Why **modern agriculture** must change

At a time when record prices for agricultural products like rice, maize and wheat are fuelling social tensions in nearly 40 countries, a report released at UNESCO headquarters in Paris on 15 April concludes that the rules of modern agriculture must change. The report is co-sponsored by FAO, the Global Environment Facility, UNDP, UNEP, UNESCO, the World Bank and WHO.

The way the world grows its food will have to change radically to serve the poor and hungry better, if countries are to cope with a growing population and climate change while avoiding social breakdown and environmental collapse. That is the central message of the *International Assessment of Agricultural Science and Technology for Development*. It proposes a series of options for charting a new course, including greater acknowledgement of the role of the small-holder farmer, new trade rules and an 'agro-ecological' approach to farming.

The fruit of three years' work involving 400 scientists and piloted by a Bureau made up of government representatives from developed and developing countries, consumer groups, NGOs, producers, institutions and the private sector, the assessment was approved by 57 governments[1] in Johannesburg on 12 April. The process was first launched in 2002 by the World Bank and FAO at the World Summit on Sustainable Development in Johannesburg.

©Sergio Santimano/UNESCO

Banana plantation in Mozambique. The indiscriminate or inappropriate use of fertilizers and pesticides in most sub-Saharan countries has damaged human health and the environment. Although extremely low in Africa, pesticide misuse is still a big concern in most countries: over 50 000 tonnes of obsolete stocks of chemicals have accumulated over the past four decades. Many of these chemicals and their containers are in poor condition and threaten to contaminate soil, water, food and air. The solution could be to combine basic training on how to use chemicals safely with the promotion of practices which reduce their use, such as the greater utilization of organic and mineral fertilizers and biopesticides, combined with more substantive solutions requiring changes to agricultural policies

The report was originally intended to cover global food production only. Its purview was later extended to include social justice, traditional knowledge, health, gender issues and the environment. In its analysis of the state of global agriculture, the report covers such major issues as biofuels (*see overleaf Waiting for second-generation biofuels*), genetically modified (GM) crops, shrinking biodiversity, the use of traditional agricultural knowledge, tensions in trade, intellectual property rights, environmental degradation and the impact of climate change. It comes at a time of widespread riots in response to soaring food prices.

Tensions around the table

Drafting of the report was not without its own tensions. Industry representatives did not always see eye to eye with other sectors represented in the Bureau, particularly on the issue of GM crops. Tensions peaked in October when CropLife International members Monsanto and Syngenta dissociated themselves from the assessment.

In an editorial entitled 'Deserting the hungry?' in January, *Nature* reported the spokesman for CropLife as saying that the decision to leave the table 'was prompted by the inability of its members to get industry perspectives reflected in the draft reports. One of these perspectives is the view that biotechnology is key to reducing poverty and hunger, and it is based in part on high (and rising) levels of demand for biotech crops from farmers across the developing world,' CropLife told *Nature*. But 'the idea that biotechnology cannot by itself reduce hunger and poverty is mainstream opinion among agricultural scientists and policy-makers,' the editorial commented.

Assessment team leader Robert Watson shrugged off this setback. 'I always knew it was a social experiment,' he told *Science* in March. For the former chief scientist at the World Bank, 'if we can stimulate a debate, for instance, about the degree to which agricultural science is meeting the needs of the poor and whether everyone gains from free trade, then it's a success.'

Countries in crisis must develop self-sufficiency in food

'We are perhaps at a turning point in agriculture,' observes Guillen Calvo from UNESCO. 'After decades of inciting poor countries to develop food crops for export (cash crops) to earn foreign currency for repaying debt and other purposes, all the major development agencies are now advising these same countries to reinvest in subsistence agriculture.'

There is a growing feeling that modern agricultural practices are failing the poor. What has gone wrong? Modern crop varieties were introduced to improve crop yields and thereby reduce hunger and avoid agricultural expansion over much larger tracts of land. Modern varieties of cereals in particular, but also of root, protein and horticultural crops, have since been widely adopted. Asia grows modern cereal varieties on 60–80% of the cultivated area. They are also widely grown in Latin America. Thanks to the application of agricultural knowledge in crop and livestock breeding via genetic improvements, irrigation, improved husbandry, greater use of fertilizers, pesticides and mechanization, modern crop varieties have provided sufficient food to reduce undernourishment by half in Asia–Pacific and Latin America since 1970.

©S. Schneegans/UNESCO

Olive trees as far as the eye can see for this monoculture in the semi-arid region of Andalucia in southern Spain. Horticulture, including fruit-growing, expanded by 178% between 1970 and 2004, half of the increase occurring in China (52%), 40% in other developing countries and 8% in developed countries. This makes horticulture the world's fastest-growing agricultural sector. The share of horticultural products in trade has likewise increased

Yet, although per capita food consumption has increased, with 61% of the world population now eating more than 2730 kilocalories per day, an estimated one-third of humanity has 'not been affected by modern agricultural science.' Not everyone has benefited from the Green Revolution[2]. In much of Africa and East Asia for instance, countries have been slow to adopt modern crop varieties. In sub-Saharan Africa, where agriculture accounts for 32% on average of the region's GDP, overall per capita yields declined from 1970 to 1980 and have stagnated ever since. Some 30% of Africans are chronically hungry.

Yet poverty also remains endemic in countries like India, Mexico and Thailand which have embraced modern crop varieties. How is it that an estimated 43% of the rural population in Thailand – the world's biggest exporter of rice – now lives below the poverty line, even though agricultural exports grew by 65% between 1985 and 1995?

How is that, in Latin America and the Caribbean, which produces one-third of the world's transgenic crops, 37% of the population still lives below the poverty line and 10% is hungry or malnourished, despite higher yields? Why, when the planet's biggest exporter of food is blessed with abundant freshwater and vast tracts of arable land, does Latin America import much of its food, creating dependence on international markets and disrupting local production?

