim Borel, vice-president of DuPont, the company that developed this variety.

The soybean cyst nematode is one of the most devastating pests of soybeans in the United States, annual losses being estimated at US$1billion. Ben Matthews, a phytopathologist of the Agricultural Research Service of the US Department of Agriculture, and his colleagues have developed soybean plants containing the copy of one of the genes encoding major proteins in the nematode. The worms which ingest this copy are unable to express the corresponding gene and cannot grow normally. Greenhouse trials at the Laboratory of Genomics and Improvement of Soybeans in Beltsville, Maryland, showed that 80% to 90% of the female nematodes that fed on the roots of this transgenic soybean variety died or could not develop into adults within 30 days. Other greenhouse trials are being carried out and research is being conducted on the identification of the gene encoding the nematode protein in *Coenorhabditis elegans*, a very small worm the genome of which has been sequenced several years ago and which is used as a laboratory tool in genetic studies.

Malaysian and US researchers have sequenced the oil-palm genome (*Elaeis guineensis*). In addition, they have analyzed the expression of several genes at various stages of plant development in order to elucidate the mechanisms of palm-oil biosynthesis, thereby sequencing 12 transcriptomes. See http://wwwagrodigital.com//PlArtStd.asp?CodArt=63947.

The Centre of Plant Biotechnology and Genomics, belonging to Madrid Polytechnic University and the National Agricultural Research Institute (UPM/INIA), is leading the Spanish project Melonomics of the Foundation Genoma España, that aims at sequencing the genome of melon. This research-and-development genomics project is titled "Development of genomic tools in Cucurbitaceae, including the genomics of melon, and its application to improving breeding of these crops."

Melon (*Cucumis melo*) is a Cucurbitaceae species that has a great economic impact in Spain, which is the world's fifth biggest producer of this fruit. It is cultivated mainly in the regions of Murcia, Castilla La Mancha and Andalucía.

Melonomics aims at creating new melon varieties with interesting agronomic traits. During the period 2009-2012, this project will be funded by the public and private sector with a total of €4.142 million. In addition to the researchers of the Centre of Plant Biotechnology and Genomics, 14 research groups and five companies (including two biotechnology ones) will be involved in carrying out he project. Spain's Centre of Plant Biotechnology and Genomics (CBGP) was officially inaugurated on 27 April 2009 and has been designed to become one of the European most advanced research centres on plant biotechnology and genomics, like those already working in these areas in England, France and Germany. Its research programme aims at contributing to advanced knowledge of root differentiation, flowering, seed development, senescence, adaptation to drought and saline soils (that prevail in some regions of Spain), as well as of mechanisms of resistance to viruses, bacteria and fungi.

Breeding drought-tolerant crops

Breeding drought-tolerant crops is not only a means to respond to climate change in the areas that will be stricken by recurrent droughts and where rainfall will be reduced markedly, but also to contribute to the reclamation of arid and semi-arid zones, which cover 40% of total area of the Earth and where one-third of the global population lives. Growing drought-tolerant crops there is a key component of dryland agriculture.

Breeding drought-tolerant crops is a top research priority of seed and agrochemical companies, as it is in many public research institutions. According to the Ottawa-based ETC Group (Action Group on Erosion, Technology and Concentration), big seed companies want to secure a profitable commercial position in the international seed business. In a report published in May 2008, ETC Group revealed that Monsanto, Bayer,

BASF, Syngenta and other corporations had filed 532 patent requests on genetic sequences relating to drought tolerance. Monsanto and BASF filled 49% of the patent requests. Both companies had announced in March 2007 a US$1.5 billion partnership to develop plants resistant to extreme climatic conditions (Kempf, 2008b).

Agrochemical and seed companies wanted to involve public research centres such as those belonging to the CGIAR (Consultative Group on International Agricultural Research) network, like CIMMYT (International Maize and Wheat Improvement Center). ETC Group which considers that current and future ownership of the technology by the big companies will make more difficult the access to crop breeding techniques by small farmers, does not support the agro-industrial approach to advanced crop breeding. They consider that agronomists rather believe that priority should be accorded to supporting food and subsistence agriculture and resource-poor farmers (Kempf, 2008b).

However, the breeding of drought-tolerant maize by Monsanto in collaboration with CIMMYT and the Bill and Melinda Gates Foundation will provide income and food to small African farmers (see below). It is true, on the other hand, that private companies play a key role in the breeding of drought-tolerant crops (Monsanto alone has a collection of more than 50 genes related with drought tolerance), but they tend to cooperate with national agricultural research systems.

Laboratory work

In 1999, at the University of Toronto, Peter McCourt, professor of botany and specialist in phytogenetics, discovered that the elimination of gene *era1* from a plant resulted in a high sensitivity to abscissic acid (ABA) – a plant hormone that is produced in drought conditions. Plants deprived of this gene could detect water-stress conditions earlier and react by closing their stomata. Thus, the plant has a "molecular switch" that enables it to preserve its humidity for a longer period (Pélouas, 2007).

On the basis of this work, the Kingston (Ontario)-based biotechnology company, Performance Plants Inc., designed a patented technology called Yield Protection Technology (YPT) that relies on engineered versions of *Arabidopsis thaliana* fanesyl transferase genes. These increase sensitivity to abscissic acid (ABA), closing stomata rapidly when the plant is stressed, and they have shown good activity in canola (oilseed-rape), but only modest effects in maize under drought (Pélouas, 2007).

According to Yafan Huang, vice-president for research of Performance Plants Inc. (PPi), genetically modified oilseed-rape plants, grown in field conditions for three years in Western Canada, have yielded 26% more than control plants. The biotechnology company is trying to adapt its technology to other crop species. It has research agreements with Syngenta and Pioneer, and claimed that a drought-tolerant maize variety had been tested for two years (Edmeades, 2008).

Scientists at the University of Bonn, Germany, identified a gene that enables a South African plant to overcome drought. This plant can lose up to 95% of its water reserves and reduce its metabolism so as to revive after weeks or even months of drought. This discovery was welcomed in Germany where in 2005 a heat wave resulted in almost 80% losses in some crop harvests. The German scientists also found that a series of genes were expressed only during drought periods.

Researchers at the University of Lleida (Cataluña, Spain) were working on transgenic plants containing high concentrations of polyamines – regulators of plant growth. These researchers introduced into wheat plants a gene of oats encoding the enzyme, arginine decarboxylase (ADC), so as to obtain more polyamines that in conventional wheat. These compounds are related with resistance to abiotic stress, particularly drought, and are also potential anti-oxidants. The research objective is to clarify the role of polyamines in stress resistance and, if positive, to transfer this trait to wheat varieties.

Researchers at the Universidad Nacional del Litoral (UNL, Argentina) Laboratory of Cell and Molecular Biology (Faculty of Biochemistry and Biological Sciences) have isolated gene *Hahb 4* which confers to sunflowers a high tolerance to water stress; the gene has been transferred to a laboratory plant, which not only became tolerant to severe drought conditions, but also kept its production level.

At the University of Texas, transgenic tomatoes could survive in dry soils with little nutrients, due to the expansion of the root system volume, induced by genetic modification. The increase in root volume enabled the plants to tap minute water resources and nutrients, and thus overcome drought. Also in tomatoes, a team of researchers led by Kendal Hirschi succeeded in increasing the expression of a protein (AVP1) that is found in plants better adapted to abiotic stress.

At the University of California, Davis, an international research team, led by Eduardo Blumwald, professor at the department of plant sciences, is working on transgenic tobacco plants that can grow with less than 70%

of water delivered to conventional plants. These plants were grown in greenhouse for 40 days in the same conditions; then they were placed in water-stress conditions for 15 days, equivalent to extreme drought. While control plants wilted and lost their green colour, and progressively died, transgenic tobacco plants remained green and were not seriously affected; they kept their photosynthetic activity during the whole drought period. After the 15 days of drought, all the plants were irrigated with water during a week; all control plants died, while the transgenic ones recovered and resumed their natural growth, only showing a small reduction in the size of their seeds, despite the fact that they had received only 30% of the usual volume of irrigation water.

E. Blumwald stated that the promising results obtained not only could lead to the development of plants that could tolerate periodic droughts, but also to reducing the amounts of water in irrigation schemes applied to major food and fiber crops. The project would be applied to tomato, rice, wheat, canola (oilseed-rape) and cotton, in laboratory and field trials.

At the Agricultural Genetic Engineering Research Institute (AGERI, Ain Shams University, Cairo), Ahmed Bahieldin and his colleagues have been carrying out greenhouse and field trials of transgenic wheat since 2001, in order to test its drought tolerance, compared with conventional irrigated and rainfed wheat. They found that transgenic plants were more productive than control plants. Conventional breeding was also used by the Egyptian researchers to introduce a gene from barley into several wheat varieties, so as to make them more drought-tolerant. Both approaches could have an impact on increasing wheat acreage in a country where only 38% of the wheat consumed is met by local production.

In 2003, a research project was initiated by Brazil's EMBRAPA (Agriculture and Livestock Research Organization) in collaboration with the Japanese Centre for Agricultural Research (JIRCAS) with a view to developing drought-tolerant soybean varieties. This collaboration that includes a funding of 6 million reais, started with an agreement on the transfer to EMBRAPA of a gene encoding the protein responding to cell dehydration (DREB), which had been patented by JIRCAS. The gene was introduced into a Brazilian soybean cultivar that was sensitive to drought, and the results were very conclusive in the trials carried out in the laboratory and greenhouse. After authorization by the national biosafety commission (CTNBio), the transgenic plants would be tested in 2009-2010 in order to evaluate their drought tolerance in field trials. The project is being coordinated by Alexandre Lima Nepomuceno from EMBRAPA and Kazuko Yamagushi-Shinozaki of JIRCAS.

Large-scale plantations of drought-tolerant soybeans, in the State of Paraná, were expected to help evaluate the productivity of the new cultivars. This endeavour by EMBRAPA follows a study showing that the soybean area in Brazil – the largest behind that of the United States – would lose about 20% in 2020, due to the increase in the average temperatures (climate change). Beans, maize, sunflower and cotton could suffer similarly. Henceforth, the urgent need for more heat-tolerant crop varieties. See: http://www.greenbio.checkbiotech.org.

The United Kingdom has donated £1 million in order to carry out with India and before June 2013, a project aimed at developing pest and drought-tolerant crop varieties. This was a significant contribution to the efforts made in India in crop biotechnology, with a view to reducing losses due to a wide range of pests, estimated at about US$125 billion, and also to helping Indian farms to adapt to climate change, particularly in western India.

Drought-tolerant maize

Transgenic drought-tolerant maize is the most advanced of drought-tolerant crops under development, as it is expected to be commercialized in the United States in 2012 or earlier. A private-public sector partnership hopes to release the first transgenic drought-tolerant maize by 2017 in sub-Saharan Africa, where the need for drought-tolerance is greatest and where maize is the staple food for more than 300 million people, a significant proportion of whom suffer from starvation and malnutrition (Edmeades, 2008).

Maize is the third most important cereal under global cultivation, after wheat and rice. Maize yields in temperate developed countries average 8.2 tons per hectare, vs. 3.5 tons/ha in tropical developing countries. In both environments drought is the most important abiotic stress constraining maize grain production. This can result in yield variation of up to 10-fold in a relatively dry year (Edmeades, 2008).

Most of the 160 million hectares of maize grown globally are rainfed, and annual yield losses to drought are thought to average around 15% of potential yield on a global basis. As temperatures rise and rainfall patterns change, additional losses of maize grain may approach 10 million tons a year, currently worth almost US$5 billion. It has been estimated that 25% of losses due to drought can be eliminated by genetic improvement in drought tolerance and a further 25% by applying water-conserving agronomic practices, leaving the remaining 50% that can only be met by irrigation (Edmeades, 2008).

The distribution and adoption of drought-tolerant germplasm are pre-requisites for a successful struggle against drought. In developed countries, adoption will depend mainly on the price of seed, super and stable yield under drought occurring any time during the growing season, and competitive yield under unstressed conditions. Where a farmer can purchase open-pollinated variety (OPV) seed from a neighbour, or retain seed from the previous harvest, seed costs are minimized, so in drought-prone environments this is often the course of action taken. The purchase of hybrid seed each crop season is an example of a cost that many small-scale farmers in vulnerable areas are unable to justify, even though it can be demonstrated that the risks of crop failure are subsequently reduced by using stress-tolerant hybrids or varieties. Average maize yields in sub-Saharan Africa are 1.6 tons/ha, suggesting that hybrids will be used on the higher-yield potential areas subject to moderate stress only. Until mean yields increase substantially, there remains a need for a diversity of seed systems that deliver drought-tolerant germplasm – including government agencies, non-governmental organizations, universities and private seed companies (Edmeades, 2008).

Hybrid drought-tolerant seeds have many benefits. Commercial seed quality and seed treatments are generally better than home-stored seeds, thus reducing risks of failed plantings. The generation and sale of hybrid maize seed, as opposed to seed of OPVs, has provided the foundation of a viable seed industry in a number of developing countries, and is considered a key step in the development of a stable seed industry.

But in much of sub-Saharan Africa, the maize seed industry cannot yet offer consistent and well-tested hybrid seed options to small-scale farmers. Another constraint is the lack of a regulatory framework for transgenic crops in many developing countries. At present transgenic crops can be field tested and marketed in a few sub-Saharan countries, and this could deprive resource-poor farmers of access to a technology that can help them improve their productivity and income (Edmeades, 2008).

Who are therefore the players in developing drought-tolerant germplasm, testing and commercializing it, particularly in developing countries and sub-Saharan (mainly for resource-poor farmers)? The private sector, the public sector and private/public partnerships.

For instance, the International Maize and Wheat Improvement Center (CIMMYT), the International Institute of Tropical Agriculture (IITA), and cooperating national programmes and seed companies have successfully used the “Mother-Baby” trial system in southern and eastern Africa as

a means of generating farmers' participation in selection, adoption and seed production. They have collaborated to evaluate and then release seed in a number of countries, and the most promising of these new drought-tolerant varieties, ZM 521, is now thought to cover 1 million hectares in southern and eastern Africa. The success of this combined selection, testing and seed distribution scheme has been the driving force behind the development and funding of the Drought Tolerant Maize for Africa (DTMA) Project. This project has ambitious objectives: within ten years, generate maize germplasm with 1 ton/hectare yield increase under drought conditions; increase average maize productivity under smallholder farmer conditions by 20%-30% on adopting farms; and reach 30 to 40 million people in sub-Saharan Africa, potentially adding an annual average of US$160-200 million of grain in drought-affected areas. Under the project, drought tolerance of a number of widely used varieties is upgraded, new varieties will be developed and on-farm variety trials are being conducted at about 400 locations in target environments. Around 80 seed companies operating in sub-Saharan Africa are actively participating in testing and marketing DTMA-generated drought-tolerant hybrids and varieties. South Africa which has a mature maize seed industry is providing advice to emerging companies in the rest of the region (Edmeades, 2008).

In South Africa, in 2009, 74% of white maize and 67% of yellow maize cultivated in the country were transgenic. One of the transgenic varieties is Monsanto's YieldGard that is resistant to the stem-borer, another one has a better assimilation rate of nitrogen, which means that a good yield could be obtained without more nitrogen input. In addition, a transgenic drought-tolerant maize variety is being tested in South Africa by Monsanto, in the province of North Cape, so as to be commercialized in 2012. The majority of South African farmers believe in the benefits of transgenic crops (Hervieu, 2009b).

Regarding the role of the private sector, Monsanto is considered to be a leader in research on transgenic drought-tolerance in maize, and is scheduled to begin commercial sales of a transgenic drought-tolerant maize variety in 2012, and this variety is now in phase III testing. The transgene was probably identified from *Arabidopsis thaliana*, and the maize homolog was then overexpressed in maize in order to provide 8% to 22% yield improvement (average 15%) under a drought stress that reduces yields by about 50%. The level of improvement depends on the genetic background of the recipient hybrid, and it probably varies with environment. It does not appear to reduce yields under unstressed conditions – an important requirement for a successful transgene in North America.

The lead candidate genes almost certainly affect the strength of the source (i.e. photosynthesis) rather than the sink (kernel setting, flowering). The regulatory approval process for North America, Japan and the European Union is under way, and permission has been given to test this event in South Africa. Additional classes of transgenes relating to abiotic stress tolerance currently being examined by Monsanto include chaperone proteins belonging to the family of cold stress proteins, CspA and SspB (Edmeades, 2008).

Pioneer Hi-Bred, in 2003-2004, claimed to have identified an effective transgene that increased kernel setting under stress occurring at flowering, but this product line has been dropped. Pioneer is now testing a possible candidate for a 2013 release. The company has good testing sites under managed stress in Chile and California, but no similarly developed locations in sub-Saharan Africa. Pioneer is collaborating with Evogene, an Israeli company specializing in computational genomics, to identify putative drought-tolerance genes (Edmeades, 2008).

Syngenta has signed an agreement with Performance Plants Inc. (based in Kingston, Ontario, Canada) for access to their Yield Protection Technology (YPT). A drought-tolerant variety would be likely commercialized after 2014. Their testing sites under managed stress are significantly less developed than those of Monsanto and Pioneer. Syngenta has a weak seed distribution network in sub-Saharan Africa (Edmeades, 2008).

Other suppliers of candidate genes include BASF, which has a research agreement with Monsanto. BASF purchased the Belgian company CropDesign in 2005 and thus had access to drought-tolerance genes for rice. Dow Chemical has allied itself with Syngenta, and may supply variants of the yield stabilizing gene coding for ADP glucose pyrophosphorylase to Syngenta for testing. Dow also has agreements with Monsanto on multigene transformation technology (up to eight genes at a time). Bayer is researching genes that reduce the drought-induced oxidant load that leads to tissue damage. In general, all these companies rely on the major seed companies to provide introgression, field testing and regulatory services (Edmeades, 2008).

