Biotechnology and Sustainable Development

Findings from the UN-led International Assessment of Agricultural Knowledge, Science and Technology for Development

The landmark International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD) is the most comprehensive and rigorous assessment of agriculture to date. The IAASTD's most salient conclusion was and is that a radical transformation of the world's food and farming systems—especially the policies and institutions that affect them—is necessary if we are to overcome converging economic and environmental crises and feed the world sustainably.

> "If we do persist with business as usual, the world's people cannot be fed over the next half-century. It will mean more environmental degradation, and the gap between the haves and have-nots will expand. We have an opportunity now to marshal our intellectual resources to avoid that sort of future. Otherwise we face a world nobody would want to inhabit."
> — Professor Robert T. Watson, Director of the IAASTD

> Our perception of the challenges and the choices we make at this juncture in history will determine how we protect our planet and secure our future. (Synthesis Report, p. 3)

Future of agriculture

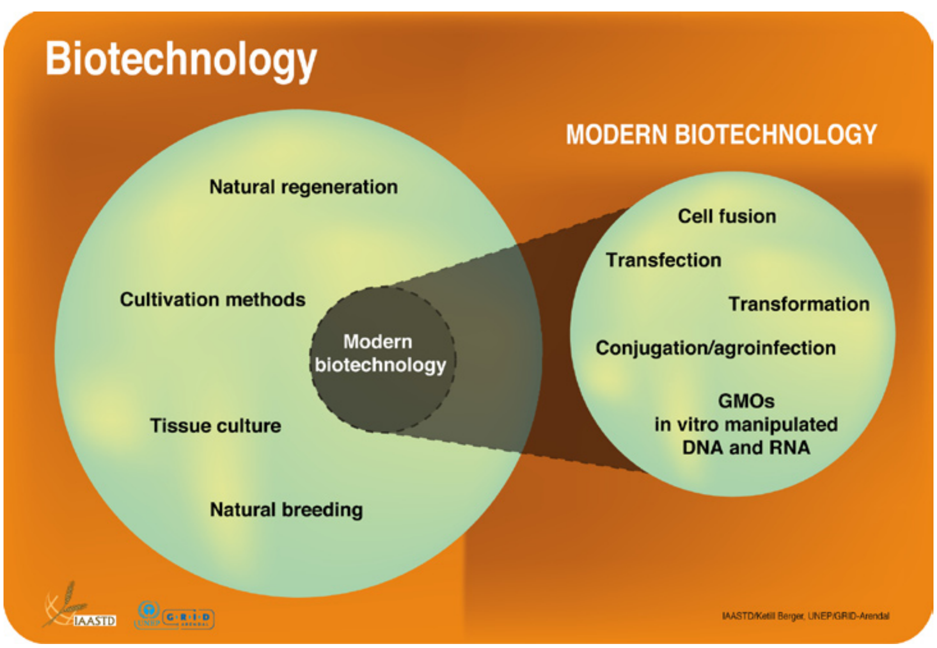
The IAASTD examined the successes and shortcoming of the world's food and agricultural systems in reducing poverty and hunger, improving rural livelihoods and health, and advancing equitable and sustainable development. In this context, the potential contribution and impacts of biotechnology were also evaluated. The report found that industrial agriculture has provided significant production gains, but that these gains have disproportionately benefited agribusiness and the well-off, while causing severe health and environmental harms, degrading the natural resource base on which human survival depends, and placing water, energy and climate security under threat. The report warned that continued reliance on simplistic technological fixes—including transgenic crops—is an approach unlikely to address persistent hunger and poverty.

> Technologies such as high-yielding crop varieties, agrochemicals and mechanization have primarily benefited the better-resourced groups in society and transnational corporations, rather than the most vulnerable ones. (Global Summary for Decision Makers, p. 23)

> Small-scale diversified farming is responsible for the lion's share of agriculture globally. While productivity increases may be achieved faster in high input, large scale, specialised farming systems, *greatest scope for improving livelihood and equity exist in small- scale, diversified production systems in developing countries*. (Global Report, p. 379, *emphasis added*)

Institutions matter!

The problem of global hunger and poverty is not fundamentally a technological problem. Existing rules and policies and dominant institutional arrangements have shaped today's food systems, and are largely responsible



Biotechnology and Modern Biotechnology Defined (IAASTD Synthesis Report, p. 41)

The International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD) asked how agricultural practices and policies can reduce hunger and poverty, improve health and rural livelihoods, and lead to fair and sustainable development around the world. The IAASTD identifies policy, research and investment options to transition towards more sustainable food and agricultural systems in future.