How is that, in India, one of the greatest beneficiaries of the Green Revolution, the number of landless rural farmers rose from 28 million to over 50 million between 1951 and the 1990s? And why does India grapple with one of the world's highest rates of child malnutrition?

The report concludes that current 'international policies promoting economic growth through agriculture do not necessarily resolve the issue of poverty.' One of the consequences of the structural adjustment policies advocated by the World Bank in recent decades, it recalls, has been the abandonment of the land by poor farmers, who can no longer afford farm inputs like the fertilizers, insecticides and pesticides which modern cereal varieties demand. The cost of these inputs is one cause of the high migration from the countryside to urban centres in search of jobs in India and elsewhere, the report observes.

Nor does liberalizing agricultural trade appear to have helped small farmers or rural communities appreciably in much of the world. Kenya for example was self-sufficient in food until the 1980s. It now imports 80% of its food, even though 80% of exports are agricultural. The report concludes that 'opening national agricultural markets to international competition before basic infrastructure and national institutions are in place can undermine agriculture, poverty alleviation, the environment and food security.'

Perhaps the most glaring example of the perverse effects of liberalized trade can be seen in Mexico. The country of origin of corn, Mexico began importing mass quantities of this foodstuff from the USA after signing the North

©Le Mignon, Misato/UNESCO

Cattle-breeding in France. The global production and consumption of livestock products have been growing dramatically in recent decades, especially in largely populated countries with fast-growing economies. Argentina and Brazil together accounted for 37% of global exports of beef in 2005, while the economic take-off in Asia, mainly in China and the Republic of Korea, is expected to generate a 22% increase in demand for beef imports over 2005. The four biggest consumers of beef are the USA, Brazil, Japan and China

Waiting for second-generation biofuels

First-generation biofuels consist predominantly of bioethanol and biodiesel produced from agricultural crops like maize and sugar cane. Production has been growing rapidly in recent years, primarily due to policies in support of them. The Americas are leaders in the field. Brazil produces 60% of the world total of ethanol from sugar : in 2005, production reached a record 16.5 billion litres, two million of which were destined for export.

Although biofuels hold out 'great hopes' for reducing dependency on fossil fuels, there are concerns that they are pushing up food prices and accelerating deforestation, thereby boosting CO_2 emissions. Research by David Pimentel and Tad Patzek at Cornell University (USA) supports the notion that 'more fossil energy is spent to produce biofuels than they provide' because of current processing methods, which would mean that biofuels actually 'create a negative balance of greenhouse gas emissions, when they were supposed to do the opposite.'

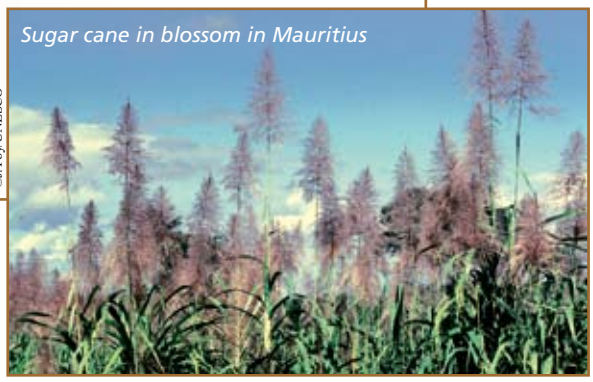
In the long term, the effect on food prices may diminish but environmental effects caused by the land and water requirements of large-scale increases in first-generation biofuels production are likely to persist.

The solution could lie in second-generation biofuels such as cellulosic ethanol and biomass-to-liquids technologies, which allow conversion into biofuels [Ed.: such as the residual parts of cereal crops (husks, stems, leaves, etc) and industrial waste (wood chips, fruit pulp, etc]. They could potentially reduce agricultural land requirements per unit of energy produced and cut back greenhouse gas emissions.

However, second-generation biofuel technologies are not yet commercially proven and their environmental and social effects are still uncertain. For example, the use of feedstock and farm residues can compete with the need to maintain organic matter in sustainable agro-ecosystems.

Bioelectricity and bioheat are usually more efficient and produce fewer greenhouse gas emissions than liquid biofuels and fossil fuels. Digesters, gasifiers and direct combustion devices can be successfully employed in certain settings, like off-the-grid areas. There is potential for expanding these applications but research is needed to reduce costs and improve operational reliability.

Source: International Assessment of Agricultural Science and Technology for Development *(2008)*



Sugar cane in blossom in Mauritius

©J. Foy/UNESCO

American Free Trade Agreement with the USA and Canada in the early 1990s. The subsidized US corn was more competitively priced than the Mexican corn produced locally, which created dependence on the imported corn. When the USA decided to use part of its production to produce ethanol, the diversification in markets pushed up the price of corn. As a result, the 'tortilla,' a staple food in Mexico, became unaffordable for most Mexicans, leading to 'tortilla riots' last year which were only calmed when the government imposed a ceiling on corn prices.

The Chinese government estimates that 10 million farmers will be displaced by China's implementation of World Trade Organization (WTO) rules, with the livelihoods of a further 200 million small-scale farmers expected to decline as a result of further implementations of trade liberalization and agricultural industrialization.

Even in North America, where the industrial model of agricultural production is most developed, 38 000 small farms went out of business between 1995 and 2000 in the USA and, in Canada, farm debt has nearly doubled since the 1989 Canada–USA Free Trade Agreement.

Despite the fact that some of their own members are adversely affected by current trade rules, many OECD member countries 'are deeply opposed to any changes in trade regimes or subsidy systems. Without reforms here, many poorer countries will have a very hard time...,' remarks one of the assessment co-chairs, Hans Herren.

Sorghum versus cocoa

'There seems to be a consensus among governments that countries in crisis[3] are going to have to develop self-sufficiency in food,' observes Calvo. 'This is tantamount to admitting that the role of agriculture cannot be solely to earn foreign currency for reinvestment in other sectors. It is important for countries to develop strong local agricultural systems and to make better use of local and regional markets. Modern agricultural practices are based on an industrial approach which neglects the small-holder farmer, who is more and more often a woman.'