Transnational maize seed companies (Monsanto, Pioneer, Syngenta, and to a lesser degree Pannar, SeedCo and Pacific Seeds) are represented in most of the larger, higher-yield potential markets of developing countries. These transnational corporations have extensive research budgets and networks for positioning products that attract research agreements with suppliers of complementary technologies, such as candidate gene

constructs. They are therefore uniquely positioned to develop and distribute high-quality transgenic hybrid seed, and to sell these hybrids in appropriate markets. The comparative advantage of transnationals will lessen only when regulatory requirements are less costly, when marker-assisted selection (MAS) becomes less expensive, and when agreements on intellectual property can be negotiated more readily. However, there is good opportunity for national seed companies to establish a market niche comprising smaller market segments, and meet national needs thanks to a balanced offer of stress-tolerant hybrids and elite open-pollinated varieties (OPVs) (Edmeades, 2008).

Regarding public/private partnerships, one important joint venture of this nature has recently been launched is eastern and southern Africa involving Monsanto as the main technology provider, CIMMYT as the source of key phenotyping sites and adapted maize germplasm, and national agriculture research programmes and seed companies as partners in testing and delivery of drought-tolerant maize hybrids. The Water Efficient Maize for Africa Project (WEMA), funded by the Bill and Melinda Gates Foundation, completed its first year of operation by the end of 2008. The African Agricultural Technology Foundation (AATF) – a Nairobi-based not-for-profit organization – will serve as the implementing agency and will spearhead efforts to ensure regulatory compliance of Monsanto's drought-tolerance transgene in target countries (Edmeades, 2008).

It should be mentioned that at the beginning of 2009 Kenya's president signed a decree on the new biosafety law that regulates the cultivation of genetically modified crops. A National Biosafety Authority has been created and will be in charge of applying the new law and spearhead policies designed in the National Policy of Biotechnology Development, approved in 2006. This new regulatory framework will be very supportive of the WEMA Project and will give a new impetus to the development and testing of transgenic crops in Kenya. This country, the fourth in sub-Saharan Africa to grow transgenic crops, is working on genetically modified maize, cassava, sweet potato and sorghum (pest and disease-resistant varieties).

The five-year WEMA Project combines new technologies directed at improving drought-tolerance in maize germplasm adapted to drought-prone regions of eastern and southern Africa, with conventional breeding for drought tolerance in maize as carried out by CIMMYT and national cooperators, using marker-assisted selection (MAS) to increase

rates of genetic gain and Monsanto's transgene designed to provide an increase of around 15% in grain yield under drought. Monsanto is providing major contributions in kind through advanced techniques in MAS, and a royalty-free concession to seed companies who wish to use the transgenic trait. Target countries are South Africa, Malawi, Kenya, Uganda and Tanzania. Impact from germplasm improved by MAS should be felt within five years, and from transgenic drought-tolerant hybrids by 2015. The WEMA Project is an important opportunity to use modern technology to address drought tolerance and make the results available for resource-poor farmers. It will also to help put in place the regulatory procedures needed to bring transgenesis technology to sub-Saharan Africa (Edmeades, 2008).

According to Vanesa Cook, leader of the WEMA Project at Monsanto, it was expected that the project, once implemented, could feed another 4.8 million people, equivalent to US$230 million of food aid, and increase the income of farmers.

The prospects are that the three approaches – conventional selection, MAS and genetic transformation – will likely be additive in effect. The first two provide a steady improvement over time, and the 15% improvement offered by Monsanto's transgene could be matched by three to five years of conventional and marker-assisted selection. If technology providers such as Monsanto, Pioneer, Syngenta or BASF are persuaded to release newly developed transgenes providing a similar boost (15%) to grain yield every five years or so, and if their effects are also cumulative (a good possibility with a complex trait like drought tolerance), then the effects of transgenes, MAS and conventional breeding for drought tolerance can result in very significant improvements in grain yield. Investments made by the private sector in the United States and Europe, matched by the public sector in China, India, Brazil and the United States, are a good prospect for achieving significant results in drought tolerance of crops and resistance to other abiotic stresses. The announcement of a US$3.5 billion investment in genetically modified crops in China over the next decade is a tangible example of this commitment (Edmeades, 2008).

New molecular biology methods are under experimentation, such as the transfer of multiple genes contained in single constructs that allow for efficient stacking of traits; the use of minichromosomes where a single heritable piece of the plant own DNA that includes the centromere region, is used to deliver several genes simultaneously. Small RNA fragments are also emerging as powerful control elements of stress response in plants (Edmeades, 2008).

"Speeding the breeding", thanks to conventional and advanced crop breeding comes at a cost. Fortunately, technology providers such as transnational seed companies have shown their willingness to share the advanced technologies, sometimes on a royalty-free basis. Linkages between suppliers and users of advanced breeding techniques have been facilitated by generous donor support, and this has been extended to the emerging seed industry in less developed areas such as sub-Saharan Africa (Edmeades, 2008).

Finally, it should be underlined that crop management methods ("good agronomy") must complement the use of drought-tolerant hybrids and will contribute significantly to increasing and stabilizing yields under rainfed conditions or under irrigation, where water supply is limited. Ensuring that planting densities are optimal, tillage is minimal, weeds are controlled and adequate fertilizer is applied at the right growth stage, all increase water use efficiency. Water supply to the crop can be raised by water harvesting methods and the use of mulch. Partial root drying, where dry and wet regimes are alternated under irrigation to reduce the volume of water supplied, can elicit a drought-adaptive response and may save up to 25% of the volume of water normally applied (Edmeades, 2008).

Elimination of farm subsidies – a hindrance to fair trade and to agrifood production in developing countries

In rich countries, particularly in the United States and the European Union, farmers have justified farm hand-outs for decades by pointing to low world prices for food and agricultural commodities. Without these public subsidies farmers claimed they would desert land. At the same time farmers from developing countries have been complaining that these farm subsidies were a hindrance to fair competition on international markets and to fair trade, because they were not subsidized and had therefore to compete with those who were cashing the difference between the international market price and their higher production costs. In addition, subsidized food and agricultural commodities imported by developing countries were cheaper than their own locally produced food, and this ruined their own smallholder agriculture. For instance, in Senegal, rice imported from Thailand was cheaper than rice grown in the southern region of Casamance, or chicken meat imported from Europe at a dumping price compared with locally raised poultry, have marginalized local farmers and subsistence agriculture.

When in 2007-208 prices for many crops reached record highs, rich countries pursued the same policy aimed at protecting their farmers. The Doha trade round negotiations failed because rich and developing countries could not reach an agreement on farm subsidies. Although the former agreed on a gradual elimination of subsidies and tariffs on agricultural imports from developing countries, both the US Farm Bill and common agricultural policy of the European Union stick to the assistance to US and European farmers. The French president, Nicolas Sarkozy, whose country chaired the council of the European Union from July to December 2008, has pushed "community preference", so as to block food imports, after asserting before his presidency that farmers should live off their earnings, not from subsidies. The European Union has adopted rules (since 1 January 2006) that indicated how imports should satisfy environmental, hygienic and animal-welfare requisites, which developing countries considered a major challenge to their capacity to comply with them (*The Economist*, 2008c).

Michel Barnier, the French agriculture minister, wanted joint European action on "food security", and insisted that feeding people was too important a task to be left to the market. His German counterpart, Horst Seehofer, dismissed the idea that the developing world would be helped by reducing European farms protection. This meant that European consumers and taxpayers will have to continue paying over €43 billion (in 2007) to support their farmers. This is bad news for poor-country farmers, who have long suffered from being shut out of rich world markers, and having products from the industrialized countries dumped on them (*The Economist*, 2008c).

It is true that Europeans have made progress in reducing export subsidies and liberalizing some markets; in 2009, for instance, the European Union became a net importer of sugar for the first time. But reformers need to continue to decrease import tariffs, which still average 23%. In 2007-2008, when European farmers earned good money, that was the best time to reduce support. If the European Union follows its offer in the Doha trade round, its farm-import tariffs would drop by just over half. Cutting them further would do more to ease food deficiency and hunger in poor countries than any foreign aid (*The Economist*, 2008c).

Regulation of the European Union on food imports

According to regulation no. 882/2004, applied since 1 January 2006, the burden of the proof of food safety should be borne by the exporting country and not by the importing one. This was considered a matter of concern

because of the cost of the required facilities and the qualified staff needed to manage the whole system. This regulation requires the exporting countries to meticulously record all procedures concerning health safety and to analyze risks at every stage of the food production chain, including the documents on the composition of foodstuffs for animals, the use of pesticides or fertilizers, as well as details of transformation and storage techniques. In other words, European Union's authorities demand the compliance with established standards of technical facilities, inspection services and staff in exporting countries, before products leave these countries (*Spore*, no. 130, August 2007, pp. 1-2).

According to the European Commission, this new system, because it clarifies what is required, should help exporting countries to implement the European Union's standards and norms. However, as the burden of the proof should be borne by the relevant national authorities rather than by individual companies, the private sector's entrepreneurs of the countries of Africa, the Caribbean and the Pacific (ACP) expressed their concern about the capacity of present governmental institutions to meet the challenge of controlling the relevant norms.

The European Union is the main trade partner of most ACP countries. The latter export to the EU agricultural and fishery products the value of which amounts to €8 billion annually. The liaison Committee Europe-ACP (COLEACP), which promotes the ACP countries' exports of horticultural products, has estimated that the new regulation would have an impact on some €3 billon of trade. This will have major implications for those countries which export most of their agricultural and fishery products, e.g. São Tome and Principe (almost 100%), Namibia (82%) and Seychelles (67%). The sector of fruit and vegetables should be mostly affected. That of fisheries should also acknowledge difficulties because it lacks the means to meet safety standards. For instance, Angola, Benin, Cameroon, Togo, Grenade and Solomon Islands were criticized for not having the adequate systems of control of the quality of fishery products. The impact on the meat sector would be less serious because few ACP countries export meat to the EU. But some them like Côte d'Ivoire, Gambia, Senegal and Trinidad and Tobago, sell foodstuffs to the EU, and they may have difficulties if the European importers strengthen their standards for overseas suppliers (*Spore*, no. 130, August 2007, pp. 1-2).

Additional expenses further to the adoption of European standards and norms could exclude some smallholders from exporting their produce, in particular niche products such as spices. In Grenada, for instance, 40% of export revenue (to the European Union) are made up by spices, while

in Comoran Islands the figure is 60%. Papua New Guinea exports about 136 tons per year, the value of which is estimated at some €3 million (*Spore*, no. 130, August 2007, pp. 1-2).

South Africa requested a revision of the phytosanitary standards of the European Union regarding its exports of fresh fruit to the Union; subsequently the European Food Safety Authority (EFSA) technical committee on phytosanitary aspects published a scientific directive on the fungus *Guignardia citricarpa*, that causes the black stain on citrus trees. Although South Africa claimed that the citrus producing-regions of Europe had a climate that does not permit the spread of the fungal disease, EFSA concluded that was not the case and mentioned that the study submitted by South Africa on climatic conditions that would favour or not the spread of the disease, had been carried out with a specialized software that had several limitations. *G. citricarpa* does not exist currently in Europe and, according to the EFSA technical committee on phytosanitary aspects, preventive measures in place in Europe were not fully efficient to control the disease and its penetration from South Africa. In fact, the committee underlined that there were many citrus varieties that could become the hosts of the fungal pathogen.

Several studies have pointed out the weaknesses of the current systems of food safety control in the ACP countries: inadequate regulation, insufficient inspection services, weak capacity of the relevant laboratories and important training needs. The European Union therefore has made the commitment to help these countries to improve their control systems. A report by Agrisystems Consortium (2006), requested by the European Union on the implications of the new standards for the ACP countries, has proposed a series of measures aimed at training more technicians and supporting the laboratories that perform quality and safety control tests. The report also underlined the need to develop a public/private partnership in order to meet the EU's norms. Several initiatives supported by the EU are in fact assisting developing countries, e.g. a €30 million programme for the adaptation to the new standards and norms, the Pesticide Initiative Programme (PIP) of COLEACP, the Programme for the improvement of safety of fishery products, and the PanAfrican Programme for the Control of Epizooties (*Spore*, no. 130, August 2007, pp. 1-2).

A study carried out in 2003 concluded that the cost of national efficient measures for the control of food safety amounted to about €2million per country. Indispensable regional bodies would cost about €5 million each. Finally, COLEACP has estimated at €120,000 the cost of a training

programme and at €3 million that of a fully equipped laboratory. The main financial burden will probably be the maintenance costs of the laboratories and relevant institutions that have been set up (*Spore*, no. 130, August 2007, pp. 1-2).

While several organizations, including the World Bank, have stated that the implementation of the new regulation would improve exports in the long term, further to building trust in the food distribution systems, farmers of the ACP countries fear that the cost of this regulation would be too high for them to bear.

The United States' Farm Bill

The 2007 Farm Bill that the US Congress delivered in May 2008, several months late, to President George W. Bush was expected to distribute US$307 billion to farm households over five years. The main restriction on collecting subsidies was a means test that applied to couples making more than US$1.5 million a year. The Bill's authors tied some future subsidy payments to 2008 record commodity prices, therefore guaranteeing already well-off farmers high incomes. Commercial farm households, which received most of the subsidies, had an average income of US$229, 920 in 2008, according to the agriculture department. And it meant that the government could owe billions in subsidy payment to these big farmers if and when commodity prices dip again (*The Economist,* 2008d).

American sugar producers, for instance, are guaranteed 85% of the domestic sugar market, according to the Bill. This measure will drain US$1.3 billion over ten years from the federal budget and will force consumers to pay an extra US$2 billion a year in higher sugar prices. In addition, the Farm Bill leads to trade disputes: Brazil was already considering a World Trade Organization suit over the barriers to bioethanol produced from sugar-cane and exported to the United States. The US Congress has also declined to soften a rule requiring the government to buy all foreign food aid from US farmers and transport it on American ships (*The Economist,* 2008d).

Those who backed the Bill in Congress were promised support for the purchasing power of food stamps, which had declined since the 1990s. Subsidies were obtained for fruit and nut growers in the western States, and even tax breaks were granted to the racehorse industry in Kentucky. The US president vetoed the Bill on 21 May 2008, but the Bill won so much support in Congress that the legislative branch gathered enough

votes to override him, thanks to Republicans voting with Democrats against their own president. The policy of heavy subsidies to US farming will continue and will not contribute to the international fair trade of agrifood commodities (*The Economist,* 2008d).

In 2009, the supporters for farm subsidies argued that tumbling commodity prices, tight credit, the halt of bioethanol expansion due to cheaper petrol, justified the aid to US farmers. But this is all relative. For instance, in the case of Iowa, the gloom due to economic crisis has been only relative: Iowa's unemployment rate has risen, but it was still only 4.9% in February 2009, while the national average was 8.1% (8.5% in April 2009). The situation in Michigan was worse. Iowa's economy, like those of other States of America's plains, has expanded rather slowly; it grew by 25% in the decade to 2007, compared with national growth of 33%. Before the recession, bioethanol production rose from 440 million gallons (1.67 billion liters) in 2002 to 2 billion gallons in 2007. A weak dollar boosted demand for Iowa's goods and the State's exports grew 28% in the year up to the first quarter of 2008 (*The Economist*, 2009c).

Iowa's economic base had also broadened. In 2007, manufacturing, services and government were the three biggest sectors, with finance and insurance a close fourth. State officials were trying to attract bioscience and information-technology companies too, with considerable success. But since May 2008, Iowa has succumbed to the national economic slump. Non-farm employment fell by 22, 400 in the year to February 2009, with 17, 400 jobs lost since October 2008. The heaviest losses have been in manufacturing of durable goods such as John Deere farm machinery. In 2008, two bioethanol companies filed for bankruptcy and others have slowed down production; but the most efficient bioethanol plants will survive, although the industry was "overbuilt" (*The Economist,* 2009c).

Nevertheless, Iowa was not drowning in the recession. Non-farm employment has dropped by only 1.5% since February 2008. Manufacturers of machinery have suffered, but Iowa's food processors remained relatively wealthy. At US$4 a bushel, maize prices were still 75% higher than the 20-year average. Though Iowa might lose more jobs, it was well positioned to bounce back. And albeit Iowa's leaders remained bullish on ethanol, the State was supporting other renewable energy projects through a new Iowa Power Fund that supported wind energy production (*The Economist,* 2009c).

The European Union's Common Agricultural Policy

The European Union is a big agricultural power. In 2007, eight countries produced 80% of total crop output: in billions of euros, France's share amounted to €37.4 billion, Italy €26.1 billion, Spain €24.3 billion, Germany €22.5 billion, Netherlands €11.6 billion, Poland €10.4 billion, United Kingdom €8.9 billion and Roumania €8.6 billion. Regarding animal production, seven countries produced 73% of the total estimated in billions of euros: France €23 billion, Germany €20.6 billion, Spain €14.1 billion, Italy €14 billion, United Kingdom €12.2 billion, Netherlands €9 billion and Poland €8.2 billion (*Le Monde,* 1 July 2008).

The Common Agricultural Policy (CAP) that subsidizes European farmers has been for a long time the main item of the European Union's budget, amounting to €42.7 billion in 2007. But this amount has been frozen in 2002 and until 2013, despite the widening of the Union to new member States. Of this total, in 2007, France received €9.2 billion, the biggest amount, and being the first agricultural powerhouse of the Union. Spain received €5.9 billion, Germany €5.6 billion, Italy €5 billion, United Kingdom €4 billion, Greece €2.7 billion, Ireland €1.4 billion, Netherlands and Denmark €1.1 billion each and Poland €1.2 billion (*Le Monde*, 1 July 2008).

It should be emphasized that the share of agriculture in the gross domestic product is higher than 3% in Spain, Poland, Roumania, Bulgaria and Greece, between 2% and 3% in France, Netherlands, Italy, Denmark and Lithuania, between 0.5% and 1% in Germany and Ireland, and less than 0.5 % in the United Kingdom (*Le Monde*, 1 July 2008).