'The report observes that intensive agriculture, with its focus on crops like cotton, coffee, soybean and palm for export, has degraded the environment without making a substantial contribution to poverty reduction,' says Calvo. 'We now realize that these policies favouring cash crops over staple food crops have placed countries in a situation of great dependency on imports. The assessment has helped to open our eyes to the failures and errors of the past.'

'There may be a general consensus among governments today of the need to revigorate staple food crops and/or subsistence agriculture,' adds Calvo, 'but opinions diverge on how to achieve this. The assessment proposes that we focus on small-holder agriculture, make better use of local and community knowledge and favour practices which require fewer agricultural inputs like chemical fertilizers, pesticides and insecticides. The overall aim of course is to retrieve self-sufficiency in food while protecting the environment.'

In this context, some emerging concepts and paradigms are attracting wider attention and support. The authors of the chapter on Latin America repeatedly refer to food sovereignty, for example, a term coined in 1996. This well-known, if hotly

©A. Clayssen/UNESCO

Post-harvest jasmine rice depot in Thailand, the world's biggest exporter of rice, ahead of Vietnam. In May, the Prime Minister of Thailand proposed creating a cartel of rice-exporting nations to fix prices. The proposal came shortly after Vietnam underbid Thailand on a contract to supply rice to the Philippines, before announcing it would be delaying delivery to guarantee supplies for its own domestic market. The FAO has since forecast a record high for rice production in Asia, Africa and Latin America this year

debated concept goes beyond self-sufficiency in food. Food sovereignty advocates the right of peoples to define their own food, agriculture, livestock and fisheries systems, as opposed to having food crops imposed on them to a large extent by international market forces. Food sovereignty is supported by indigenous peoples, peasants, some farmer's groups and by environmental organizations but does not find favour with economists who defend liberalized international trade.

Why the poor are losing out in agricultural trade

Developed countries account for about 63% of world agricultural exports. With the exception of Australia and New Zealand, all the OECD countries provide high subsidies and tariffs (border protection) for agricultural products. These protectionist measures accounted for 45% of farm gate prices in 2000–2002. Conversely, 'developing countries as a whole reduced average agricultural tariffs from 30% in 1990 to 18% in 2000,' observes the report.

The WTO Agreement on Agriculture limits the extent to which governments may support their agricultural producers. For developing countries, the ceiling is fixed at 20%. In any event, resource constraints limit the extent to which many governments can actually support their farmers: to 2% for example in Bangladesh and 8–10% in India and Vietnam. Middle-level exporting countries like India are trying to obtain 'agreements which will maintain their own existing levels of support while reducing the levels allowed to developed countries.'

This is because small-holder farmers suffer from competition from imports that are cheaper than their own products, owing to the high subsidies on exports in OECD countries, as in the case of the 'tortilla' crisis in Mexico. To cite another example, opening up sections of agricultural markets to liberalized trade led to a 55% fall in cotton prices in India between 1996 and 2003 in the face of competing imports from subsidized producers, like those in the USA. Many destitute cotton farmers in India were driven to suicide.

Yet food price support for domestic producers to help them compete with imports from subsidized producers can have perverse effects. In the 'Green Revolution belt of Punjab Haryana in India, for example, continued minimum price support to wheat and rice continues to stall attempts at diversification,' observes the report, 'as the rates of return from assured grain prices inhibit a shift towards more risky, if higher return, crops.'

'Uniform rules on the nature and measures of support cannot be applied to developed and developing countries alike,' notes the report. 'Least developed countries are unable to match the competitiveness of larger and more complex economies. Differential market access, for given time periods, can help least developed countries benefit from international trade.' The World Bank is currently implementing a project to assess the impact of liberalization and structural adjustment strategies on rural livelihoods.

Agriculture severely degrading land and water

'Although considered by many to be a success story,' Watson observes, 'the benefits of productivity increases in world agriculture are unevenly spread.' Moreover, 'we are putting food that appears cheap on our tables but it is food that is not

©Bernard JacquotUNESCO

Fishing boats in Ghana. Fish is an important source of protein in sub-Saharan Africa, where about 10 million people make their living as small-scale fishers, processors and traders, more than what many small-scale fisheries can sustain. As climate change causes fish species to disappear from sub-Saharan Africa's 13 rivers, commercial aquaculture will grow, dominated by large producers like Nigeria, South Africa and Madagascar but with countries like Côte d'Ivoire, the Republic of Congo, Ghana and Kenya also expanding their aquaculture rapidly. Aquaculture has been the world's fastest-growing food-producing sector for 20 years and currently represents about 40% of the world's total food fish supply. Global fish production – encompassing both wild harvests and aquaculture – increased by about 230% between 1961 and 2001

Issues in agribiotech and genetic engineering

Advances in biotechnology hold great promise for poverty alleviation and environmental protection. Polymerase chain reaction technology, for example, can be used to reduce cattle production of methane, a greenhouse gas. Grain crops can now be utilized to reduce nitrogen and phosphorus levels in animal waste. These tools can also be used to characterize indigenous animal genetic resources to understand key factors in disease resistance and adaptation and thereby further protect local breeds.

'Nevertheless,' observes the assessment, 'the impact on poverty reduction and safety of many of these technologies is currently unknown.'

Which organisms are genetically engineered and where do they grow?

Currently, most of the commercial application of genetic engineering in agriculture comes through the use of GM crops. The commercial use of other GM organisms, such as mammals, fish or trees, is much more limited.

Genetic engineering (GE) of crops has emerged as a major agricultural technology over the past decade. Herbicide tolerance and insect resistance – the latter based on traits from *Bacillus thuringiensis* (*Bt*) – dominate the market, although GE traits come in other categories, such as pest and disease resistance, tolerance of abiotic stress (like drought), yield, nutrition and vaccines.