Evolution of subsidy policy

Largely gone are the days when the European Commission in Brussels set prices and paid billions of euros to buy up excess production to be stored in Europe's legendary "wine lakes" and "butter mountains", later on to be dumped on world markets at a price far below their production cost. Now the European Union spends on subsidies nearly €43 billion each year, even though it has expanded from 15 to 27 member States. Export subsidies for sugar, milk and beef have been pared back from about €10 billion per year in the 1990s to €2.4 billion in 2006, and may be phased out altogether by 2013. As of 2004, most subsidies were no longer tied directly to the production or export of specific crops. Now farmers have an incentive to grow only what is most profitable, not what will draw the highest subsidy (Theil, 2008).

As a result, EU's exports are falling rapidly in sugar, poultry, cereals and other raw or nearly raw goods. But rising shipments of finished products like sausage and ham have helped Europe to become the biggest agricultural exporter, ahead of the United States. In the case of dairy products, since the EU drastically cut export subsidies, the EU's share in the global trade of dried milk powder – a relatively cheap commodity used in food manufacturing or baby milk formula – has plummeted from 50% in 1999 to 27% in 2007. Much of that milk is now processed into higher value cheese to feed a booming global market, now that the growing middle class of Asia, Russia and the Middle East are consuming more Gouda, Parmesan and Camembert. With its strong brands and efficient supply chains Europe has expanded its share in the global cheese trade from 35% to 42% since 1999. Of all the major agricultural powers – including the United States and Brazil – the European Union has become the least dependent on the sale of interchangeable bulk commodities, which can be grown more cheaply in the developing world. The figures for commodities are 7 % for the EU, 37 % for the United States and 28 % for Brazil, compared with 67% for finished products for the EU, 43 % for the United States and 44 % for Brazil (Theil, 2008).

Change in policy regarding wasteful subsidies is opposed by farm groups and big agro States like France and Spain, while new figures show that 80 % of the aid goes to the largest 20 % of farms, thus nullifying the argument that the aid is needed to support small, traditional farmers. And time seems to be helping reform. When the 12 new member States' farm and development subsidies are fully phased in, many of the richer Western Europe countries that used to be net beneficiaries of EU funds will have become contributors – at which stage they will be keener to contain costs. That includes France, the strongest opponent to reform so far (Theil, 2008).

In fact, it is hard to see how the European Union's biggest budget item (34% of total expenditure) can escape a drastic reduction, when the EU needs more spending on military security and regional development. In March 2008, Sweden, which was to hold the EU presidency during the second half of 2009, became the first to call for the complete abolition of agricultural subsidies (Theil, 2008).

When the global food crisis hit Europe, its leaders claimed to be deeply concerned by the impact of soaring food prices on the "vulnerable" at home and abroad (see the conclusion of an EU-Latin America summit on 16 May 2008). Yet in Brussels several agriculture ministers called for the retention of policies that make food in Europe expensive. Michel Barnier, the French minister, stated that the food crisis was an excellent reason to

"preserve" Europe's capacity to produce food. But not any food. "I do not believe in industrial farms", explained M. Barnier, and he added that consumers wanted farms in every corner of the land, no matter how remote, and "a varied diet with lots of local produce, full of colour and taste". Several governments seem to argue and, for instance, most of them wanted to keep a ban on imports of American poultry washed in chlorine, to remove pathogens picked up during intensive rearing. Ministers discussed, but failed to agree on a move to ban whole classes of pesticides, further to pleas from the United Kingdom that this would cut wheat yields by 20 % to 30 %. And several countries expressed disquiet about phasing out milk quotas that limit production (though abolition must wait until 2015). It also suggests ending remaining subsidies linked to production, in favour of payments for tending the landscape while choosing what to grow. Most of these ideas will be gradually adopted in some form, albeit watered down (e.g. governments will still be allowed to subsidize farmers to rear sheep and goats on nice, if unprofitable, mountainous areas) [*The Economist*, 2008d].

For instance, on 16 July 2007, the European Commission had proposed to authorize farmers to cultivate their whole arable lands from the fall of 2007 to the spring of 2008, with a view to increasing farm output and decreasing the tensions on the cereal market, due to a lower 2006 harvest and a rise in demand. This proposal was welcomed by France, Germany, Poland, Spain and Sweden. For the European commissioner for agriculture, Marianne Fischer Boel, keeping fallow land that dates back to 1992 has become obsolete since the CAP reforms have permitted to limit overproduction. In addition, at the global level, there has been a deficit of cereals for several years. Consequently, two reasons led EU's member States, such as France, to request an increase in agricultural production: world stocks were at their lowest level (for 30 years in the case of maize and for 12 years in the case of wheat), and a worsening of the situation was always possible. All countries wanted to rebuild those stocks in order to prevent soaring prices. In addition, increasing production and availability of commodities for the agrifood industry would have a positive impact on the consumers (Clavreul and Ricard, 2007).

However, if 10% of agricultural land is kept fallow in the EU, one should not expect an increase in production of the same order when this area is cultivated. Because part of fallow land would contribute to agrofuel production and another part is devoted to environment protection in the form of mandatory strips of grass along rivers and of fauna reserves. Finally, the plots which are kept fallow, are the least productive, and farmers will not be so interested in cultivating them; in addition since 2006 they have been cashing aid, whether or not they cultivate their land,

because of the "decoupling principle". Consequently, about half of the 3.7 million hectares of fallow land existing in the European Union would be cultivated, their output being estimated by the French agriculture ministry at an additional 10 million tons of cereals. This would not be significant at global level, but on local or regional markets a few million tons could have an impact on price variation (Clavreul and Ricard, 2007).

More ominously, France and other countries that support the CAP have won a clause allowing CAP money to be spent on state-funded insurance for farmers hit by bad weather or disease. Senior officials stated France wanted to turn them into American-style income insurance for farmers, in which the public pays out when prices fall. But rising prices and income should mean that bigger cuts in the CAP (as well as in the US Farm Bill) are possible, but the strong supporters of the CAP sent a quite different signal: even when farming is profitable, subsidies are still wanted to boost production (*The Economist*, 2008d).

Community preferences

France and Germany are demanding that foreign competitors must apply EU rules on hygiene, animal welfare and labour laws, or face import tariffs. Defenders of this "community" preferences claim to be working for the benefit of consumers. But *The Economist* (2008d) considers that is unconvincing: if food were genuinely unfit for consumption, it should be banned, not taxed at the point of entry to make it expensive. Demanding food safety from foreign rivals is fair enough, stated Sweden's agriculture minister, Eskil Erlandsson, as is objecting if they use child labour. But if Europeans wanted to produce food in a special region or way, "let them label it, and see if the market will pay for it". If it does not, EU governments should not impose their own high-cost model on the rest of the world (*The Economist*, 2008d).It is true that high tariffs that restrict imports from developing countries, are still in place.

Nicolas Sarkozy was the first French president to call a major reform of the subsidy system. Speaking in March 2008 at the Paris Farm Fair, he told farmers they must become entrepreneurs and not just work for subsidies. But he also called for new "community preferences" and "true market stabilization policies", which can only mean more regulation. This underlined how politicized agricultural issues still are. But the growing benefits that EU's farmers are reaping from markets and trade could change the situation (Theil, 2008).

For instance, after the EU cut back its sugar subsidies, one-third of the land devoted to sugar-beet has gone out of production. Most EU countries have also stopped the subsidies for beef, which paid farmers once for each head of cattle, again for each animal that was slaughtered and a third time to export the beef abroad. Since the end of this triple-aid, some of the least productive livestock farmers (often those with the poor grazing lands and dependent on costly grain for feedstock) have dropped out. Livestock numbers in Ireland, Scotland and Germany have decreased, while beef imports from Brazil and Argentina were rising. In France, milk production is being shifted from the less productive southern regions to the richer pastures of Brettany. In this region, powerful dairy conglomerates have come to dominate the multibillion-dollar global cheese and yoghurt trade, while small cheesemakers ship their Brie and Camembert to gourmet stores of Paris, London, and, increasingly, Moscow and Shanghai. Lactalis, Europe 's biggest cheese and dairy group, has seen it subsidies cut by 88%, but it is doing better than ever before; it sells its Président-brand cheese and butter in 165 countries and cashes 55% of its €9-billion annual turnover abroad. Most of EU's dairy giants like Campina and Nordmilch were heavily subsidized, exporting bulk milk powder at a price guaranteed by the EU. But, as in the case of Lactalis, things are changing and they have to compete better with much less subsidies (Theil, 2008).

These changes lead to winners and losers. Large farms find it easier to plan and invest, while small farms are under pressure. However, it is not just the big farms and conglomerates that are penetrating new markets. Smaller farms can find incentives in growing horticultural plants and herbs. In the Italian city of Parma, the 171 families that form the consortium of Parma Ham, have translated their tradition into a US$2 billion global business, appealing to a growing number of gourmets in the industrialized and emerging markets. Exports to the United States alone soared by 24% in 2007. Slow food, the Italy-based organization promoting organic foods and local production, stated its members were capitalizing on growing demand for regional foods and traditionally made specialty products – a niche market, but a growing one that proves that farmers can stick to tradition and still have a decent income. It should not be hidden, nevertheless, that globalization and competition will force many farms out of their activity: one EU official estimated that another 3 million of Europe's 13 million remaining farmers would give up by 2012 (Theil, 2008).

Legitimacy of farm subsidies

The discussions on the reform of the Common Agricultural Policy (CAP) raise the overall issue of the legitimacy of farm subsidies, which has been and still is at heart of the tedious negotiations at the World Trade Organization. The opponents consider that US food aid and farm subsidies in both the United States and the EU member States are a major hindrance to the development of agriculture in the developing countries and to their export capacities (in addition to tariffs imposed on their products entering the United States and the EU). This bone of contention has been the main reason for the failure of the world trade negotiations (Doha Round).

The supporters of subsidies consider that this assistance is legitimate as it enables the development of agriculture and guarantees food security. With respect to CAP, European farmers fear that it may be dismantled in the medium term, while the European Commission wants the farmers to be more reactive to market opportunities. Thus, when commodity and food prices soared in 2007-2008, the amounts of funds cashed by the farmers decreased. According to a report of the Organisation for Economic Cooperation and Development (OECD) published on 26 June 2008, the share of subsidies in the farmers' income in its member States (United States, EU, Japan, Australia, etc.) had decreased in 2007 for the third consecutive year. This share – 23% - had never been so low since OECD had been compiling the relevant data, i.e. over 20 years (the share amounted to 37% in 1986-1988). But while in the past the decrease in the proportion of subsidies in the farmers' income was due to changes in the agricultural policies themselves, in 2007 the main reason was the rise in commodity and food prices (Clavreul, 2008d).

As the OECD has estimated that these prices will remain high during the forthcoming decade (despite the fall observed in 2009), it requested its member States to seize the opportunity of the increase in farmers' income in order to pursue the reduction of subsidies. OECD's experts stated: "not to seize the opportunities for reform would result in extending governmental measures that upheave the markets". They nevertheless reckoned that efforts had been made to link subsidies to good environmental practices and to disconnect them from production options (Clavreul, 2008d).

By mid-2009, the CAP, created 50 years ago with the objective to ensure the food self-sufficiency of the Old Continent, was still a matter of a harsh debate, e.g. between France and the United Kingdom on the

importance of its budget, or between farmers who are often very critical of the policy. The CAP, with €55 billion in 2008, remains the first item of the European Union's budget, and many consider that it is costly, inequitable, inadapted and even useless. In France, for instance, there has been during the winter of 2009 a conflict between cereal producers and livestock raisers about the government's measures aimed at establishing a fair balance of subsidies, in order to "relegitimate" the CAP. Cereal producers will receive less farm subsidies, while those who were considered forgotten, e.g. biological or organic farmers, sheep herders and owners of livestock raised on grass pastures, will see an increase in their income (Clavreul, 2009d).

Thereafter, there has been the publication of all kinds of aid delivered by the CAP – a mandatory measure decided by the European Commission. Thus it was realized that in France – the main beneficiary of the CAP – among the farmers who received most of the subsidies, i.e. €9.5 billion of a total €10.4 billion, 10% received 36% of the aid, i.e. more than €50.000 per year each, whereas 30% received only 2.5% or less than €5.000 per year each. This publication may help accelerate a fairer distribution of aid, in addition to letting everybody know who receives how much and who abuses the system of aid. But it means above all a clearcut progress towards transparency (Clavreul, 2009d).

In this regard, a study published on 7 May 2009 by Farmsubsidy.org, an association which promotes transparency of farm subsidies, has analyzed the publication of all the CAP's beneficiaries. The surprising result was that although France remained the main beneficiary of the CAP, it was not there where the greatest number of millionaires benefiting from the policy was found. It is in Italy where one finds 180 millionaires out of a total of 710. Spain follows suit with 165, France with 142, the Netherlands with 47, Belgium with 22 and Ireland with 6. It is also Italy which was at the top of the list of the biggest subsidies in 2008: two sugar-producing groups, Italia Zuccheri and its competitor Eridania Sadam, received €139.8 million and €125.3 million, respectively. This was due to the restructuration of the sugar production sector, decided by the European Commission in order to reduce an excessive production, and which led to the delivery of subsidies to those who closed down their factories (Clavreul, 2009d).

One should underline that such transparency has been achieved after years of campaigns by associations and the media, thus demonstrating that CAP was a public policy funded by all the European tax payers who have the right to be informed fully and correctly. These publications also showed that CAP is not just a matter of specialists, but that it concerns all

citizens who can realize that it is not only about agriculture but also about food, economics and land use management. For instance, CAP allocates subsidies, though small, to charity associations or food banks which buy food for poor people. More questionable, are subsidies for exports, e.g. the French poultry group Doux, which has received about €63 million in 2008. Even though industrial companies claim that exports create or maintain jobs, tax payers may question the legitimacy of this kind of aid, when one deals with the export of surpluses, with the negative impact it entails for developing countries' agriculture. It is true that subsidies for exports have decreased markedly and many think that they should disappear (Clavreul, 2009d).

Some analysts therefore consider that CAP should be reformed, but not be condemned as a whole. After having been an important tool for the modernization of agriculture in Europe, it now protects rural areas and preserves their future as areas of sustainable agriculture; it helps them to adapt to climate change and it is a guaranty for food safety. CAP cost is high, but its share in the EU's budget has fallen to 40% in 2008 from 70% in the 1970s. It seems to be the only real common policy. It obviously need reforms and improvement in order to correct its aberrations and bureaucratic slow pace of change, but some are of the opinion that CAP protects European consumers, and not only the farmers through ensuring their food security in addition to keeping food prices more stable than elsewhere (Clavreul, 2009d).

To sum up, the legitimacy of assisting European farmers remains an issue, particularly during a period where commodities and food prices would remain relatively high, or at least volatile. At the global level and particularly in developing countries where agriculture is not subsidized and is an important source of income (locally and/or through exports), CAP as well as the US Farm Bill are criticized, and they are hampering the conclusion of the Doha round of international trade negotiations. France defends the retention of the Common Agricultural Policy and it is worth knowing and understanding its arguments.

French agricultural policy

France is, behind the United States but ahead of Canada and Brazil, the world's second-biggest exporter of agrifood products. It is also the first producer in the European Union and even though agriculture contributed only 3.4% of gross domestic product in 2007, it remains a strategic asset and its modernization is being pursued with the help of the state and that of the Common Agricultural Policy (CAP). With 567,200 farms

and agricultural enterprises and over 1 million of people employed in the sector (and 2.6 million jobs associated with agriculture), France has become self-sufficient in some agrifood chains. Every French farmer feeds 60 persons. The 13,000 enterprises of the agrifood chain (i.e. agriculture, fisheries, sylviculture and agrifood industries) had an annual turnover of €145 billion in 2007, i.e. the equivalent of the sales of 500 Airbus planes (Toustou-Chelidze, 2009).

At the 2008 Paris Farm Fair, Michel Barnier, minister of agriculture, emphasized that France will implement a "plan for sustainable and responsible fisheries", as well as a plan named "Ecophyto 2018" that aims at halving the use of pesticides over 10 years, and the plan "Biological Agriculture" that will foster the trebling of areas devoted to this kind of agriculture from 2008 to 2012, or the "Plan for Energetic Performance" that aims at reducing the energy consumption of farms. The ministry published a document titled "Objective Lands 2020" that describes this innovative strategy (Mamane, 2009).

Regarding organic or biological agriculture, the ministry's plan is ambitious: trebling the areas devoted to this kind of agriculture in five years. But the market of bioproducts has had an annual growth rate of 10% over the last 10 years. One of the measures of the "Biological Agriculture" plan is to help the structuration of the bioproduct chains : €15 million over five years. For instance, bioproducts will be incorporated to foods served in state-subsidized collective restaurants (20% in 2012); regional bioproduct chains will be supported. The plan also intends to support farmers who wish to move from intensive agriculture to organic agriculture; a farmer can sell its products under the label AB (Agri Bio) only two to three years after converting its land; consequently, the agriculture ministry has increased by 55% the budget concerning agro-environmental measures (+ €36 million over three years) and cancelled the threshold of €7,500 per farm that limited the amount of this kind of assistance. In addition, as of 2009, organic farmers will be offered tax exemption on €4,000 instead of €2,000 (Mamane, 2009).

One should recall that even though the number of organic farmers has trebled and that of the cultivated hectares has been multiplied by five since 1975, France's organic agriculture represents only 1.8% of arable land and involves 2% of all the farmers (2007). It does not even meet national needs and France imports bioproducts. The overall objective of the plan is to enable all the actors of the agrifood chain to reach a critical size in order to overcome their high costs and supply difficulties.

The major handicap of organic agriculture is both the price paid to the producer and that paid by the consumer (Clavreul, 2007e).

Another strong aspect of the French agricultural strategy is the support for agrifood exports (one-third of French production is exported) through three main series of measures: renewal of the modalities of support, implementation of a sectorial plan for agrifood export and conclusion of agreements with several countries in order to foster trade. In addition, the government helps young farmers to set up their enterprises: every year, 16,000 people start an agricultural enterprise and 10,000 of them are less than 40 years old. They receive a lump sum when they start and they will be allowed to adapt their training to their professional projects. In the case of young farmers in mountainous regions, the threshold of the lump sum has been increased from €55,000 to €70,000. In 2008, more than €350 million from the national budget and EU's aid (CAP) has been devoted to helping farmers to initiate their project (Mamane, 2009).

How France matches its medium-term agricultural policy objectives with the adaptation to the CAP reform decided in 2003, and to the reform foreseen in 2013? At the end of 2007, the European Commission made a number of proposals aimed at orienting production more towards market needs, through a limitation of regulation mechanisms (quotas, fallow land, buying out of unsold stockpiles, subsidies to a chosen type of production, etc.). France which remained in 2008 and 2009 the main beneficiary of farm aid (some €10 billion) wanted to open the debate on the CAP reform expected in 2013 without waiting for the discussions on the EU's 2010 budget. In so doing, the French agriculture ministry wanted that financial decisions be made on the basis of a political vision and not the other way round. In other words, France wanted to go much further than just mending CAP, but to achieve an in-depth reform (Clavreul, 2008a).

Regarding the missions of the CAP, France stresses that it is not just a policy for farmers, but that it should be called a common food policy, whose objective is to feed 500 million Europeans. This view is generally supported, as well as the refusal to use, as proposed by the European Commission, direct aid funds (the first pillar of CAP) to finance rural development and environment preservation (the second pillar) [Clavreul, 2008a].

With respect to regulation tools, there is a need to stabilize the markets in order to protect farmers against the fall in prices as well as the consumers against their rise, e.g. in 2008. Volatility of prices that will be more prevalent

with climate change is considered a threat, and there is a debate on the kind of mechanisms for crisis management and on individual insurance that would replace the current tools (Clavreul, 2008a).

The elimination of milk quotas foreseen in 2015, but which the European Commission already wants to decrease, is also an issue. France is afraid of the concentration of milk production in the western part of the country and of the disappearance of jobs from several areas (where environmental problems could occur, because cows maintain pastures). Finally, French farmers are particularly worried about the impact of total decoupling of aid (i.e. there will be no more linkage between subsidies and the choice of production), which is the European Commission's goal. In 2003, France chose a partial decoupling. Many think that if the market is the only stimulus, all farmers would produce the same thing, e.g. cereals. In France, because of the need to achieve food security, there should be a variety of agricultural produce (Clavreul, 2008a).

The French agriculture ministry wants to change the options taken in 2003 for the calculation of farm aid. It wishes to find a better balance in the distribution of that aid towards productions that need it most, e.g. organic agriculture or sheep raising. But this idea worries cereal producers, while some economists are of the opinion that in the future the sector of large-scale crops should be completely liberalized and farm aid be focused on livestock rearing, which is more vulnerable (Clavreul, 2008a).

France remains a big producer and exporter of wheat. In June 2007, wheat production has been estimated at 35-36 million tons, but late rainfall in July brought down this forecast to only 31.5 million tons, compared with 37 million tons one year earlier. Of this harvest, 4.7 million tons were to be exported. World wheat production was about 602 million tons, out of which 105 million tons were expected to be traded on a global scale. France exports large quantities of wheat to North Africa and the Middle East, which generally suffer from a cereal deficit. For instance, French exporters deliver an average 800,000 tons of wheat per year to Morocco; this amount fell to 396,000 tons in 2006 – an exceptional agricultural year. But in 2007, due to drought, Morocco had to import 3.3 million tons of soft wheat, and France was a major supplier (Oudoud, 2007).

Maize cultivation in France has soared from 300,000 hectares after the second world war up to 2 million hectares in 1975, and the crop is found throughout the country. However, maize grain growers had to reduce

the cultivation area by 500,000 hectares over three years, due to possible lack of irrigation water (Clavreul, 2007b).

The extension of oilseed-rape (colza or canola) throughout France illustrates how the agricultural landscape changes according to new outlets and commodity price variation. Due to agrofuel production (biodiesel), oilseed-rape cultivation reached two records in 2007: 1.572 million hectares (plus 12% in 2007, after a 14% increase in 2006 and 9% in 2005); it is the fourth large-scale crop, behind soft wheat (4.87 million hectares), maize (grain and fodder, 2.84 million hectares) and barley (1.69 million hectares). The second record was that for the first time in 2007 areas devoted to agrofuel production (870,360 hectares) were larger than those cultivated for the production of edible oil and export (701,640 hectares). In 2008, however, soaring wheat prices enticed farmers to reduce the acreage of oilseed-rape. This kind of change occurred during the early 1980s when farmers grew soybeans and thereafter abandoned the crop, or by the end of the 1990s when malting barley varieties offered good market opportunities, but this is less the case nowadays (Clavreul, 2007b).

While some 40,000 to 50,000 hectares could be planted with oilseed-rape in the south-west of France, it is in the north that the crop could be extended significantly. Another obstacle to the expansion of the crop is the fact that, contrary to maize, it should be grown within a three-year crop rotation; otherwise, the risks of disease increase. Specialists estimate that oilseed-rape area should reach 1.6 to 1.7 million hectares in 2010, while new energy-producing crop species such as sorghum and miscanthus, could appear in the French rural areas (Clavreul, 2007b).

CASE STUDIES

India's agricultural progress

Indian food grain production has reached 230 million tons in 2008, compared with 190 million tons in 1998 and over 210 million tons in 2004, the average yield having reached 1.85 tons per hectare, compared with 1.55 tons/ha in 1998. Over the period 2002-2007, the average annual agricultural growth rate change has been +12.5% in Gujarat, +8% in Bihar, +8% in Rajasthan, +5% in Andhra Pradesh, +4% in Madhya Pradesh, 2.5% in Punjab, 2% in Uttar Pradesh and 2% in West Bengal (Kazmin, 2009).

When India elected a new parliament in 2004, middle-class city-dwellers were euphoric over their country's global recognition as an emerging economic and political power. But rural people, about 65% of total population, were reeling from a drought in 2002-2003, which led to a 7% contraction in agricultural production (the average yield per hectare of food grains fell down to 1.525 tons per hectare and overall production to 175 million tons). A milder drought followed just two years later. Farmers expressed their distress and anger by voting against the incumbent Bharatiya Janata Party (BJP)-led coalition, leading to their defeat (Kazmin, 2009).

Much of rural India's current relative good situation is due to bountiful rains that have boosted agricultural production. High global commodity prices forced the government to raise official procurement prices: 1,700 rupees per quintal of lentils in 2008, 1,000 rupees per quintal of wheat and 650 rupees per quintal of rice. But the Congress-led government also pushed state banks to increase rural lending, waited US$14 billion in farmers' debts and adopted a law that gives one adult from every rural household 100 days of guaranteed paid labour a year. Together, these measures have helped raise the incomes of many households with sufficient farmland to generate an agricultural surplus, although millions of landless labourers still live in extreme poverty. The benefit to

larger farmers of high global commodity prices was capped by export bans the government imposed on many staple agricultural products (Kazmin, 2009).

Agricultural progress was accompanied by the improvement of farmers' standard of living, as demonstrated by the surge throughout rural India of sales of mobile phone connections and motorbikes. In April 2009, during the parliamentary elections, the Party of Congress has been struggling to convert rural India's relative buoyancy into votes (Kazmin, 2009).

A few weeks after its victory, the Party of Congress and the coalition it formed to govern India presented to the Parliament a law aimed to eradicate hunger in the country. The "law of national food security" enforced the monthly distribution of 25 kg of rice or cereals, at a price of less than €0.05 per kg, to the 65 million families living under the threshold of poverty. Although India is the world's second-biggest rice producer, it is home of one-third of the global population suffering from undernutrition. According to a report published by UNICEF (United Nations Child Fund) on 2 June 2009, 40% of children born in India were underfed (Bouissou, 2009a).

In 2002, Sonia Ghandi, president of the Party of Congress, had denounced that untolerable situation. Seven years later, and despite an average annual economic growth of about 8.5%, the situation remained dramatic. The public distribution system, launched in 1992, aimed to supply food to the poorest; but, according to an audit carried out in 2005 by the agriculture ministry, only 20% of the 400 million Indians that were targeted by the system had access to it; the system cost €4 billion per year. Bureaucracy and corruption were largely responsible for that failure (Bouissou, 2009a).

The government decided to eradicate the corruption that was undermining the public distribution system through aligning it on another programme launched in 2005: the National Rural Employment Guarantee (NRG). The latter guarantees 100 days of work to the poorest rural families and the beneficiaries are entitled to demand their allocation of work to the head of their village. It has therefore hoped that staple food will reach the poor more effectively and at the fair cost. But this will not be the end of the struggle against hunger, because as stated by Monkombu Swaminathan, "food security is an illusion without access to drinking water". In 2009, there were still 125 million Indians that had no access to potable water (Bouissou, 2009a).

Over the period June to September 2009, the monsoon rains that generally bring 90% of rainfall across India, have been insufficient : 29% less than the seasonal average. Of the 626 Indian districts, 177 were stricken by drought, that may be the worst in the last 20 years. This exceptional situation could worsen the difficulties of the agricultural sector – the source of living for 60% of Indian population. For instance, drought will increase the overconsumption of underground water, when the country is already suffering from a water crisis. Nine States of the Indian Union have been affected by the 2009 drought. In Bihar, one of the most affected, farmers were protecting their irrigation sources with guns, and this State was requesting €3.3 billion from the government in order to overcome the crisis. In a district of Uttar Pradesh, farmers were leaving their lands and moved to New Delhi. While trying to cope with the impact of the drought, the Indian government stated there would be no food crisis, because the stockpiles of wheat and rice amounted to 51 million tons (Bouissou, 2009b).

Cultivation of Bt cotton and "cotton suicides"

Over the 18-month period (June 2005 - December 2006), more than 1,200 farmers in the cotton bowl of India (Vidarbha, the north-eastern corner of the State of Maharashtra) had taken their own lives to escape debt to money-lenders. This was widely blamed for the previous government's defeat in the 2004 election and overshadowed India's position in the Doha Round of global trade negociations, where it heads a group of more than 40 poor countries that want to shelter their farmers from foreign competition. In 2006, Oxfam, a charity organization, published a study arguing that the farmers' plight was worsened by their "indiscriminate and forced integration" into an "unfair global system" (*The Economist,* 2007).

The Vidarbha suicides have many causes, most of them homegrown, stated M.S. Swaminathan, the father of India's green revolution. The farmers borrowed money at punitive rates, so they could drill wells and buy costly "biotech" cotton seeds. But diesel for the pumps leapt in price, and the seeds proved ill-suited to small plots, mostly rainfed. If the crop fails, "a man loses hope", said M.S. Swaminathan; "he has the money-lender waiting at the door every day and taunting him". None of this is globalization's fault. But farmers have also been hurt by the low world price of their crop, which has fallen by more than a third since 1994. In 2006, the State government cut the guaranteed price it paid for cotton from about 2,000 rupees (US$56) per 100 kg to 1,750. Prices were low partly because cotton was heavily subsidized by rich countries,

principally the United States. The Doha round aimed to cut these handouts "ambitiously" and "expeditiously". If they were cut completely, it might add about 13% to world prices, according to one estimate by two World Bank economists. A more likely scenario, in which cotton subsidies were cut by a third (and export subsidies eliminated), would add less than 5% to the price (*The Economist,* 2007).

In the meantime, India's government could impose a "countervailing" tariff on dumped cotton. But cheap fibers were advantageous for the textile industry, which was keen to take advantage of the end, in 2005, of the old quota regime. India's cotton tariff was just 10%, much lower than its tariffs on other commodities such as sugar. And exporters of yarn and cloth did not even pay that. Cheap cotton kept the textile mills humming: were subsidies to be removed, India would lose out overall by the equivalent of about US$84 million, according to the World Bank economists (*The Economist,* 2007).

Regarding the accusation made by some environmental non-governmental organizations that the farmers' suicides in Vidarbha were due to the failure of harvests after sowing genetically modified cotton seeds (*Bt* cotton), it seems in fact that the seeds that caused harvest failure were smuggled seeds which were not the GM ones. Although one cannot exclude crop failure even when using certified GM seeds, because of weather conditions and unusual pest invasion, the record of *Bt* cotton in India is a good one. Yields have increased and the use of pesticides has decreased, thereby reducing the number of intoxication cases among farmers. In addition, as mentioned earlier (see p. 184), since March 2009 a new transgenic cotton variety, developed by the Indian Council for Agricultural Research (ICAR), has become available to Indian farmers; that is particularly interesting for those of them who practise dryland agriculture, like in Vidarbha. The Bikaneri Nerma (BN-*Bt*) pest-resistant cotton variety was made available to farmers at a reasonable price through the Central Institute for Cotton Research (CICR), State Agricultural Universities, Agricultural Technology Information Centres, as well as through public and private seed corporations. These measures will certainly prevent the smuggling of seeds to a large extent.

In fact, the Vidarbha lamentable situation and farmers' distress should be put in the context of great poverty that still strikes the rural world in India. In the case of Vidarbha, only 7% of cultivated land is irrigated, compared with an average 16% in the State of Maharashtra. While India's economic growth in 2007 was estimated at 9.2%, the share of agriculture in the gross domestic product was declining steadily: only 18% (Bouissou, 2007).

The industrial sector, while moving to a knowledge-based economy, did not absorb agricultural labour, often illiterate. Cultivated plots are very fragmented in most cases and yields are therefore low. Manufacturing industry could have offered hope to Indian farmers, but it often led to expropriations so as to create economic zones; that was the case in West Bengal, at Nandigram, where the communist State government was planning to convert 4,000 hectares of arable land into a special economic zone; but the decision was rejected by angry farmers who took to the streets and fought with the police (Bouissou, 2007).

On 1 July 2006, India's prime minister announced a €680 million aid to cotton growers that were hurt by the falling prices of the commodity. In addition, the government decided to launch a US$350 million project for infrastructures building. This would allow the development of manufacturing industry and the creation of jobs for rural people. It would also help transport crop harvests to their sites of consumption (it was estimated that one-fourth of agricultural production was wasted, because of the lack of adequate transport means). [Bouissou, 2007].

Since the adoption of *Bt* cotton in 2002, the area cultivated with this pest-resistant variety has been multiplied by 150 between 2002 and 2008, and as a result India became a major exporter of cotton. Over that six-year period, the country had a revenue of US$3.2 billion, while cotton yields were doubled and the use of pesticides was halved. In 2008, 5 million small farmers were cultivating 7.6 million hectares of *Bt* cotton, i.e. 82% of the 9.3 million hectares devoted to cotton cultivation across India (compared with 3.8 million farmers and 6.2 million hectares in 2007 or 66% of total acreage).

Among genetically modified crops on which India scientists are working, there were, in addition to *Bt* cotton, the first *Bt* egg-plant, a chickpea variety resistant to a legume pest, ringspot virus-resistant papaya. Egg-plant plays a key role in the Indian diet, but it needs heavy applications of insecticides to control stem and fruit-borers. Consequently, the development of a *Bt* egg-plant will reduce the use of pesticides and help the 1.4 million small farmers who cultivate this crop species.

The International Service for the Acquisition of Agri-Biotech Applications (ISAAA) has published a report on the field trials and commercialization of genetically modified crops in India in 2008, under the title *Biotechnological crops in India : the dawn of a new era* (available through : http://www.isaaa.org/resources/publications/downloads/The-Dawn-of-a-New-Era-pdf).

According to a study made in 2007, 70% of Indian middle-class people were consuming GMOs and were willing to pay 20% more for biotechnology-derived foodstuffs such as "golden" rice with a higher provitamin A content.

China

Rural reform

The situation of farmers who still make up more than 50% of China's population, is a major concern for the Chinese authorities, for both economic and social reasons: official statistical data showed that, during the first half of 2008, more than 20,000 illegal expropriations of farmers' land had occurred, as a result of collusion between local representatives of the communist party and real-estate entrepreneurs. Social unrest in the rural areas is a real threat and an alarming prospect for the Chinese authorities. In addition, tens of millions of migrant workers (farmers-workers) called "mingong" are working in urban areas to feed their families living in the villages, and often live in lamentable conditions. In 2006, at the end of the parliament annual session, the prime minister, Wen Jiabao, stressed the importance given by the government to rural issues by stating that it was just about time for the "cities to support the rural world" (Philip, 2008).

At the 2008 plenary assembly of the communist party, President Hu Jintao had tried to herald the rural reform and to appear as the heir of Deng Xiaoping, the great "reformer". The latter, in 1978, decided to grant farmers the right to exploit their lands, which remain the collective property of the village committees, that is to say of the state. Until October 2008, Chinese smallholders who used to farm small plots could not enjoy that exploitation right as they wished. The new rural reform published by the communist party on 19 October 2008 foresees that farmers can "transfer, subcontract or rent" that right, which would encourage the concentration of land, increase productivity and, subsequently, create a real consumption internal market, which is still lacking in China. Farmers are therefore poised to abandon their land in order to have a supplementary income. To counter the global economic downturn, China has to evolve towards an economy that depends less on exports and investments, but more on triggering internal consumption, not only in the urban areas but also in the rural ones. Consequently, increasing farmers' income is a major objective (Philip, 2008).

Some analysts, however, have underlined that the new rural reform was still unclear and that it was far from leading to the privatization of land, which was the objective of the boldest supporters of the reform. The official press agency Xinhua indicated that the text had been amended "41 times", which testified to the heat of the debate between supporters and opponents of that reform. Other experts emphasized the potential perverse aspects of this rural mini-revolution, as they feared that more freedom in the disposal of the right to farm or use land might lead to the deprivation of farmers' rights to their land (Philip, 2008).

Agricultural biotechnology

China positions itself as a world player in plant and crop biotechnology, not only to keep abreast of scientific and technological developments, but also to compete at top level in the field of genetically modified crops, plant genomics and its applications to advanced crop breeding. This area of research, development and innovation had the full support of the government, as expressed by the prime minister Wen Jiabao. In 2008, China has launched a US$3.5 billion research-and-development programme on genetically modified crops, with a view to improving food security throughout the country.