The four primary GM crops in terms of global land area are soybean (57%), maize (25%), cotton (13%) and canola/oilseed rape (5%), with the USA (53%), Argentina (18%), Brazil (11%) and Canada (6%) major producers. In Asia, GM cotton production occurs in smaller-scale systems in India (3.7%) and China (3.5%). Sixteen other countries make up the remaining area (4.8%) of GM crop production.

In what form do GM crops reach the consumer?

GM crops are mostly used for extractive products (oil from soybean, starch from maize) or for processed products such as cornflakes or tortillas. Wholegrain GM maize is only consumed as food aid sent to famine areas, while some parts of GM cotton plants are used for animal feed. A great diversity of novels traits and other crop plants are under development, such as for pharmaceutical and industrial purposes. 'Their impact will need to be evaluated in the future. The main challenge here will be to keep GM pharma and industrial crops separate from crops for food.'

GM crops are only grown commercially in three or four European countries, primarily in Spain. This is because consumer demand for GM foods is 'almost non-existent' and consumers are able to avoid buying GM foods owing to the strict labelling laws in the European Union for food products. This problem does not apply to non-GM foods: 75% of cotton imported into the EU today from the USA and China are GM varieties.

©US Dept of Agriculture

Soil scientist measuring maize crop growth in the USA. In North America and Europe, the amount of agricultural research funded by the private sector has grown tremendously, a factor that has largely determined the direction taken by research. Big transnational corporations thus wield considerable influence on agricultural science and its priorities

Have farmers benefited from GE crops on the land?

It is a matter of debate. GE crops have been shown to favour the establishment of large holdings and farms. Some studies indicate a lower use of insecticides, others a significant rise in herbicide use. New evidence of high insecticide use by Chinese growers of GE insecticidal crops (*Bt* cotton) has demonstrated that farmers do not necessarily reduce their insecticide use even when using a technology designed for that purpose.

Field and laboratory studies 'show a great diversity of impacts [of GM crops] on non-target organisms, including arthropods and plants.' In Latin America, for example, where *Bt* crops are grown extensively, scientists are concerned that the *Bt* toxin 'may affect beneficial insects that feed on pests that eat the *Bt* crop. There is also evidence that the pollen from *Bt* crops deposited on the leaves of wild plants around the areas planted in *Bt* crops may kill other lepidopterans that are not pests, such as the Monarch butterly. And that the *Bt* toxin adheres to soil colloids and lasts up to three months, having a negative impact on the populations of invertebrates that help in the decomposition of organic matter.'

One controversial topic surrounds claims that GM crops reduce pesticide use and thus help to conserve biodiversity. Here again, there is contradictory evidence. Most field studies were conducted in pesticide-intensive, large-scale monocultures like those in which 90% of GM crops are currently grown. Consequently, these results have limited applicability to low-input, small-scale systems with high biodiversity.

When *Bt* crops were introduced into farming systems which did not use synthetic pesticides, as in the case of organic maize production systems, 'there were no benefits in terms of reduced insecticide use. In fact, in comparison with insecticide-free control fields, certain non-target taxa were less abundant in *Bt*-crop fields.'

Canadian farmers are one casualty of the European aversion for GM foods. After adopting GM varieties themselves, Canadian farmers lost their market for US$300 million of canola (oilseed rape) to GMO-free markets in Europe. Maize exports from the USA to Europe have also declined from 3.3 million tones in 1995 to 23 000 tonnes in 2002 'due to fears about GMOs.' The American Farm Bureau estimates this loss has cost US farmers US$300 million per year.

What about the unintentional spread of GM traits?

The consequences of this could be serious. In 2006, unapproved GM traits which had originated in rice field trials in the USA and China were found in commercial rice sold in European supermarkets; when imports were consequently banned, farmers in both countries suffered serious economic losses, later compounded by the cost of certifying that their crops were free from unapproved GM traits. Similar controversy followed the discovery of transgenes in landraces of maize in Mexico.

There is evidence of increased invasiveness or weediness as the result of the unintentional gene flow of GM traits, such as herbicide and insect resistance, into cultivated and wild or weedy relatives. In Canada, organic oilseed rape production in the prairies was largely abandoned because of widespread genetic contamination with transgenes or transgenic oilseed rape.

GE risk analysis has acknowledged the possibility of negative ecological effects from the deliberate or inadvertent release of transgenes into the environment through pollen-mediated gene transfer to weedy relatives of GM crops and through horizontal gene transfer. For most crops grown under regulatory approval, such as maize in the USA, the likelihood is negligible. In other cases, as for canola in Canada, low levels of transgenic DNA have entered non-GM seed supplies. There have also been cases of the food supply being contaminated, with possible litigation ensuing against farmers for the non-intentional presence of transgenic DNA in their crops. This is likely to emerge as an even bigger issue as pharmaceuticals are introduced into crops.

Despite technical solutions to prevent such gene movement – such as limiting transgenes to the chloroplast genome not carried in pollen or the controversial terminator technology [Ed. which makes the seeds a farmer buys sterile, preventing him or her from replanting them the following season] – and traditional plant variety purity protocols, no method is likely to be completely effective in preventing movement of transgenes.

There are regulations or guidelines for risk assessment in the USA, Canada and the European Union. Some groups feel that pre-market testing for environmental risks of GM crops to non-target organisms need to follow the protocols for chemicals, such as pesticides.

The Cartagena Protocol on Biosafety was adopted under the Convention on Biological Diversity and entered into force in 2003. It is the first international agreement for the control of modern biotechnology. It applies the precautionary principle to the use and transnational movement of transgenic crops.

Source: International Assessment of Agricultural Science and Technology for Development *(2008)*

always healthy and that costs us dearly in terms of water, soil and the biological diversity on which all our futures depend.' It is estimated that one-third of the Earth's severely degraded land has been damaged by agricultural activities.

The nitrogen dilemma

Nitrogen is vital for food production because it is an essential constituent of amino acids, proteins, nucleic acids and DNA that are vital for living cells, including plants.