Even though the area planted with GM crops is not as large as that of the United States or Argentina, it is quite significant and it is poised to increase in the coming years. The adoption and cultivation of transgenic pest-resistant (*Bt*) cotton, since the 1990s have contributed to an 80% reduction in pesticide use, according to government scientists; transgenic seeds are used in more than 65% of the cotton varieties cultivated in China. "We have shown that it is not just Western countries that can innovate in this area", stated Jikun Huang, director of the Centre of Chinese Agricultural Policy in Beijing. According to Feike Sijbesma, a former chairman of EuropaBio (European Association of Bioentreprises) and a managing director of DSM, the Dutch chemical company whose activities include making drug ingredients, "Chinese companies filed more green biotechnology patents in Europe in 2007 than European companies did".

In addition to *Bt* cotton, the Chinese government is reviewing the release of genetically modified rice. It would be the first country to approve and commercialize the GM version of a main staple food crop. Greenpeace declared that it had found evidence that GM rice from field trials had entered the food chain in several parts of the country. China will certainly

adopt "golden" rice when it is finally approved and commercialized in 2011-2012, alongside with India, the Philippines and other southeastern Asian countries.

Argentina

Economic turbulences

In 200-2001, a major economic and financial crisis led to social unrest throughout the country and to the resignation of President Fernando de la Rua. Adolfo Rodríguez Saa who replaced him, resigned after five days, defaulting on the country's public debt. Following him, Eduardo Duhalde, a peronist, abandoned a fixed exchange rate (1 peso = 1 US$) and devalued the national currency by 70%. As bank restrictions prevented Argentines from using their spared funds, riots and social unrest peaked again. In 2002, some US$100 billion had left the country, i. e. 10% of gross domestic product (GDP), but capital drain slowed down, and internal demand of sectors having incomes in dollars has been stimulated (Legrand, 2007).

Argentine officials, especially Nestor Kirchner (peronist) who was elected president in May 2003 and his government, were determined to keep the peso weak, mainly to protect local industry and to improve the country's competitivity on world markets. Public debt was renegotiated. The very favourable exchange rate (3 pesos for one US$) revived the economy. As Argentine products became competitive, imports fell down and exports began to increase, especially in the agrifood sector. Soybeans alone made up 25% of exports. The agrifood sector also benefited from a favourable international context, thanks to the rise in commodity prices and the opening up of markets in China and India. By 2005, most of Argentina's idle plants were back in action (including the automotive industry, the sales of which have risen fourfold since the 2002 crisis), but new investment was insufficient to sustain rapid growth. The government increased wages and pensions, growth continued, but inflation jumped to about 20% a year. Although there were arguments about this exact figure, inflation was not only due to the rise in prices and wages, but also to the increase in the price of raw materials and energy, as well as to the strong domestic demand. Many sectors that feared a rise in inflation, anticipated the trend and increased their prices. The challenge for the government was therefore to stop that trend (Legrand, 2007*; The Economist*, 2008a).

To better understand the turbulences of Argentina's economy as well as the challenges faced by Argentine officials, the comparison with Brazil is

enlightening. In the last quarter of 2007, Brazil grew at an annualized rate of 6.4% and Argentina at 8%. In Brazil, the finance minister announced a tax of 1.5% on foreigners' purchases of Brazilian treasury bonds to cool capital inflows and slow the steady appreciation of the currency, the real. The governor of the Central Bank stated that his major concern was still inflation (which cheaper imports helped to control). President Luiz Inácio Lula da Silva concurred, describing inflation that has stricken the country for a long time, as a "degrading disease". Both the president and the governor of the Central Bank often said they would prefer steady growth at 5% a year for 15 years to a faster turbulent journey towards riches (*The Economist,* 2008a).

In Argentina, by contrast, officials targeted the exchange rate rather than inflation, as they kept the national currency weak to protect local industry. Brazil's Central Bank policy, which pursued a target for inflation, resulted in the appreciation of the real on the back of record commodity prices, prompting protests from industrialists. But the Central Bank has kept its benchmark interest rate at 11.25% since September 2007. Even so, domestic demand was strong. Because of low inflation, in real terms the growth of Brazilian incomes started to keep pace with those of Argentines. But Brazil had far more room for manoeuvre if the outlook turned less favourable. Argentina, by contrast, with inflation rising even higher – and becoming harder to calculate – will become less attractive for investment. In fact, foreign direct investment to Argentina rose just 12% in 2007, compared with an 84% increase (to a record US$35 billion) in Brazil, according to the United Nations Economic Commission for Latin America – CEPAL (*The Economist,* 2008a).

Six months after the presidential and legislative elections held on 28 October 2007, and which saw the victory of Cristina Fernández, the wife of Nestor Kirchner, Argentina's economy was again going trough turbulence. Framers went on strike and halted their production because of an increase of the export tax on agrifood commodities. The price of Argentina's bonds has plunged as investors showed little confidence in the government. According to unofficial calculations, inflation reached 25% (officially, it was 9%). The statistics agency stopped releasing poverty figures. Using an independent estimate of inflation, the poverty rate had risen from 27% in 2006 to 30% by early 2008, with 1.3 million Argentines descending into poverty in 2007, according to calculations made by Ernesto Kritz, a labour economist in Buenos Aires (*The Economist*, 2008c). Social divide remained a major concern: in December 2006, according to the official figures, the wealthiest 10% Argentines earned 35 times more than the poorest 10% (Legrand, 2007).

To control inflation and stabilize the economy, the government needed to allow the peso to appreciate, curb spending growth and energy subsidies, and raise interest rates. In March 2008, the president decided to raise taxes on agricultural exports. Benefiting from record world commodity prices and a favourable exchange rate, farmers had until then accepted the levies. But the tax increase, together with rising inflation, cut the profit margin on soybeans to just 6%, for instance. The farmers launched an unprecedented campaign of strikes, roadblocks and protests in city centres. Later on, the farmers suspended their movement to allow talks to take place. Finally, the government agreed to reduce the tax increase (*The Economist,* 2008c).

In a country of 39 million people, including 16 million of active persons, the average gross monthly salary was 1,715 pesos (€375) in 2007, and the minimum salary amounted to 800 pesos. Argentina is currently the world's third-biggest producer of soybeans (19% of global production, compared with 38% for the United States and 25% for Brazil). The crop was grown on 15 million hectares in 2007 and the harvest amounted to 45.5 million tons. Argentina is the world first exporter of soybean oil (since 1996) and of soybean meal (since 1998). Agriculture and agrifood industry play a key role in Argentine economy (Legrand, 2007).

Regarding energy production, while natural gas production has been rising (52 billion cubic meters in 2006, compared with 47 billion cubic meters in 2002), that of oil has been decreasing since 1998, down to 716,000 barrels a day in 2006, compared with 890,000 barrels a day in 1998. Half of the electricity is produced from hydroelectric power (40%) and nuclear plants (10%) [Legrand, 2007].

Salvation from the agricultural sector

As of 2002, the soybean boom, along with the devaluation of the peso, has transformed life in the most fertile region of Argentina, where there has been a massive immigration from the neighbouring provinces; the economy roared back to life in the fields, agrifood industrial factories and agricultural machinery plants. "Soybean fever" revived the rural areas that had been agonizing during the 1990s due to the parity between the peso and the US dollar. At that time a harvesting-threshing machine, imported from the United States, used to cost less than one bought in Argentina (Legrand, 2007).

Soybeans is the main crop, grown on 50% of cultivated lands: 15 million hectares in 2007, compared with 6 million hectares ten years earlier.

Yields and total output have been growing over years and particularly since the mid-1990s, thanks to the combination of no-tillage farming and the use of genetically-modified seeds (herbicide-tolerant varieties); 90% of produced soybeans is transgenic. Argentina has the world's second-largest area of transgenic crops (soybeans, maize and cotton): 21.0 million hectares in 2008, just behind the United States (62.5 million hectares) and ahead of Brazil (15.8 million hectares) – its major competitor. The 2007 45.5-million-ton harvest of soybeans is poised to rise, although it suffered from a severe drought in 2009.

Argentine farmers benefited from the soaring prices of agricultural commodities during the global food crisis, despite the increase in the export tax imposed by the government and thereafter reduced to about 32%. China is the first client and importer of Argentine soybeans, and the Chinese market will remain an important one despite the fall of commodity prices in 2009.

In addition, soybeans can be used as an agrofuel (biodiesel) and therefore find another important commercial outlet, as stated by Jorge Weskamp, president of Rosario's commercial stock exchange. Rosario is the main city of Santa Fe province and a very dynamic harbour from which most of agricultural commodities are exported. Santa Fe is the world biggest oilseed center with a daily production of 150,000 tons of vegetable oil (2007). The province's output represented 21% of the country's total exports in 2007 (Legrand, 2007).

Argentina is also the world's leading exporter of sunflower seed oil. The 2006-2007 harvest rose up to between 4.4 million and 4.5 million tons (+18%), underpinned by high prices and a drought that reduced the 2006-2007 wheat area. The lack of rainfall, indeed, had complicated wheat sowing especially in western Buenos Aires province that accounted for 60% of Argentina's wheat production. Consequently, what was not sown with wheat went to sunflower, according to the Argentine Sunflower Association (ASAGIR). In 1999-2000, there was a record sunflower harvest with 6 million tons.

Argentina exports 80% of sunflower oil it produces. Exports to Europe alone account for a third of its sales abroad. Global demand for the edible oil is growing alongside that of other vegetable oils used in the production of biodiesel. As with other agricultural commodities, the prices of sunflower seeds rose significantly in 2006 and 2007: by early 2006, the price at the port of Rosario was 490 pesos per ton, while by the end of August 2006 sunflower seeds were traded at about 545 pesos per ton!

Argentina was considered as one of the first granaries of the world at the beginning of the 20th century. It is now the world's eighth producer of agricultural products and food. Cereal harvests have reached record levels: 95 million tons in 2007 and 100 million tons in 2008. Due to soaring prices, agricultural exports brought an income of about US$20 billion in 2008. The efficiency of the Argentine agricultural model attracts foreign investors and in fact 90% of agricultural exports are handled by a dozen multinational corporations mainly American. On the other hand export taxes are an indispensable revenue to the government: in 2007, for instance, taxes on cereal exports brought about US$4 billion in the government's coffers (Legrand, 2007). It has been mentioned earlier that farmers strongly reacted to the decision made by President Cristina Fernández to almost double the export tax. That was considered by the farmers as a measure that will not only reduce their standard of living, but also their competitiveness on the world markets, especially when they have to compete with countries that subsidize their farmers, e.g. the United States. While the tax increase was reduced to a reasonable level, Argentine farmers' competitiveness remains good. Like other farmers throughout the world they have been hit by the financial and economic crisis (credit crunch), as well as by the fact that agricultural commodity prices tumbled in 2009. But, as mentioned earlier, the forecasts are that prices will rise again and farmers will be encouraged to cultivate and produce more.

Another factor of Argentina's good competitivity in agriculture is the steady growth of biotechnology that is fully supported by the government and the private sector. In 2007-2008, there were more than 70 companies working in biotechnology, including 20 involved in animal health and genetics, 25 in human health and diagnostics, 25 in agriculture and several that produced industrial enzymes, pigments, bioinsecticides and biofertilizers (inoculants). The annual turnover of Argentine biotechnology is about US$3 billion, according to Marcelo Argüelles, president of the Argentine Forum of Biotechnology (FAB).

Regarding agricultural biotechnology, local seed market has an annual turnover of over US$700 million, including US$150 million for hybrid seeds and involving about 23 companies active in crop breeding, micropropagation of plants, pest resistance, herbicide tolerance and inoculant production.

Brazil

Economy : a Latin American giant evolving towards a global power

Brazil is the world's fifth-largest country, behind Russia, Canada, China and the United States. With 187 million inhabitants it is also the world's fifth-most populated country, behind China, India, the United States and Indonesia. It is an agrifood power, being the world's leading producer of coffee, cane sugar, citrus fruit and orange juice, and beef, and the world's second-biggest producer of soybeans behind the United States. Brazil's aeroplane-building company, Embraer, ranks fourth in the world, and the Consorcio del Valle do Rio Doce (CVRD) is the world's leading producer of iron ore.

Main economic and social data

In 1992, almost 36% of Brazil's population was surviving with less than US$2 per day. Fifteen years later, that proportion has been decreased to 19% of the whole population. While remaining one of the countries where the gap between the poor and wealthy people is the largest, Brazil is also with Chile and Mexico one of the few countries where this gap is reduced. The Gini coefficient (where 1 corresponds to the highest inequality and 0 to full equality) has been reduced in Brazil from 0.59 to 0.56 between 2001 and 2006 (i.e. by 5%).

On 28 March 2007, through another way of assessing the gross domestic product, it was found that Brazil's economic growth had been underestimated for 11 years by 10.9%. Consequently, GDP growth for 2006 was 3.7%. Such revision was good news, because Brazil's economic growth was considered too weak, compared with that of India and China where it was over 10% per annum (Gasnier, 2007).

It is now calculated that the wealth created by the biggest country of Latin America was over US$1,000 billion or €751 billion, which meant that Brazil was closer to the seventh rank in the world economy (that of France). However, in 2006, Brazil remained at the 10th rank in current dollars. In 2010, it may overtake Canada and Spain, and reach the 8th rank, if Russia's growth does not accelerate. The new figures included the so-called "informal" economy, which involved 40% of the active population (Gasnier, 2007).

The calculation of GDP showed the following distribution: services produced 64% of wealth (in addition to telecommunications, financial activities have expanded considerably); industry has receded to 27.7%; and agriculture, which was leading exports, rose to 8.3% (Gasnier, 2007).

São Paulo is one of the most important industrial regions in the world; 22% of Brazil's population is concentrated there, i.e. more than 40 million people; it generates 35% of GDP, 30% of filed patents and 32% of national exports. Performance of large Brazilian companies on world markets, such as Embraer in aeronautics, as well as the boom of agrifood exports, have become the showcase of the Brazilian economy (Gasnier, 2006b).

However, according to the 2005 Report on Human Development by the United Nations Development Programme (UNDP), Brazil was at the 63rd rank, while Argentina was 34th, Costa Rica 47th and Mexico 53rd. Since 1975, Brazil has shown constant progress. Life expectancy at birth reached 68 years and 10% of the whole population lived extreme poverty, i.e. with less than US$1 per day per person (Gasnier, 2006b).

Struggle against poverty

To alleviate poverty, the Brazilian government, under the leadership of President Luiz Inácio Lula da Silva, elected in October 2002, is carrying out the federal programme Bolsa Familia, which addresses two types of poor families: those who have a monthly revenue of less than 50 reais (€17.7) and receive an equal amount from the government; and those with a monthly revenue of about 100 reais, and children up to 16 years old, receive 15 reais per child, only if they send their children to school and take them for medical check-ups. The Family Fund reaches the poorest quarter of Brazil's population. Another boost to the family budget has been the marked decrease in the price of rice (Gasnier, 2006b).

For all this the women credited Luiz Inácio Lula da Silva, the first Brazilian president whose background is as humble as theirs. Accordingly they voted for him in October 2006, in the first round of Brazil's general election. The man who proclaims the poor to be "every cell" of his body was backed by 57% of the voters who earned up to 700 reais a month, according to a polling firm (*The Economist*, 2006b).

The Brazilian government has launched microcredit programmes with a view to fostering the economic activity in the rural areas, through the National Programme for Consumption of Family Agriculture (PRONAF), as

well as in the urban areas through the Programme for the Creation of Jobs and Incomes. One should also mention the money transfers associated with the pension system, one of the most generous in Latin America. In 2005, Brazil's president extended the benefits of this pension system to the poorest workers and housekeepers, by granting a pension equivalent to the minimum wages, while at the same time shortening the duration of pension contribution and decreasing its proportion. Nevertheless, in a country where informal economy still contributed to almost 50% of national economic activity, half of the workers had no social protection (Gasnier, 2006a).

The study of households, published annually by the Geography and Statistics Brazilian Institute (IBGE), concluded that in 2005 incomes had increased and socio-economic disparities had been reduced. Wages that since 1996 and the decline of inflation had shown no increase, rose 4.6% in 2005, and the range of incomes had been narrowed: the lowest wages increased by 6.5%. The trebling of the minimum salary (€150) in four years was one of the explanations. The proportion of the incomes of 50% of the least wealthy Brazilians – historically blocked at 11.2% – reached 16.3% of total salaries. Since 2003, 6.1 million jobs have been created, so that the unemployment rate fell from 13% to 10.7% in July 2006. Yet the overall economic growth, topping at 2.3% in 2005, was unequally distributed over the country. But, for once, the Northeast, a semi-arid region where lived half of the Brazilian poors, has been characterized by an economic boom, according to the Rio-based non-governmental organization Institute of Social and Economic Analyses (IBASE). In this region, where the Brazilian president was born, the Family Fund has played a key role. The €3 billion distributed to 11.1 billion households had a significant impact on the economy of backward areas, particularly through the sales of foodstuffs and building materials (Gasnier, 2006b).

For the first time and over the last 15 years (1990-2005), according to the IBGE socio-economic survey, poverty has been reduced and at least 300,000 families could be drawn out of extreme poverty (Gasnier, 2006b).

It should be recalled that just after his election, the struggle against poverty was the president's first challenge. He launched the programme dubbed "Hunger Zero" (Fome Zero), with the objective of enabling all Brazilians to eat three times a day. Business people feared uncontrolled public expenses, but in fact President Lula and his team were very careful about safeguarding economic stability. The Movement of Landless

Farmers even stated that he was "too conservative", while the extreme left compared the €40 billion devoted to debt reimbursement with the €6 billion allocated to the Family Fund and small agriculture (Gasnier, 2006a).

Economic policy

Winning a second mandate on 29 October 2006 (60.83% of ballots), President Lula could claim that he held his promises regarding foreign public debt. The latter was still high, equivalent to 45.7% of GDP (compared with 52.5% in 2003), but its composition had drastically changed; by reducing the part of the debt indexed on exchange rates or on interest rates, the government has eliminated, to a large extent, the sources of vulnerability to an external shock; the International Monetary Fund had been reimbursed and had no more influence on the country's economic policy. Important hard currency reserves had been accumulated: US$72 billion in September 2006, compared with US$16 billion in October 2002, when the president was elected. In addition, the good and sustained international context, the high rise in prices of raw materials, the general fall of interest rates and the conquering of external markets thanks to the devaluation of the national currency in 1999, had facilitated this favourable transition (Gasnier, 2006b).

Between 2003 and 2005, bank profits increased by 80.5% and reached €21 billion. Bradesco, the second private bank of the country, recorded in 2005 the largest profit ever realized by a Brazilian or Latin American bank: €1.9 billion (+39%). The first public Brazilian bank, Banco do Brazil, recorded a 37.3 % increase. The good health of financial institutions had a simple explanation: they benefited from a high director rate of 14.25% (Selic), imposed by the Central Bank that was obsessed by the need to master inflation in a country which in 1994 had a daily price increase of 1%. But a new factor might temperate this easy way to draw profits: the boom of credit to individuals, supported by Lula's government in order to stimulate the purchase of durable goods, e.g. housing, as well as all kinds of microcredits (Gasnier, 2006b).

Shortcomings

And yet Brazil was not as sound as Lula's popularity ratings. Economic growth has been slow compared with other countries in Latin America, and with the three "BRIC" countries – Russia, India and China. The economic growth rate indeed is closer to that of an industrialized country than to that of developing one. Between 2003 and 2006, this average rate was 2.8% per year, compared with 10% in China, 7% in India, or

5.5% in Thailand. A major reason for this slow rate was a huge public sector, keeping interest rates high and that has grown more voracious under Lula's government (Gasnier, 2006b; *The Economist*, 2006b).

When Lula took office, he turned his attention to social policy. While suppressing inflation and containing the deficit, he has transferred more cash to households through the Family Fund and increases in the minimum wage. The upshot was that the central government's spending was set to rise from 16.9% of GDP in 2003 to 19% in 2006. Although the total real income of Brazil's poorest households rose 28% between 2004 and 2005, that of the middle class increased just 1.6% (*The Economist*, 2006b).

The economic and well-being improvement has been unevenly spread in geographic terms. While the economy of the poor Northeast has been stimulated by cash transfers, in the southern State of Rio Grande do Sul, the economy shrank 5% in 2005, because of drought, which hurt farming, and the strong real, which damaged industries such as shoe and furniture manufacture. The economy of Rio de Janeiro, the second-largest city, has not grown since 1975; enterprise there is thwarted by bureaucracy and high taxes; a third of the income in the metropolitan area comes from pensions (*The Economist*, 2006b).

Investment, the best indicator of the economy's long-term health, has edged up from 18% of GDP in 2003 to 20% in 2006, not enough to sustain growth rates of more than 4%. Lula has promised that investment would rise to 25% of GDP in his second term (*The Economist,* 2006b).

The reforms required to boost Brazil's growth included formal independence for the Central Bank, which would allow it to achieve its inflation target with lower interest rates, lower trade tariffs, a simpler tax system and, above all, a long-term plan to reduce spending and the net public debt. With taxes close to their limit (tax revenue hit a record 37% of GDP in 2005) and spending rising inexorably, the government should struggle to deliver the primary budget surplus of 4.25% of GDP that it had promised (*The Economist,* 2006b).

Brazil's dismal standard of public education seemed intolerable, prompting the president to campaign on the slogan "development with income distribution and quality in education". In 2005, for the first time, the education ministry tested all primary public schools in urban areas. In June 2006, it published the results of the national tests, school by school. Each was given its own targets to improve its scores. To help meet those targets, the government intended to distribute an extra 5 billion reais to

schools in the ten poorest States. A thousand teacher-training centres were to improve teaching quality. A genuine management shock would allow school directors to choose their teachers and would hold them accountable for the results. Fernando Haddad, who was the education minister, admitted that Brazil was still in the "ante-room" of such a discussion, but thought targets and tools would "change the culture" of education. By 2022, he stated, Brazil's scores should be as good as the industrial-country average (*The Economist*, 2006b). Education and health should receive more investments: instead of 6% of GDP, as recommended by UNESCO, Brazil has invested 3.8% in education, while health expenses fell to 1.77% of GDP in 2006 (Gasnier, 2007).

Prospects

After being reelected on 29 October 2006, with almost the same score as in October 2002, President Lula's challenge was to find the path to a stronger economic growth in order to maintain and even increase the improvement of the standard of living of the Brazilian poors. To that end, Brazil had solved its structural problems of monetary instability, capital drain abroad, protectionism of markets. In 2007, the annual growth rate reached at last a level above 5%, and it was to remain at the same level in 2008 despite the financial crisis. The real remained strong vis-à-vis the US dollar. Inflation was back to 4.5% in 2008, after having reached 1,000% two decades earlier. Interest rates remained high at 15%, but enable the middle class to borrow money. And millions of Brazilians could consume more (Le Boucher, 2008).

Middle class which felt neglected should be better treated. But, like the state, Brazilians spend too much and GDP growth was largely due to consumption. The increase in wages, associated with the distribution of Bolsa Familia to 11 million poor households, has induced more spending, particularly in house equipment (Gasnier, 2007).

Direct investments must be increased, while reducing public debt in order to attract investors. For instance, Thyssen Krupp was to invest US$4.6 billion in a new steel plant. In 2007, Brazil received US$35 billion foreign investments, an 84% increase over 2006 (Le Boucher, 2008).

Reforms that had been delayed for a long time should be carried out such as those relating to pensions, productivity of administrative services and elimination of bureaucratic hindrances of all sorts. Corruption present everywhere must be tackled seriously as it is a major hurdle to economic and social development. Wealth has been created and it should

be distributed less unevenly, and particularly to the poor. The premises of President Lula's second mandate were good, but challenges were also great. No doubt that the global food crisis and the soaring prices of raw materials helped Brazil economically, as it is a big exporter of food commodities and minerals, but thereafter the downturn affected its farmers and ore exporters. Nevertheless, Brazil could seize opportunities for growth, while steadily pursuing its policy at national and international level.

Trade

In 2006, Brazil's trade surplus increased to an all-time high as near record commodity prices and surging global demand increased exports. This surplus expanded to US$46.08 billion from US$44.8 billion in 2005, the trade ministry stated in a report on its web site. Exports rose to an all-time high of US$137.47 billion in 2006 from US$118.3 billion the year before, while imports increased to US$91.39 billion from US$73.5 billion the year before.

According to an economist at ABN AMRO's Brazilian unit, "prices of metals and strong global economic activity offset the potential negative effect of the strengthening of the Brazilian currency on the trade balance". For instance, on 27 December 2006, Japanese and Korean steel producers signed with the world's biggest producer of iron ore – Brazil's CVRD (Consorcio del Valle do Rio Doce) – an agreement that foresaw a 9.5% increase in the price of iron ore in 2007. Prices of iron ore had increased by 19% in 2006 and 71.5% in 2005. The other iron-ore producers, particularly the second- and third-largest – BHP Billiton and Rio Tinto – should accept the 2007 increase that will thus consolidate the 189% increase over four years. China had imported in 2006 some 25% more iron ore than in 2005, so as to produce one-third of the global output of steel.

For the first time in Brazil's history, in April 2009, China became its first trading partner, instead of the United States. One month earlier, it had already become the biggest importer of Brazilian goods. That was a historical landmark for both countries. At the beginning of the 19th century, after three centuries of Portuguese hegemony, the United Kingdom took the lead, when the Brazilian Empire opened up its ports to foreign maritime powers. Since the 1930s the United States have consolidated their position as the first trading partner of Brazil, and it is now Asia, with China at the helm, which leads the trade exchanges with the Latin American giant (Langellier, 2009).

Brazil's exports to China have been multiplied by 15 (in value) between 2000 and 2008, and grew 75% between 2007 and 2008. This resulted in a trade surplus, during the first four months of 2009, that was twice that recorded during the same period in 2008. Consequently, the three first trading partners of Brazil are China, the United States and Argentina (Langellier, 2009).

But these good results also reflected a significant decrease in imports from China due to the credit crunch that affected national enterprises and prevented them from investing and purchasing the equipment they needed. In addition, the composition of Brazil's exports to China was not satisfactory: commodities and raw materials, such as soybeans or iron ore, that became cheap because of the devaluation of the real versus the US dollar and of the economic downturn, were rising, while high added-value manufactured or semi-manufactured goods, were on the decline. At the same time, China was selling more industrial products to Brazil, particularly in electronics. In order to counter this trend, and to just boost trade exchanges that represented only 1% of China's external trade, President Lula visited China on 18 May 2009 (Langellier, 2009).

Regarding the whole trade exchanges of Brazil in 2008, the proportion of manufactured products went down to 21% from 29% one year earlier, while that of primary products increased from 30% to 40%. In 2010, Brazil was hoping to boost its trade with the United States, which was its first traditional buyer of manufactured goods (Langellier, 2009).

Besides China, Brazil's exports to Asia have boomed. In April 2009, exports to Taiwan and South Korea doubled. As economic experts forecast that economic growth would resume in Asia as of 2010, Brazil wanted to benefit from that opportunity. The growth of trade with Asia was Brazil's best chance to maintain its share in world trade. In fact, according to a study carried out by Getulio Vargas Foundation and Ernst and Young consultancy, published in May 2009, the annual growth of Brazil's exports of manufactured goods from 2009 to 2030 (1.8%) would be significantly lower than that of world trade (3.7%). Consequently, Brazil's share in global exports would be reduced from 1.1% to 0.9%. As emphasized in the study, Brazil must therefore improve its competitivity, hindered by the cost of energy, the delay in improving infrastructures, the heavy taxes and the low investments in research and development (Langellier, 2009).

The Amazon forest challenge: fighting rampant deforestation and designing a coherent forest policy

By mid-June 2006, the director of Brazil's Forest Service stated that more than 70 million hectares of the Amazonian rain forest will be either off-limits to development or reserved only for sustainable use by the end of 2006. Only 30 million hectares had been declared protected before 2003, when Brazil's president Luiz Inácio Lula da Silva took office, pledging to decrease deforestation. The government has since declared the protection of almost 20 million hectares, while State authorities protected an additional 8 million hectares (*The Daily Yomiuri*, Yokohama, 16 October 2006, p.7).

Many environmentalist organizations, including Greenpeace, have criticized the government, however, underlining the protected areas were announced but very little was done to ensure they were not invaded by loggers, farmers and cattle ranchers. The director of the Forest Service replied that the country had spent US$93 million fighting deforestation, including hiring agents for Brazil's environmental protection agency. He added that Brazil would present a proposal to the international environmental meeting in Nairobi in November 2006, to reduce emissions of greenhouse-effect gases. Federal and State officials planned to protect an additional 15 million hectares by the end of 2006. Some of that land would be near the BR-319 road connecting the Amazonas State capital of Manaus to Rondônia State, and which was expected to attract developers to the area after being paved (*The Daily Yomiuri*, Yokohama, 16 October 2006, p.7).

In an attempt to create Brazil's first coherent, effective forest policy, the government of President Lula has begun auctioning off timber rights to large tracts of the rain forest. The winning bidders will not have title to the land or the right to exploit resources other than timber, and the government will exercise a close monitoring of the bidders that will pay a royalty on their activities (Rohter, 2007a).

The plan will help reduce tensions over land ownership in the Amazon, which loses about 20,000 km² every year to clearcutting and timbering. In theory, 70 % of the forest is public land, but miners, ranchers and especially loggers have felt free to establish themselves in unpoliced areas, strip the land of valuable resources and then move on, mostly in the so-called "arc of deforestation" on the eastern and southern fringes of the jungle. But the call for monitoring of the loggers allowed into the rainforest largely untouched centre will come from a new Forest Service

with only 150 employees and from State and municipal governments. That concerns environmental and civic groups because local officials are more vulnerable to the pressures of powerful economic interests and to corruption. Furthermore, the new system assumes that the world community will also play a part and buy timber only from merchants who are properly licensed and will avoid unscrupulous dealers (*The Economist*, 2006a; Rohter, 2007a).

Stephan Schwartzman, an Amazon specialist at Environmental Defense, Washington, D.C., agreed that this system was an improvement over the current situation, which was totally out of control. But he stated "everything is going to depend on how it is done and whether the financial and human resources are there to make it work" (Rohter, 2007a).

Jorge Viana, a member of President Lula's party (PT) and who was governor of the Amazon State of Acre until 1 January 2007, contended that "this was one of the most important initiatives that Brazil had ever adopted in the Amazon precisely because you are bringing the forest under state control, not privatizing it" (Rohter, 2007a).

There were in fact signs that Brazil was moving in the right direction, as shown in particular by Brazil's environment minister, Carlos Minc. In Mato Grosso State, Blairo Maggi, the governor and whose family company is the world's biggest soybean producer, loathed by many non-governmental organizations (NGOs) for its poor record on slowing deforestation, hosted a conference on developing markets for ecosystem services, with the idea of paying stewards of the forest to halt deforestation. The meeting in Cuiabá, Mato Grosso's capital, was attended by governors of Amazon States and foreign NGOs with a preference for market solutions to climate change. There were already some small schemes in Amazonas State in which foreign companies eager to offset carbon emissions paid a fee for forest preservation. In 2008, Brazil launched a national fund along these lines, seeded with a US$100-million donation from Norway. B. Maggi wanted something similar. "We need to stop deforestation but we need the finance to do it", he stated (*The Economist*, 2009b).

B. Maggi stated that only 8% of Mato Grosso's territory was given over to commercial farming. Its high productivity meant that the State was Brazil's biggest producer of cotton and rice as well as of soybeans. By contrast, about a quarter of its land was occupied by extensive cattle ranches that produced one cow per hectare per year. Making this land more productive would result in halting deforestation meant to increase output, according to B. Maggi. Larger producers were also more

capable of sticking to agreements not to use recently deforested land, such as the one that existed between NGOs and soybean producers, including B. Maggi. Unfortunately, cattle ranchers followed a different logic and would not be turned into agrobusinessmen overnight (*The Economist*, 2009b).

If Brazil encouraged foreigners subscribing to funds to save the forest, these might gradually tip the scales against deforestation. Instead of being felled and monetized when required, the standing forest could become a source of income. And for Brazil it would be a rather easy way to curb emissions of greenhouse-effect gases (*The Economist*, 2009b).

An "agricultural superpower"

The former US Secretary of State Colin L. Powell called Brazil an "agricultural superpower", poised to overtake the United States as the world's leading exporter of agricultural commodities and foodstuffs. Although this may not happen soon, there is no doubt that Brazil has made in a decade or so outstanding progress in the development of its agriculture and a very powerful agribusiness.

During the period 1975-2002, agricultural productivity annual growth rate reached an average 3.3%, much more than the 1.8% recorded in the United States. During the period 1990-2005, grain production doubled, that of meat was triplicated; and thanks to effective policies of funding, research and development (R&D) and trade, food processing represented 30% of the gross domestic product (GDP), while exports of agrifoodstuffs made up more than 44% of total exports and generated 40% of jobs. Not only Brazil has become self-sufficient in food, but it has also become one of the biggest suppliers of many countries, due to the great improvement of its productivity and competitivity.

Rural economy and agroindustry are so important that two ministries are in charge: that of agriculture, livestock and supply, and that of rural development. The Agriculture and Livestock Research Organization, EMBRAPA, is playing a key role in agriculture and rural development, not only in R&D, but also in the transfer of technology to both the small farmer and the world of agribusiness. EMBRAPA has in three decades become a world research leader in tropical agriculture and is moving rapidly into areas like biotechnologies and bioenergy. It has therefore become an obligatory stop for any developing world leader visiting Brazil.

Over the period 1975-2006, Brazil doubled the area devoted to agriculture, from 40 million to 77 million hectares, while the number of tractors rose from 320,000 to 790,000. The number of cattle head increased from 102 million to 170 million, milk production rose to 9.4 million tons, and 1.3 million tons of frozen or refrigerated meat were annually exported. Brazil, the world's leading producer of sugar, supplies 25% of the global sugar market, and produces 80% of orange juice sold in the world.

Over the same period 1975-2006, coffee production rose from 780,000 tons to 1.4 million tons per year, Brazil maintaining its rank of world's first producer and exporter. Cotton exports reached 400,000 tons a year. Banana exports amounted to 250,000 tons a year, compared with 30,000 tons by the mid-1970s.

Various tools are in place to support agricultural development and expansion, such as modern financial tools, the plant and animal health programme, a logistics and infrastructural plan, the biosafety law that ensures the safety of biotechnology innovations, and a consistent agenda for commercial negotiations in international fora. In this respect, many trade agreements have been and are being concluded with a view to conquering new markets and to increasing and diversifying the exports to traditional buyers of Brazilian goods.

In addition, Brazil has been making heavy investments in several areas of R&D, such as genetics, nutrition, health, training and retraining, agricultural machinery, and all kinds of infrastructure work, so as to improve its capacities and competitivity of its agribusiness. With respect to boosting external trade, the APEX (Brazilian Agency for the Promotion of Exports and Investments) succeeded, in five years of activity as an autonomous enterprise, in assisting Brazilian entrepreneurs to export their products to more than 60 countries. In particular, the exports of soybeans to China have increased to meet the rising demand of this country, and the government did widen its financial and technical support for the producers of this oilseed crop, as well as for producers of other food crops and inputs that contribute to the generation of jobs and the improvement of balance of trade.

The goal of all these policies is to add in 2020 another 60 million tons of grains to the current production and 10 million tons to the exports of beef. Moreover, Brazil will expand the area devoted to the production of agrofuels, i.e. sugar-cane, soybeans, sunflower and oil-palm. The minister of energy and mining, Edison Lobao, announced that Brazil will increase

bioethanol production by 150%, so as to reach 64 billion liters per year in 2017. Exports of bioethanol would increase from 5 billion liters in 2008 to 8 billion liters in 2017, Brazil thereby consolidating its position as the world's biggest exporter. Of the US$352 billion to be invested in energy during the eight-year period (2010-2017), 6.5% will be allocated to agrofuels, i.e. US$23 billion.