Before the 20th century, the fixation of gaseous nitrogen in reactive forms which living organisms can use occurred only naturally, via a small number of micro-organisms in the soil and through lightning.

In 1918, Fritz Haber from Germany was awarded the Nobel Prize in Chemistry for combining gaseous nitrogen (N_2) with hydrogen (H_2) to produce reactive ammonia (NH_3). Thirteen years later, his compatriot Carl Bosch would receive the same prize for devising a way to produce ammonia on a commercial scale as fertilizer. The discovery of how to convert non-reactive gaseous nitrogen into reactive forms for agriculture removed an important barrier to the rapid growth of the human population but it came at a high cost.

In some parts of Europe, North America and Asia, there is now *too much* reactive nitrogen: the excess nitrogen applied in agriculture seeps into soils and groundwater, polluting the environment. Large parts of Africa and Latin America, on the other hand, have *too little* naturally occurring reactive nitrogen and more is used by cropping than is replenished by fertilizers, causing widespread depletion of soil nutrients which hinders attempts to feed the rapidly growing population. The dilemma will be how to optimize the use of nitrogen to sustain human life while minimizing the negative impact on the environment and human health.

Source: Human alteration of the nitrogen cycle. *UNESCO-SCOPE Policy Brief, No 4, April 2007: www.unesco.org/mab/pub.shtml; for further information: a.persic@unesco.org*

©Dominique Roger/UNESCO

Tomato harvest. Chemical fertilizers have boosted crop yield enormously but at a high environmental cost. Nitrogen fertilizers are particularly problematic, as plants cannot absorb all the nitrogen they contain. The residue contaminates soil and groundwater, and can be carried to the coast via rivers where it causes algal blooms which deplete oxygen levels in the ocean, creating dead zones

The report observes that, in East and South Asia and the Pacific, the current agricultural development path is increasing pollution, 'notably from nitrogen.' Some 60% of the ecosystems are degraded or used unsustainably and nitrogen pollution from fertilizers and domestic animal waste is expected to rise (see *The nitrogen dilemma*). Without political commitment, 'the downward spiral towards socio-economic turmoil and ecological degradation may be rapid and perhaps even irreversible.'

Irrigation was essential to achieving gains from the new high-yielding, fertilizer-responsive crop varieties. Between 1961 and 2000, the area of irrigated land worldwide doubled to 277 million ha, equivalent to about 18% of farmed land. Today, two-thirds of the world's irrigated land is in Asia, where it accounts for almost 35% of cultivated land. Some 40% of world cereal production comes from irrigated land, including as much as 80% of China's grain harvest. Yet, in several Asian countries practicing intensive agriculture, cereal yields are no longer increasing, despite irrigation. Crop yield increases in East and Central Asia for instance are generally below the world average, leaving most countries net food importers.

Irrigation has had a high social and environmental cost. Entire communities have been displaced to make way for large dams and the diversion of water away from rivers, lakes, oases and other wetlands dependent on groundwater has caused salinization, channel erosion, a decline in biodiversity, the introduction of invasive species, problems of poor water quality and genetic isolation through habitat fragmentation. At the same time, it has penalized floodplain and other inland and coastal fisheries.

Salinization and waterlogging of soils from inefficient irrigation is a major problem in Central and West Asia and North Africa; it affects more than half the irrigated lands in the Euphrates plains and in Pakistan. Nearly half the region's renewable water resources are below the minimum level necessary for development (500m^3 per person per year).

As the population grows, competition for water will intensify. Agriculture already accounts for 70% of all water consumption. The report warns that, 'under current water-use practices, increases in population and changes in diet are projected to increase water consumption in food and fibre production by 70–90%.' Add to this the anticipated effects of climate change on Africa, Asia and the Pacific and you have an explosive cocktail. Between now and 2020, the amount of water available per person in East and South Asia and the Pacific, for instance, will drop to one-third that in 1950, or even less.

Biodiversity threatened by agriculture

One of the more insidious causes of the current food crisis is the global homogenization in eating habits. 'Many countries have abandoned their traditional foods in favour of a more Western model with its focus on a handful of cereals and a copious consumption of meat and sugar,' observes Calvo. 'This has created an enormous dependence on overseas markets. We have not yet reached the point of no return but the message is clear: if countries don't maintain a rich agricultural biodiversity, they risk a growing dependence on a shrinking choice of cereals.'

Natural enemies

The natural enemies of pests – their predators, parasitoids and pathogens – can be used as pest control agents. Globally, the annual economic contribution by natural enemies has been estimated in the hundreds of billions of dollars worldwide.

Biological control provides natural enemies with suitable habitats and resources and limits use of disruptive pesticides. Since these approaches are locally adapted, they rarely produce products that can be widely marketed and have attracted little interest from the private sector. Yet they form the cornerstone of much ecological pest management. Practical applications include the Biologically Integrated Orchard systems of California (USA), vineyard habitat management and rice ecosystem conservation.

The predatory lacewing can control leafhoppers in grapes

The importance of natural enemies is highlighted by the often explosive outbreaks of pests introduced into regions which are devoid of specific natural enemies. Dramatic early successes in the late 19th century spurred classical biocontrol efforts around the world but these methods were later displaced by the widespread adoption of cheaper, fast-acting synthetic pesticides. Confidence in biocontrol declined, until problems arising from pesticide use rekindled interest. Initially, work in developing countries focused on large-scale commercial, industrial and export tree crops with less direct impact on small-scale farmers. Subsequent programmes focused on staple food crops and on building indigenous capacity.

Biological pest control has a long history in Africa. Kenya for example managed to control the coffee mealybug (*Phenacoccus kenyae*) biologically countrywide after it appeared in the 1920s. Interestingly, the persistent use of insecticides led to resurgences in the 1950s on the larger estates but not on small-holder coffee plantations. A factory for biological control using *Bt* began production in Nairobi in 2004.