In 2009, Brazil's GDP growth was estimated at between 1.5% and 2.5%, due to the economic crisis that caused a 3.5% contraction of economic growth during the last term of 2008. The Institute of Applied Economic Research (IDEA) confirmed that Brazil's annual economic growth will be positive in 2009, but lower than the 5.1% rate achieved in 2008. Private bankers were less optimistic and forecast a 0.58% growth for 2009. Experts predicted a deficit of the balance of current accounts between US$18 billion and US$25 billion, as a result of the decrease in exports and foreign capital drain.

Outstanding examples of agribusiness development

As an example of agribusiness development, what is happening in Mato Grosso State is very illustrative. Many pioneer farmers came to this State from southern Brazil in the 1970s. Today Campo Verde, east of Cuiabá (the State's capital), is the centre of a very rapid agrifood development. The commodity boom is causing the local population to grow from nearly 30,000 in 2007 to 10,000 by 2020. But rather than attracting farmers to grow more crops –all available arable land in the municipality has been used– the municipal authorities wanted to add value to commodities *in situ* (verticalization). Thus, Sadia, Brazil's biggest meat processor, which already had chicken farms and a feed factory in the town, put Campo Verde on a shortlist of possible sites to receive a chicken-processing plant and other facilities that would create 3,000 direct and 9,000 indirect jobs thanks to a US$101 million investment (Wheatley, 2007).

While Sadia had yet to decide between Campo Verde and other sites for its new plant, it was carrying out an R$800 million programme that encompasses chicken and pig processing plants and a feed factory at Lucas de Rio Verde, also in Mato Grosso State (Wheatley, 2007).

Sadia was also expanding overseas and entered a joint venture with its Russian distributor, Miratorg, to produce among other things chicken nuggets for McDonald's restaurants, making it the chain's first non-US global supplier. Processed products and value-added cuts – for

instance precisely weighed fillets for the Japanese market – made up an increasing share of its sales. Sadia's director of international relations stated such changes were part of a broader global shift in its markets (Wheatley, 2007).

Perdigão, Sadia's biggest competitor, has also expanded both overseas and at home. In 2007, it bought Plusfood of the Netherlands and opened a plant in Brazil producing processed meats only for export. "Our strategy is to constantly increase the share of value-added products in our mix", stated Nelson Vas Hacklauer, the business director. "These are volatile markets and having more value added gives me a steadier income" (Wheatley, 2007).

Another example is that of the agroindustrial megaproject initiated in 2009 by the Brazilian company Mónica Semillas, with headquarters in Mato Grosso since the mid-1970s and in Santa Cruz de la Sierra, Bolivia, since the early 1990s. It consists of cultivating 12,000 hectares of cereals in the high plains of Colombia, starting with 3,000 hectares that were planted with maize and rice in November 2008. Later on, sorghum and legumes will be grown. The Brazilian company's investments will comprise the purchase of land, machinery, inputs and equipment for agricultural production, as well as the hiring of local labour.

Support for family agriculture

By contrast with the very powerful agribusiness, in 2006 Brazil's small-scale or family agriculture included 82% of rural properties, provided employment to 13 million people and produced 40% of vegetables and fruit consumed in the country (Gasnier, 2006a).

President Lula's government has, in addition to agrarian reform (260,000 farmers settled instead of the 400,000 announced), diversified its aid to family agriculture. The Programme for Support for Family Agriculture (PRONAF) budget had climbed to €3.2 billion in 2006 from €820 million in 2003, and helped 1.6 million farmers. PRONAF grants loans to farmers. For instance, a family can receive a €5,500 loan from the Banco do Brazil; after three years of non-reimbursement, the period for reimbursement is extended to ten years. A cooperative manages the plantation and distributes one-third of the income to the families; the rest is reinvested so that, for instance, the plantation area is doubled. Consequently, the farmers do not receive any more money from the Family Fund. This example applies to the *assentamento* (settlement supported by the government) of Canudos, 60 km of Natal (capital of the

State of Rio Grande do Norte); this agricultural community was created in 1997 as a result of the agrarian reform. Forty families owned 10 hectares each for farming and living. Some families pooled their efforts within a cooperative, Coopetec, for banana and papaya plantations. The objective was to privilege food crops, so as to meet their nutritional needs and to improve their income (Gasnier, 2006a).

Another federal initiative is the Programme for Foodstuff Acquisition: the company in charge of the management of agricultural stockpiles (CONAB) has decentralized the purchases from farmers, without bids. Thus, 150 products such as donkey meat, Brazil's nuts, fish and honey, were directly purchased from the farmers, without intermediaries, and paid in cash. These foodstuffs were immediately distributed to kindergardens, nursery schools, pensioners' houses, restaurants for poor people. This was considered a key pilot project that could become an international reference (Gasnier, 2006a).

Nevertheless, NGOs such as Actionaid (international) complained that Lula's government paradoxically had allocated ten times more credits to big agribusiness companies than to small farmers. In addition, the agrarian reform was considered too slow: only 260,000 had been settled instead of the 400,000 announced by the government (Gasnier, 2006a).

Research and development

Mark Cuckler, manager and acting director of the Agricultural and Rural Development Department of the World Bank, stated: "a key reason that Brazil has done so well with its agricultural economy is that it has invested heavily and intelligently in front-end agricultural research, and EMBRAPA has been at the forefront of that effort". EMBRAPA owes much of its reputation to its pioneering work in the cerrados, the vast savannah lands that stretch for more than 1,700 km across central Brazil. Deemed useless for centuries, the region has been transformed in less than a generation into Brazil's grain belt, thanks to the fertilization of soils by the addition of phosphate and lime. The optimum mixture was established by EMBRAPA's scientists. EMBRAPA also championed the main crop for the region by developing more than 40 tropical varieties of soybeans. As a result, Brazil became the world's top exporter of soybeans and beef, and a fast-rising exporter of cotton, three-quarters of which is produced in the cerrados. Encouraged by that success, EMBRAPA's scientists have turned their attention to wheat. Two new varieties of wheat with good yields have been grown in 2006 and there is also a strong possibility of adapting barley to this agroecosystem (Rohter, 2007b).

Although Brazil's sugar-cane-based bioethanol programme is largely focused outside the cerrados (i.e. São Paulo State), EMBRAPA has an agroenergy division that is concentrating on ways to produce biodiesel. EMBRAPA's scientists have identified some 30 plants that could be used for that purpose and are focusing on oil-palm. "Palm oil composition is one of the best for agrofuel production", stated Maria do Rosario Lobato Rodrigues, director of EMBRAPA's Manaus laboratory where the research is being carried out. "Oil-palm has a high carbon-fixing capacity, does not require the use of chemical products to produce, and no part of the plant is ever wasted" (Rohter, 2007b; Sasson, 2008a,b).

In 2005, the Brazilian Congress passed a law that allowed EMBRAPA to profit from its research and has widened the agency's ability to form joint ventures. Initially, most such agreements were with Brazilian companies, but EMBRAPA and BASF, the German chemical corporation, announced a partnership to develop and market a genetically modified, herbicide-tolerant soybean variety, expected to be on the market by 2012, and will compete with Monsanto's Roundup Ready varieties (Rohter, 2007b).

Although it had exchange programme that had brought scientists from Latin America, Africa and Asia to work in its laboratories, EMBRAPA opened its first overseas office in Ghana, headquarters of the Forum for Agricultural Research in Africa. This has been a good and potentially important move, because there are many places in Africa, such as Zambia, with savannah soils and rainfall conditions similar to Brazil's cerrados. According to Norman E. Borlaug, "soybeans and maize, together with beef production and improved pasture grasses for grazing, are all things that will be fit to transfer from Brazil" (Rohter, 2007b). See also Sasson (2006, 2008a).

Economic downturn and its impact on Brazilian agriculture

By early 2008, high oil prices, low food reserves and growing consumer demand in developing nations sent food prices soaring, and Brazilian farmers and ranchers strove to increase production, making huge profits as prices for soybeans and other commodities skyrocketed.

At the beginning of 2009, grain and beef prices have plummeted, partly because of slowing demand and greater supply worldwide. And with sharply reduced foreign orders for its iron ore, steel and automobiles as well, Brazil acknowledged a drastic reduction of its overall economic growth. Most farmers, for instance in Mato Grosso do Sul State, reported they were losing money on yields 40% to 80% of normal. In that region,

after the financial crisis hit in the autumn of 2008, the worst drought in 20 years occurred and affected three of Brazil's five top grain-producing States and large swaths of grain-producing land in Argentina and Paraguay. Tight credit was making harder for most farmers to buy seeds, fertilizers and machinery. Demand had plunged for Brazilian beef and coffee, and for soybeans, used worldwide as animal feed and as important additive in cereal, pasta and other processed foods. The credit crunch also had made it difficult for importing countries to obtain loans to buy food (Clendenning, 2009).

Brazil's 2009 soybean harvest was expected to produce 58 million tons, down from 60 million in 2008. Beef exports for January and February 2009 totaled 171,000 tons, down sharply from 230,000 tons shipped abroad a year earlier. Since the crisis hit, the price of milk that farmers in Mato Grosso du Sul used to receive from dairies had dropped to US-cents22 a liter, while production costs amounted to US-cents27 a liter. And dozens of slaughterhouses hit by the credit crunch had shut their doors in both Mato Grosso do Sul and the neighbouring agricultural powerhouse State of Mato Grosso, idling thousands of meat cutters (Clendenning, 2009).

There is therefore no doubt that Brazil, as other agricultural countries, has been affected by the financial, economic and social crises, but there was a buffering impact with respect to the global food crisis, thanks to Brazil's exports of commodities and food security at home. If the current predictions materialize, the prices of raw materials and agricultural commodities will rise again, along with a slow economic recovery; and the powerful Brazilian agriculture will seize the new opportunities and play again a key role at global level.

Mexico

In Mexico, with a population of about 109 million people (estimate: July 2007), the gross domestic product (GDP) of some US$1.353 trillion (estimate: 2007) was distributed as follows: agriculture, 3.9%; industry, 26.3%; and services, 69.9%. GDP growth rate reached 3% in 2007 (*International Herald Tribune*, 17 April 2008, p. 12).

Since the North America Free Trade Agreement (NAFTA) has come into effect in 1994, the average growth of Mexico's agricultural exports had stood at 10% (amounting to US$13 billion in 2007). A major protest by farmers in Mexico City on 3 January 2008 against the banishing of NAFTA's last tariffs on maize, sugar, milk and beans was a clearcut indicator that all was not well in Mexico's rural areas. While some larger States in northern

Mexico are using efficient farming practices to increase productivity, the agriculture ministry indicated that only 6% of farmers were highly efficient. Home to 25% of the population, rural Mexico is a cause of concern as poverty is still a reality, and subsistence farmers are often under-producing (*International Herald Tribune*, 17 April 2008, p. 12).

In light of the NAFTA developments, the possibility of cheaper produce entering from the north has created discontent, but in reality much of Mexico's needs for these products come from shortfalls in domestic production. For instance, Mexico imports around 10 million tons of maize per year – its basic staple food; this amount is equivalent to half of consumption needs. The agricultural sector must become more competitive, and this can be only done if producers, processors and agricultural associations make a widespread commitment to change and modernization. The federal government has also a major responsibility in terms of policy and funding. According to the president of the National Agricultural Council (CAN), that commitment was finally coming as agriculture was back on the political and financial agenda (*International Herald Tribune*, 17 April 2008, p. 12).

President Felipe Calderon's government awareness of the need for rural development was evident in the National Development Plan for 2007-2012. Along with plans for improved infrastructure and economic diversification in rural areas, the agricultural sector has been positioned as a key industry for development. The plan aims at taking better advantage of Mexico's strategic position and unique geography. According to the president of the agricultural holding company Grupo Ceres, Guillermo Elizondo, and regarding the support for transgenic crops, the situation is changing favourably, especially after the approved of cultivation of transgenic maize in defined areas of the country. "I think that biotechnology and genetic improvement by gene transfer is here to stay, and we will have to adapt", he stated (*International Herald Tribune*, 17 April 2008, p. 12).

Some regions can really compete by growing alternative crops, such as fruit and vegetables, which are currently dominating Mexico's agricultural exports. In the eastern State of Sinaloa, fruit and vegetables, along with maize, are the main products. This gives the region the competitive advantage of being a winter supplier of fresh produce to the United States. Sinaloa's secretary for economic development stated that agriculture could contribute even more by adding value to the production process. The president of CNA stated in this respect: "Mexico sells commodities; we export fruit and vegetables instead of selling

preserves or other products. To change this, we need to innovate, train producers and invest in productive associations among our farmers". Indeed secondary products such as beer, tequila and bakery products have become staple favourites outside Mexico, proof that international markets are receptive to quality Mexican goods (*International Herald Tribune*, 17 April 2008, p.12).

Greater cooperation between producers and processors can also contribute to increasing competitivity of Mexico's agricultural sector. For instance, the agreements between beer manufacturers and bakery farmers are a good example of the close relationship between producers and consumers that are much more preferable to having to import basic ingredients because of domestic shortfall (*International Herald Tribune*, 17 April 2008, p.12).

In the case of the dairy sector, there was in 2008 a shortfall of almost 2.5 million liters of milk between demand and supply, despite an increase in production. This deficit was covered by imported powdered milk, making Mexican demand of this product one of the world's biggest. In addition to the issue of productivity of the sector, the industry had felt pressure from the soaring prices of feedstuffs during the global food crisis (*International Herald Tribune*, 17 April 2008, p.12).

One of the country's biggest milk producing groups, Alpura Group, was leading the drive for improved efficiency and productivity through technical innovation and infrastructure investment. Alpura, formed over 35 years ago as a farmers' association, oversees its milk production from start to finish. The group processes 2.8 million liters of milk daily in two processing plants, with milk supplied by more than 160 dairy farms throughout the country. The eleven companies that formed part of the group, whose activities included manufacturing supplementary products and improving the efficiency of livestock, contributed to Alpura Group's approach to combine technology and constant quality control (*International Herald Tribune*, 17 April 2008, p.12).

Cuba

Agricultural development as well as the supply of enough food to the population remains a great challenge for the Cuban authorities 50 years after the Cuban revolution. This situation is in sharp contrast with the outstanding development of biotechnology, including agricultural biotechnology, during the last 20-25 years in this small island country of 12 million people.

During the 1990s, when the commercial relationship and assistance cooperation between Cuba and the USSR collapsed, Raul Castro would have said that "beans were more important than guns". At the beginning of August 2009, in his speech closing the parliamentary session, Raul Castro, Cuba's president since February 2008, reported that his government had to reschedule its foreign debts because of the lack of hard currency. Cuba was going through the worst economic crisis since the "special period'' that followed the collapse of the USSR. According to the Cuban officials, the crisis had two main causes : in 2008, three hurricanes had devastated the island, causing losses estimated at US$10 billion, i.e. 20% of gross domestic product. The havock caused in crops and harvests led Cuba to almost double its food imports (paid in hard currency), mainly from the United States (the US government had excluded foodstuffs from the trade embargo imposed on Cuba since 1960). Consequently, trade deficit soared by 65% in 2008 : imports rose by 41% to US$14.2 billion, whereas exports amounted to just US$3.7 billion. The second cause of the economic crisis was linked to the global economic recession. The price of nickel, Cuba's main export item, plummetted, while tourists spend less time and money in the island, even though their total number in 2009 was expected to be close to the 2008 record figure, i.e. 2.35 million people (Jacot, 2009).

R. Castro warned in his speech that the state was going to eliminate "excessive allocations" so that "the social expenses correspond to our real possibilities". It is worth recalling that free education and health care for all were a major achievement of the 1959 revolution that has never been eroded. On the other hand, restrictive measures will worsen the standard of living of Cubans, whose average monthly salary is around US$20, and who receive minimal food rations. After postponing the retirement age to 65 years for men and 60 years for women, i.e. five years more, the government took measures to save energy in June 2009 (less air conditioning in public buildings, reduction of industrial production during the peak consumption times, and relying more on animal draught than on machinery). Cuba could meet 47% of its oil consumption during the first half of 2009, then production decreased; imports of oil from Venezuela at a preferential price, help to meet national needs (Jacot, 2009).

Since Raul Castro has taken over the leadership in 2007 from his brother Fidel Castro, several measures have been taken to boost agricultural production. The debt of the state to the farmers was paid. The prices of meat, milk and potato have doubled or trebled in 2007, and that of tobacco has been upgraded. In the four provinces of Holguín, Ciego de

Ávila, Villa Clara and Havana, agricultural tools are being sold in some stores in convertible pesos (equivalent to the dollar) to those who own hard currency. These are simple tools and not machines, such as hoes, sickles, spades, nails and horseshoes, that before could be bought after tedious and time-consuming efforts. In addition, the agriculture ministry would not concentrate in Havana the available resources and sales, that would be decentralized at municipal level (Paranagua, 2008).

Some experts estimate that the implmentation of the 1959 agrarian reform has been hampered by excessive centralization and by the creation of inefficient state-owned latifundia. While half of the state-owned arable area remains idle, "private" producers and cooperatives supply over 60% of foodstuffs, derived from crops grown on only 30%-35% of cultivated land. These experts consider that a new agrarian reform is needed, in order to allocate land to those farmers who are willing to cultivate it, either through access to property or through the creation of effective cooperatives. Farmers need freedom and legal guarantees in order to grow their crops and bring their harvests to markets. In other words, Cuban agriculture needs drastic transformations that should not be postponed (Paranagua, 2008).

In 2008, Cuba spent US$1.5 billion to pay for the import of 84% of its foodstuffs, while the island's exports covered only one-third of its imports. Most of these foodstuffs (e.g. rice, beans, catfish and pork) were imported from the United States and paid in cash. The resulting imbalance of commercial trade causes serious problems of liquidity that generate the complaints of foreign companies (Paranagua, 2009).