A predatory Polistes wasp looking for bollworms or other caterpillars on a cotton plant

Ecologists have raised concerns about the potential impact on non-target organisms of introduced biocontrol agents. However, the safety record of invertebrate biocontrol is well-established, thanks to a substantial body of research. Moreover, there are now rigorous screening protocols and methodologies for environmental risk assessment of biocontrol agents: FAO, CABI, BioScience and the International Organization of Biological Control have developed a Code of Conduct for the Import and Release of Biological Control Agents.

Contrary to classic biocontrol, 'augmentation' involves mass production of naturally occurring biocontrol agents to reduce pest pressure. The decentralized artisanal biocontrol centres of Cuba offer one model of low-cost production for local use. Augmentative control in Latin American field crops and throughout the European glasshouse system are other examples. Growing consumer interest has helped to establish a small but thriving biocontrol industry in industrialized countries mostly, with some uses in developing countries where pesticide use is difficult or prone to trigger pest outbreaks, as in the case of sugar cane, cotton and fruit trees.

The costs of producing, storing and distributing living organisms have made these products less attractive to the private sector than chemical pesticides; currently they comprise only 1–2% of global chemical sales. Their relatively limited use also reflects chronic underinvestment in public sector R&D and a regulatory system that disadvantages biological alternatives to chemical pesticides.

Global challenges for biocontrol include a possible growth in exotic pest problems due to globalization and climate change. Natural enemies have previously demonstrated their capacity to adapt to changing climates encountered in expanding their geographic range and to control invasive species in a safe and sustainable manner. These attributes, along with the imperative to reduce pesticide contamination of drinking water supplies, suggest that biocontrol will play a growing role in future pest management practices.

Source: International Assessment of Agricultural Science and Technology for Development *(2008)*

Loss of genetic diversity represents a serious problem south of the Sahara, for example, because a number of species and crops that represent a very small part of global trade are local food staples, such as tef and yams. It is paradoxical that sub-Saharan Africa lacks micronutrient-rich foods, despite possessing an enormous potential for crop genetic resources. Ethiopia for example has 12 potentially valuable crop plants, including the vegetable okra (*Abelmoschus esculentus*) and the legume crop yeheb (*Cordeauxia edulis*).

If international trade promotes a narrow specialization in a few specific products, the development of improved varieties has similarly focused on a narrow range of cereals and animals, threatening 'discarded' varieties with extinction, despite their valuable contribution to the gene pool and their utility for the local economy.

Harmful agricultural practices, such as the excessive use of nitrogen fertilizers, inefficient irrigation or the unintended contamination of plants and arthropods by GM crops, are having a disastrous effect on biodiversity. Expanding the area covered by agriculture is another threat, as it reduces the size of natural habitats and key migration corridors.

The report cites other reasons for not expanding agricultural land. Both Africa and Latin America, it notes, have 'significant traces of undeveloped land that could be cultivated but estimates suggest that only a small fraction of these areas – 7% of Africa, 12% of Latin America and the Caribbean – are free from the types of severe soil constraints that limit profitable and sustainable production.' In addition, many of the remaining undeveloped areas are of regional and global importance for biodiversity and ecosystem services, such as the continents' tropical forests.

The monopoly control of plant genes is also a biodiversity issue. In a textbook case in May, *The Washington Post* reported that the world's agribusiness giants, BASF (Germany), Monsanto (USA) and Syngenta (Switzerland), had 'filed [about 530] applications to control nearly two-thirds of the climate-related gene families submitted to patent offices worldwide.' These GM crops have been engineered to withstand drought and other environmental stresses. According to the Ottawa-based ETC Group, an activist

body that supports subsistence farmers and whose report was cited by the newspaper, 'the move could undermine public-sector plant-breeding institutions… which have long made their improved varieties freely available.'

'Gene patents generally preclude the age-old practice of saving seeds from a harvest for replanting, requiring instead that farmers purchase the high-tech seeds each year,' recalled the newspaper. It cited one BASF patent claim for a gene tolerant of environmental stress 'which seeks to preclude competitors from using that gene' in more than 30 of the most common crops, including maize, rice, soybean, coffee, canola and wheat.

Richard Jefferson, the founder of Cambia, a non-profit institute based in Australia that helps companies work together on patents, occupies the middle ground. 'I don't mind Monsanto developing these tools', he told the *Washington Post*. 'I mind that we don't have an economic ecology that lets other companies compete with them.'

Time to redirect knowledge towards preserving the 'agro-environment'

The report calls for redirecting the wealth of agricultural knowledge and expertise the world has built up over recent decades towards strategies that combine productivity with protecting natural resources like soils, water, forests and biodiversity.

©Alexis N. Vorontzoff/UNESCO

Grinding millet in Mali. Soil moisture stress affects more than 80% of Africa's agricultural land, limiting nutrient uptake and thus productivity. There is ample scope for small-scale irrigation and water harvesting in sub-Saharan Africa, where irrigation is rare: just 4% of arable land, compared to 35% in Asia and 15% in Latin America

It is recommended that agricultural science place greater emphasis on safeguarding natural resources and on 'agro-ecological' practices. These practices include the use of natural fertilizers, biopesticides (*see Natural enemies*) and traditional seeds, the avoidance of monocultures – particularly vulnerable to outbreaks of pests and disease – and reducing the distance between agricultural production and the consumer. With food riots now also breaking out in cities, one option advocated by the report is to foster peri-urban agriculture and vegetable gardens in city suburbs. Among the advantages of peri-urban agriculture: lower transport costs meaning fewer greenhouse gas emissions and cheaper retail prices for foodstuffs, a greater use of local crops, the maintenance of green belts and job creation.

Other policy options include ending subsidies that encourage unsustainable practices like intensive agriculture and using market and other mechanisms to regulate and generate rewards for agro-environmental services. Countries could explore the potential for paying farmers who leave valuable wetlands undrained, for example, or who use forests to reduce carbon emissions. However, if farmers are to adopt sustainable practices, they will also need to be able to count on long-term land and water-use rights and tenure, as well as measures which reduce risk, such as credit and insurance schemes.

The report suggests providing incentives to promote integrated pest management and environmentally resilient germplasm management, as well as for alternative markets like those for green products, certification for sustainable forest and fisheries practices and organic agriculture, and the strengthening of local markets.

There are various interpretations of integrated pest management, from the 'toolbox' continuum emphasizing diverse technical and biologically intensive options – but not within an ecological framework – to integrated 'pesticide' management focusing on the use of lower dose, less hazardous and more selective pesticides. CropLife mentions non-chemical approaches like biocontrol but presents this option as being 'generally

What do we mean by agro-ecology?

Agro-ecology is a science which stems from a blend of scientific and indigenous knowledge (ethnoscience); it sets out to reduce the negative impact of conventional agricultural systems through productive diversification and the use of ecologically friendly technologies.

©S. Schnegans/UNESCO

Wheat in Spain

While agro-ecological methods vary and are by definition mostly site-specific, those wishing to embrace agro-ecology should adopt the following criteria:

- Use renewable sources of energy instead of non-renewable sources
- Use biological nitrogen fixation
- Use on-farm resources as much as possible
- Sustain soil nutrients and organic matter stocks
- Conserve water and use efficient irrigation systems
- Conserve genetic resources and maintain local landraces
- Manage ecological relationships and re-establish ecological relationships that can occur naturally on the farm
- Use intercropping, which entails cultivating two or more crops on the same land at the same time, and cover cropping systems. A cover crop is any crop grown to provide soil cover in order to prevent soil erosion by water and wind
- Minimize disturbance and use, for example, reduced tillage or no-till methods, to combat soil erosion from wind and water, and increase rates of water infiltration and groundwater
- Match cropping patterns to the productive potential and physical limitations of the farm landscape
- Use multiple varieties and landraces of crops and animals on farms, avoid dependence on single crops/products (monoculture) and use alternative markets
- Ensure that local people control their development and augment farmer participation
- Promote a multidirectional transfer of knowledge, as opposed to 'top-down' knowledge transfer, and use indigenous knowledge.

Could European companies be starting to see farmers as partners?

As prices for raw materials soar, attitudes towards investing in agriculture may be changing in the business world. In May, the UK *Financial Times* cited Mark Lundy, senior research fellow at the Consultative Group on International Agricultural Research, as saying that 'food producers can no longer afford to ignore farmers. It used to be very much a buyers' market. Now companies have to position themselves as good partners.'

Examples in Europe include Barry Callebaut, a Swiss chocolate manufacturer which bought a 49% stake in Biolands, an exporter of organic cocoa based in Tanzania, in April. 'Biolands runs a smallholder programme involving 20 000 farmers, paying farmers for delivering beans. It also trains them and gives them seeds,' reported the *Financial Times*. Cocoa prices rose by almost 50% between September and February but, by investing in producers, Barry Callebaut gets to control part of its cocoa supply. 'We try to buy more and more cocoa directly from cooperatives or other organizations because it's giving us full control over the quality,' the company told the newspaper, which reported plans by Biolands to extend the Tanzanian project to other countries.

Meanwhile, Cadbury Schweppes plans to invest £30 million (US$59 million) over the next decade in cocoa farms in Ghana, which provides nearly three-quarters of its cocoa. The company created the Cadbury Cocoa Partnership with UNEP earlier this year.

In Cameroon, Diageo, the British beverage group that owns the Guinness beer brand, is investing £250,000 in local farms over the next five years to encourage farmers to grow sorghum. This will enable Diageo to reduce its reliance on imported barley, the traditional ingredient in its beer. Nick Blazquez, Managing Director of Diageo's Africa business, told the *Financial Times* that sourcing raw materials locally 'reduces our need for foreign exchange, shortens our supply lines and develops our relationship with the local community.'

Bags of cocoa in São Tome & Principe

In Ecuador, the London-based brewer SABMiller has run into 'a land competition' with the biofuel industry. For Andy Wales, head of sustainable development at SABMiller, the company needs to develop better relationships with farmers, so that they will grow rice for SABMiller rather than maize for biofuel producers. SABMiller uses rice in the brewing process to add starch to beer. SABMiller also has several projects in Africa encouraging farmers to grow sorghum for the brewery, the *Financial Times* reported.

The Fair Trade Movement cited by the assessment could testify to the fact that ensuring poor farmers are adequately rewarded for the crops they produce can also be good business. The British branch claims to have more than 3000 certified retail products in the UK, for a retail value of £493 million in 2007.

Source: Wiggins, J. (2008) Africa's farms reap rewards. Financial Times*, 7 May. UK.*

too often unreliable or not efficient enough to be commercially used on their own.'

A third type of integrated pest management is based on detailed indigenous technical knowledge (ethnoscience). One example of indigenous pest management is intercropping, a method which entails cultivating two or more crops on the same land at the same time. Indigenous pest management may also tolerate weeds, insect pests and crop pathogens at times, if these provide important foods, medicines, ceremonial materials and soil improvers.

Organic agriculture is one form of integrated pest management. It avoids all use of synthetic fertilizers and pesticides. Consumers – and thus growers – are increasingly turning to organic agricultural systems. The term can be misleading, as organic does not necessarily mean agroecological. The production of organic bananas in some parts of Central America and Ecuador, for example, consists of large expanses of monoculture; the reason they obtain organic certification is because they do not use agrochemicals.

It is frequently stated that organic agriculture, because of its lower yields, will not be able to supply enough food to feed the world. One controversial study[4] cited by the report concluded from examining 300 case studies worldwide that 'organic agriculture could produce enough food on a per capita basis to provide 2540–4380 kilocalories/person/day, depending on the model used. Based at the University of Michigan (USA), the authors also found that, 'in developing countries, organic farms outperformed conventional practices by 57%, demonstrating that intensification using organic methods is possible.'