The global economic meltdown was also affecting Cuban economy and even worsening the overall situation. Thus the economy minister has revised its annual economic growth predictions for 2009 from 6% to 2%. The Centre of Studies of the Cuban Economy of Havana University was even predicting a recession. As the prices of raw materials plummeted worldwide, so did the price of nickel, and according to official figures this caused a loss of US$720 million. The former source of revenue, sugar, has disappeared; sugar-cane harvest has decreased over the years (down to 1.5 million tons of cane sugar in 2008), sugar factories were closed down, and Cuba had to import sugar in 2008 and 2009 (Paranagua, 2008, 2009).

Agricultural production fell by 7.3% in the first quarter of 2009, and meat production fell by 14.7%. In order to raise production, R. Castro has

offered land to "private" farmers. That was the first of the major structural changes he announced in 2007. The distribution of land started in 2008 and 80,000 candidates received plots. As the programme was not fast enough, R. Castro decided to accelerate it and declared it was a "national priority" After saying "the land is there, here are the Cubans, let us see if we get to work", he hammered : "land is here and waits for your sweat" (Jacot, 2009).

Despite all these difficulties, some due to the international situation, others homegrown, agriculture depends on political and social decisions, but also on agronomic research and innovation, and extension services that will transfer to the farmers the results of the former in the most efficient way. And in this respect, one should recognize that good progress has been made over the last two decades, for instance in agricultural biotechnology, including livestock health.

Regarding transgenic crops, in 2008, after 15 years of laboratory and greenhouse research and development on a wide range of crop species (e.g. maize, soybeans, rice, sweet potato), there was not a single transgenic crop grown on commercial scale in Cuba. However, there has been advanced research and development concerning genetically modified (GM) crops with insect resistance – a top priority. Research is also being carried out on drought and salt tolerance as well as on the production of pharmaceuticals in tobacco. Trials on GM crop species have to meet all biosafety requirements issued by the National Biosafety Center and the Institute of Food Safety, e.g. allergenicity tests, non-use of antibiotic-resistance markers, control of gene flow, impact on biological diversity (there is an ecotoxicity network in Cuba, which studies the changes in micro- and macro-fauna and flora, under transgenic crops), economic and social impact.

Following these requirements, field trials have been conducted in five provinces of Cuba on a variety of maize (FR-Bt1) genetically modified to resist the attacks of *Spodoptera* and other Lepidopteran pests, and to tolerate the Basta herbicide (ammonium glufosinate). The results were clearcut: no damage has been observed in the transgenic plants, which contained very low amounts of aflatoxin (because of the marked reduction of the presence of toxin-producing fungi). More field trials and safety tests have been required by the Institute of Food Safety. Additional studies have been completed by the end of 2008, particularly on the impact on biological diversity of the cultivation of transgenic maize. In December 2008, after the authorization delivered by the National Biosafety Center, 50 hectares of field trials were to be carried out in five provinces, with

a view to producing enough transgenic seeds to plant 6,000 hectares and scale-up commercial production in 2009 (Carlos Borroto, personal communication, 2008).

In cooperation with the Institute of Tuber and Root Crops, the Genetic Engineering and Biotechnology Center (CIGB) is conducting trials on a transgenic sweet potato (*boniato*) clone 24 that is resistant to a weevil (*Cylas formicarius*), a Coleopteran species that causes heavy losses in this staple-food crop. Research is also being carried out on a tomato hybrid variety, Campbell 126, that is made resistant to tomato yellow leaf curl virus (TYLCV), using interference RNA; as a result, the virus does not multiply in the plant, that becomes completely "immune" and could be used as a progenitor for seed production (Carlos Borroto, personal communication, 2008).

Rice-genomics studies are being carried out on high tolerance to drought and salt – a cooperation between CIGB and the National Agricultural Research Institute (INIA). On the other hand, a genetic marker (SCAR) has been associated with resistance to blue mold disease in tobacco. A defensin gene has been identified and transferred to potato in order to introduce resistance to *Alternaria solani*; field trials were to be carried out in 2009. A liquid bionematicide, commercialized under the name of Hebertnem, is used to treat 60% of crops in Cuba, including the Cavendish banana variety; this environment-friendly biopesticide replaces methyl bromide, the spraying of which is prohibited because of its negative impact on the ozone layer (Carlos Borroto, personal communication, 2008).

Cuban scientists have been working for a long time on the production of pharmaceuticals in tobacco – a plant they know very well. This research work is part of the medical and pharmaceutical biotechnology achievements for which Cuba is renowned in Latin America and worldwide. Thus, the anti-hepatitis B immunogenic protein has been produced in tobacco plants and has been authorized by the Cuban regulation authority for commercialization under the name of Heberbiovac 2006. In November 2008, the World Health Organization completed a positive thorough evaluation of the production process in tobacco. In cooperation with the Institute of Tobacco, CIGB has used the PMP (Plant Made Pharmaceutical) variety, with large leaves, to produce this pharmaceutical and others. Plantibody PhR3 against EGF (epidermic growth factor) has also been produced in tobacco, in cooperation with the Cuban Center of Molecular Immunology (CIM). A fraction of antibody SC-FVG4 clone 1 has been expressed in tobacco seeds, up to the concentration of 6 g per kg of tobacco seed fresh weight (Carlos Borroto, personal communication, 2008).

One should recall that in the area of immunology Cuba has been able, over the last 20-25 years, to create ten research institutions with about 600 immunologists, and a national network of 137 immunodiagnostic laboratories, as well as several centres for production of vaccines, antibodies, biopharmaceuticals and diagnostic tests. A recent and important vaccine-production institute is the Carlos Finlay Institute, which bears the name of the Cuban discoverer of the yellow fever virus. Agustín Lage, director of the Center of Molecular Immunology stated: "the most remarkable aspect of Cuban immunology (biotechnology) is its strong connection with public health". And indeed over the last 25 years, Cuba's efforts and achievements in medical and pharmaceutical biotechnology have contributed to decreasing infant mortality down to 6 per 1,000 births and to increasing life expectancy to 77 years.

In addition, the products of Cuban R&D institutions in medical and pharmaceutical biotechnology are currently exported to 40 countries: 11 vaccines, more than 40 biopharmaceuticals (recombinant proteins and monoclonal antibodies); immunodiagnostics. In 2009, there were about 91 new products in the development process and more than 60 clinical trials were being carried out in 65 hospitals. Furthermore Cuba's biotechnology centres have filed about 900 patents outside the country. All these figures show that the following challenges had to be met: provide a good research basis, and setting up effective connections between research, production, education and training, and public health. Supported by constant political will at the top level of the country's government, and a steady investment policy (over US$1 billion in 20 years), multidisciplinary research teams have been able to develop new technologies and products, i.e. to generate innovation. This innovation has its origin in the national commitment for public health; therefore it serves public health and the country's overall economy (about US$250 million-worth exports).

There is therefore hope that agricultural biotechnology will effectively contribute to rural and agricultural development, in the same way as medical and pharmaceutical biotechnology did for health care. It is true that biotechnology alone cannot feed the Cubans and that many other measures have to be taken in the political and social arena. But it can help if its results are transferred rapidly an effectively to farmers who should be given the incentives to cultivate their lands and increase their productivity.

Canada : more than a breadbasket

As other agricultural and mining countries, Canada has benefited from the global food crisis and soaring prices of raw materials and rural commodities, and thereafter it was hit by the global economic meltdown and the tumbling of prices for raw materials. But it is poised to rebound when the world economy recovers.

For instance, Saskatchewan, the western Canadian province, boasted the fastest economic growth rate of any Canadian province, not just because of wheat but a rich mix of other crops (e.g. canola, chickpeas and green lentils of which Saskatchewan is the world's biggest exporter), as well as potash, uranium, oil and natural gas, all of which enjoyed record prices in 2007. Potash Corp, a fertilizer company based in the province's capital Saskatoon, has become one of the biggest companies on the Toronto stock exchange by market capitalization. Saskatchewan is in fact one of the richest places in natural resources of the world. It is the world's biggest producer of uranium and of potash (the ton of potash cost US$1,000 in 2008, compared with US$300 in 2007). The United States buy more crude oil from Saskatchewan than from Kuwait (*The Economist*, 2008g).

The province was settled before the first world war by European farmers, attracted to the area by free land. In 1931, Saskatchewan was the third most populous province in Canada, behind only Ontario and Quebec. Depression and drought then led to eight years of decline. Now, thanks to its export boom, Saskatchewan has become a rich province, like Alberta, which means that it no longer qualifies for federal handouts for certain social services. Canada's economy contracted in 2008, mainly because of the impact of the American slowdown on Ontario's industry. Crop prices became volatile, due to the economic crisis and bad weather. But the province's government hoped to overcome the downturn and to attract labour from more affected provinces, e.g. Ontario, with a view to increasing the overall population by 10% in ten years. The 2009 economic growth rate will be far from the 3.9% achieved in 2008 and the budget surplus will be much less than the US$3 billion, but it seems that prosperity will return to the province with its problems such as the high increase in housing costs, in wages and the claims of Aboriginal groups, who make up 14% of the population and complain they are not receiving an equal share of the province's economic growth (*The Economist*, 2008g).

Saskatchewan contributes to the good health of Canadian biotechnology and bioeconomy (in 2007, the annual turnover of Canadian biotechnology

amounted to CAN$78 billion, i.e. 6.4% of the country's GDP), as it is home of the Plant Biotechnology Institute – a world class research centre renowned for its work on cereals, canola and legumes.

Morocco

Morocco, in north-west Africa, is characterized by a Mediterranean-type climate, despite its long Atlantic coast, and is therefore susceptible to recurrent droughts. Desertic, arid and semi-arid lands predominate, but fertile soils along the Mediterranean and Atlantic coasts provide an important supply of agricultural products – cereals, vegetables and fruit. Despite the efforts made to industrialize the country, agriculture (on small and large scale) remains an important part of Morocco's economy.

In 2007-2008, Morocco has been severely hit by soaring food and oil prices, as the country depends on imports of crude oil for its energy consumption and also, depending on the good or bad harvests, on imports of wheat, maize and oilseeds. Such a situation has raised serious concerns about food security and social stability (Tuquoi, 2007).

In 2006-2007, aggregate food import bills increased by 72%. In 2007, the food import bill was over twice its 2003 value: 27 billion Moroccan dirhams (MDH; in 2009, 1 US$ ≃ 10 MDH), compared with 12 billion MDH in 2003. Wheat imports in 2007 amounted to 1.1 million tons from the United States, 1.2 million tons from France, 600,000 tons from Canada, 200,000 tons from Kazakhstan, about 290,000 tons from Germany and Russia, and around 350,000 tons from other countries. The price of the ton of imported wheat climbed up to 2,500 MDH, compared with 1,700 MDH in 2006 and in 2003. Maize imports soared to 2 million tons, those of barley to almost 600,000 tons, the respective prices reaching (in 2007) 1,950 MDH and 2,200 MDH per ton (Mohamed Aitkadi, personal communication, 2009).

Consequently the share of food imports in total imports rose from 7.3% in 2006 to 10.3% in 2007, while the rate of coverage of food imports by exports declined in one year from 137% to 83%. The trade deficit grew 40.8% and nearly represented 23% of gross domestic product (GDP). For the first time in six years, the current account showed a deficit of about 0.1% of GDP (Mohamed Aitkadi, personal communication, 2009).

The rise in staple food and oil prices in 2007 had an inflationary effect that was mitigated by the following government measures :

- freeze of the mechanism of fuel price indexation with oil price on international markets;
- reduction or even suspension of import taxes on some staple foods such as soft and durum wheat, barley, powder milk and butter.

In 2009, the cereal harvest has been a good one; the figures published by the National Interprofessional Office of Cereals and Legumes (ONICL) indicated the wheat harvest amounted to 6.5 million tons, including 4.5 million tons of soft wheat. This was a 72.6% increase over the 2008 figure (+78.7% for soft wheat). The whole production of three cereals (soft and durum wheat, and barley) reached 10.2 million tons. Consequently, the domestic demand will be better met and the cereal bill was to be reduced, as shown by the 42% reduction of wheat imports at the end of February 2009. At the end of April 2009, food imports amounted to 9.164 billion MDH, compared with 12.287 billion MDH one year earlier, i. e. a 25.4% decrease. Such result was due to a 55.2% reduction of wheat and maize purchases. The average price of the imported ton of wheat fell down from 3,665 MDH in April 2008 to 2,360 MDH in April 2009 (Boukhalef, 2009).

By mid-August 2009, cereal stockpiles reached 2.3 million tons. With respect to processing, also by mid-August 2009, soft wheat crushings amounted to almost 200,000 tons (including 50,000 tons of subsidized flours and 150,000 tons of non-subsidized ones). According to ONICL, this activity was 5% higher than one year earlier (Boukhalef, 2009).

Morocco has developed a new agricultural strategy called "Green Morocco" (Le Maroc Vert), in order to benefit from huge opportunities such as a very strong growth in domestic demand, an increasing overall demand for Mediterranean-type (diet) foodstuffs, recognized comparative advantages for a number of key products, and the accessibility to European and US markets in terms of logistics and customs. The new strategy also aims to overcome major existing obstacles such as the vulnerability of a large number of farmers, the lack of flexibility concerning land issues, the overuse and depletion of water, the industry framework not enough tuned to deregulation, and the lagging modernization of the agriculture ministry's managerial structures. The strategy revolves around two pillars: on the one hand, the development of a sector of modern agriculture, with high productivity and high added value; and on the other, a strong effort to struggle against rural poverty through the support for, and the development of, smallholder agriculture, as part of an overall policy of solidarity. Both approaches are based on concrete projects, i.e. the conversion of about 1.4 million hectares (irrigated and rainfed) by 2015 into highly productive areas, the sales of which would reach

between 60 and 70 billion MDH (mainly corresponding to vegetables, fruit, citrus, olives, oilseeds); and three key programmes aiming to significantly raise the living standards of 500,000 to 600,000 farmers through 300-400 projects needing an investment of 16 to 18 billion MDH. The reconversion programmes (50-70 projects) target the cultivation of olives, figs, almonds and other fruit; the intensification/quality improvement programme (100-150 projects) deals with cereals, date-palm, forestry, sheep and cattle; the diversification or niche programme (100-150 projects) concerns bee-keeping, truffles, small livestock and snail. The total area of the three smallholder programmes was estimated at 800,000-900,000 hectares (Mohamed Aitkadi, personal communication, 2009).

For instance citrus acreage reached 80,000 hectares in 2007, compared with 74,000 hectares in 1996, the year of the previous census carried out by the agriculture ministry in collaboration with the growers. By early 2008, a national plan was to be launched in order to foster the development of this sector, with respect to production, processing and export of citrus fruit. The total number of citrus growers was 12,000, and 65% of them were small producers, which meant that the sector is very fragmented. Consequently, its competitivity must be improved, e.g. the renewal of the orchards, the introduction of new varieties (orange trees are the oldest among citrus varieties), the gradual replacement of flood irrigation by drip irrigation (flood irrigation is used in 50% of the whole acreage, which is a nonsense in a country which lacks water). The overall policy concerning the modernization of the citrus sector fits within the overall strategy of "Green Morocco" (Akisra, 2007).

The potential impact of the overall agricultural strategy is huge in economic and social terms : the development of a highly productive and value added agriculture targeting 400,000 farms, through 700-900 projects and involving investments of 110-150 billion MDH, and the modernization of small farms (300-400 projects involving 600,000 to 800,000 farmers) thanks to investments of 15 to 20 billion MDH, were expected to create 1 million to 1.5 million jobs, to reduce rural poverty (through doubling or trebling the income of 2 million to 3 million smallholders) and to generate a domestic product estimated at 70 billion to 100 billion MDH (Mohamed Aitkadi, personal communication, 2009).

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Out of press : September 2009

Imprimerie Lawne, 11 rue Dakar, Rabat, Morocco

About the author

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His research and work have culminated in over 200 publications, including many books and reviews on biotechnology in developing countries over the last 36 years.

About the book

In 2007-2008, the world has been hit by a major food crisis, the symptoms of which were: soaring agricultural commodity and foodstuff prices, food riots and social unrest in many developing countries, and a new face of hunger (in 2009, FAO estimated that the total number of people suffering from hunger reached 1.020 billion, including not only those who were struck by chronic starvation, but also those who lost the ability to purchase food due to the economic and social crisis). The millennium development goal to halve the number of hungry people by 2015 will not be achieved.

In addition to describing the symptoms of the global food crisis, the book presents its main causes : weather vagaries and climate change, particularly recurrent droughts in commodity-exporting countries; phytosanitary threats to cereal crops; soaring oil and agricultural input prices, as well as high increase in transport costs at national and international level; commodity export bans by countries wanting to ensure their food security; falling stockpiles of grains and speculation; and production of agrofuels.

The author emphasizes that the key cause of the crisis is the worldwide inadequate food supply. For more than four decades agriculture has not received the priority it deserves in terms of investment and national policy. Instead of producing more and better, it was thought that food would remain cheap and abundant, and that the issue was that of distribution and not of production.

Although, in 2009, agricultural commodity and raw material prices tumbled, average food prices remained volatile and higher than in 2006. Several signs indicate that they will rise again, following the gradual recovery of the world economy and the increase in crude oil price. The challenges of food security, food quality and safety, as well as of more costly staple foodstuffs should therefore be met in the years to come. In 2050, 9 billion people should be fed on our planet and agriculture output should be doubled. Consequently, top priority must be given to food crops and subsistence agriculture, particularly in Africa and Asia, and another “green revolution” is needed. We have the technological tools, such as efficient and environment-friendly agronomical practices, crop biotechnology and plant genomics for supporting advanced crop breeding. But political and social measures are equally important, as well as fair agricultural trade regulations aimed at helping the small-scale and poor farmers in order to produce more to feed themselves and to have access to local markets.

A few case studies are presented at the end of the book, with a view to showing how countries have reacted to the global food crisis and are adjusting their agricultural policies in order to produce more and better.

ISBN n° 978-9954-8908-7-4