Going out to bat for small-holder farmers

The report judges agricultural policies which focus on supporting small farmers as being of higher priority today than technical solutions. It observes for instance that, in developing Asia, the rural–urban divide has been exacerbated both by the displacement of small farmers from land taken over for industrial use and by the emphasis on trade, which 'has led to neglect of rural development and of non-tradable sectors of the economy.'

For FAO Director-General Jacques Diouf, it is urgent to reverse the decline in the level of public resources spent on agriculture and rural development. He believes 'investments

by the private sector in agriculture and related sectors would be forthcoming if appropriate investments in public goods were put in place.' Faced with soaring prices for raw materials, some businesses in Europe seem to be jumping the gun (*see Could European companies be starting to see farmers as partners?*)

'We must produce more food where it is urgently needed,' says Diouf. 'We have to ensure that small-holder farmers have proper access to land and water resources, and essential inputs such as seeds and fertilizers to … increase their supply response to higher prices, boost their income… and ultimately benefit consumers as well.'

The current food crisis is a wake-up call

The paradigm shift urged by the report towards more responsible agriculture cannot be realized overnight. It will take sustained, coordinated effort on the part of the world's governments and the willing implication of the private sector. The current food crisis is a wake-up call, a warning that a sporadic food crisis could turn into a chronic crisis if nothing is done to change modern agricultural practices in the months and years to come.

'UNESCO can do its bit,' concludes Calvo, 'by encouraging farmers to diversify production styles and the foodstuffs they grow, to integrate traditional knowledge systems into agricultural practices and to use science, technology and good management practices to protect both agribiodiversity and the environment in general.'

'It is time to look beyond the reductionist image of agriculture as being no different from any other industry,' he urges. 'Perhaps we should speak instead of "agri-cultures", in the sense of "agrarian cultures", a term which to my mind better reflects the biological and cultural diversity of farming around the world.'

©A. Clayson/UNESCO

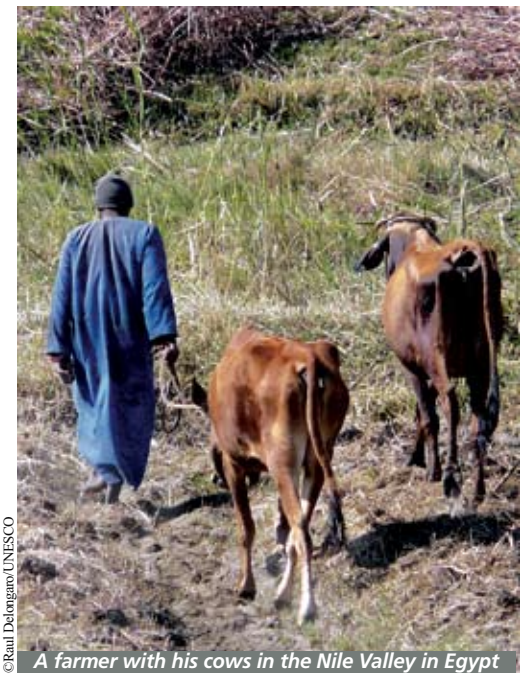
Taking the pig to market in Zumbahua, Ecuador

There will be an opportunity for the world's eight wealthiest countries (G8) to begin making this paradigm shift in July. For the first time in 27 years, the global food crisis will be on the agenda of the G8. Japan's Prime Minister Yasuo Fukuda will be hosting the meeting, which is expected to discuss food trade, biofuels, ways of boosting farming output and how climate change affects agriculture.

Another important rendez-vous on the international agenda will be the conclusion of the Doha round of trade talks by WTO members. However, after more than six years of stop-start negotiations marked by strong disagreements over the rules of agricultural trade, the Doha round is at a standstill. At a time when much of the world is facing an economic recession exacerbated by food and oil crises, this deadlock does not augur well for the future.

Susan Schneegans

Read the assessment: www.agassessment.org/;
for details: s.arico@unesco.org; g.calvo@unesco.org



©Raul Delongaro/UNESCO

A farmer with his cows in the Nile Valley in Egypt

1. *Armenia, Azerbaijan, Bahrain, Bangladesh, Belize, Benin, Bhutan, Botswana, Brazil, Cameroon, China, Costa Rica, Cuba, Dem. Rep Congo, Dominican Republic, El Salvador, Ethiopia, Finland, France, Gambia, Ghana, Honduras, India, Iran, Ireland, Kenya, Kyrgyzstan, Lao PDR, Lebanon, Libyan Arab Jamahiriya, Maldives, Moldova, Mozambique, Namibia, Nigeria, Pakistan, Panama, Paraguay, Philippines, Poland, Rep. Palau, Romania, Saudi Arabia, Senegal, Solomon Islands, Swaziland, Sweden, Switzerland, Tanzania, Timor-Leste, Togo, Tunisia, Turkey, Uganda, Uruguay, Vietnam, Zambia. Three governments did not fully approve the Executive Summary of the Synthesis Report: Australia, Canada, USA*
2. *On the Green Revolution, see* A World of Science, *October 2006*
3. ***Africa**: Burundi, Central African Republic, Chad, Congo, DRC, Côte d'Ivoire, Eritrea, Ethiopia, Ghana, Guinea, Guinea Bissau, Kenya, Lesotho, Liberia, Mauritania, Sierra Leone, Somalia, Sudan, Swaziland, Uganda, Zimbabwe – **Asia**: Afghanistan, Bangladesh, China, Iraq, Korea (DPR), Nepal, Sri Lanka, Tajikistan, Timor Leste, Viet Nam – **Latin America and Caribbean**: Bolivia, Dominican Republic, Ecuador, Haiti, Nicaragua* **Europe***: Moldova (Source: FAO)*
4. *Badgleya1, Catherine et. al. (2007) Organic agriculture and the global food supply.* In Renewable Agriculture and Food Systems*: 22: 86–108: http://journals.cambridge.org (Cambridge University Press)*