The Assessment was conducted by over 400 scientists and development experts from more than 80 countries. It was sponsored by four United Nations agencies, the World Bank and the Global Environment Facility. The IAASTD findings were approved at an Intergovernmental Plenary in April 2008 and published in 2009.

The full set of IAASTD reports are available at www.agassessment.org.

for the extreme inequities in access to food and resources seen today. For example, the influence of transnational agribusiness over public policy formation has contributed to the establishment or interpretation of institutions (such as global markets, trade and intellectual property rules) in ways that have eroded food and livelihood security in the poorest countries.

> Few existing problems in agriculture are solely caused by a lack or failure of technology but instead derive from other social, economic or legal frameworks. It is therefore critical to first define what problems are best solved by changing legal frameworks, trade policies or human behaviour and, second, which are best solved using technology. Technology should meet the community's needs without making local agriculture less sustainable. For example, importing high-cost biotechnology seeds to grow crops for fuel on water-stressed land neither saves water nor reduces the impact this land-use decision has on food production. (Heinemann, p. 5)

Solutions are plentiful

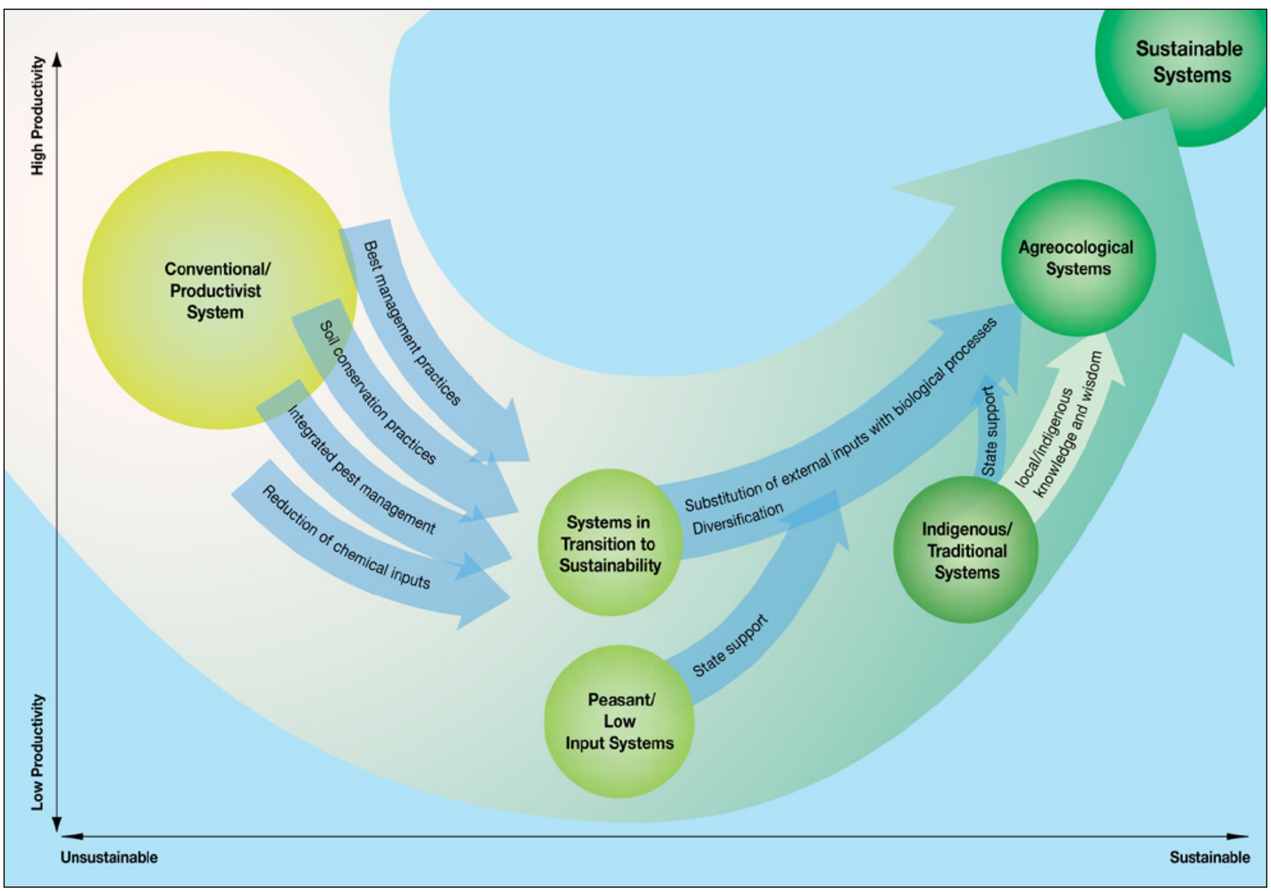
The IAASTD highlighted an array of promising solutions:

- revising policies and institutions to strengthen the small-scale farm sector;
- increasing investments in agriculture—in particular, in agroecological science and farming;
- ensuring small-scale farmers' secure access to land, water, seeds, markets, infrastructure, credit and information;
- revitalizing local and regional food systems;
- revising laws of ownership and access; and
- adopting equitable trade rules.

A reconfiguration of agricultural research, extension and education is also needed—one that recognizes the vital contribution of local and Indigenous knowledge and innovation, and that embraces equitable, participatory processes in decision-making. Through these changes, the IAASTD suggests, we can establish more socially and ecologically resilient systems, while maintaining productivity and improving profitability for small-scale farmers.

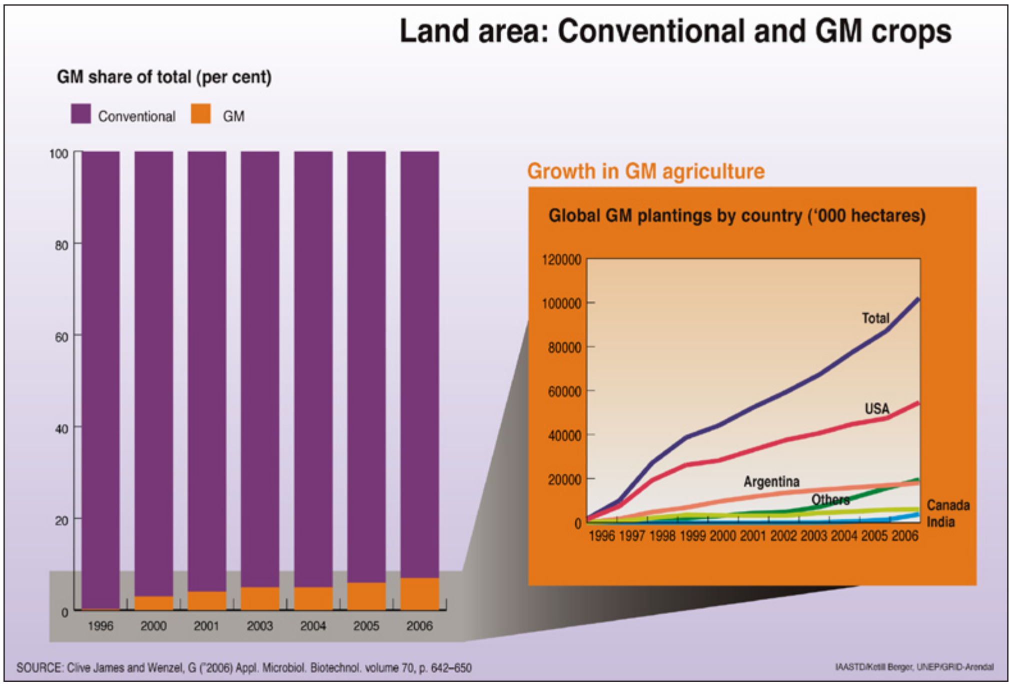
Whose technology?

The IAASTD compared the dominant "technology push" model of development with more integrated participatory models of knowledge production and sharing, and found the latter more likely to advance equitable and sustainable development.



Transition to Productive and Sustainable Systems
(IAASTD Latin America and Caribbean Summary for Decision Makers, p. 9)

Agricultural Land by Conventional and GM Crop Planting (1996–2006): Keeping Scale in Perspective
(IAASTD Synthesis Report, p. 42)



The dominant policy model for promoting innovation is called the linear model, or the transfer of technology model. Also known as 'technology supply push', this approach relies on the agricultural treadmill, i.e. market-propelled waves of technological change that squeeze farm-gate prices, stimulate farmers to capture economies of scale, deliver high internal rates of return to investments in agricultural research, but also encourage externalisation of significant social and environmental costs.

While the technology push model provided the basis for the positive impacts of the Green Revolution in favourable areas and under defined conditions that typically included high subsidies on fertilisers and pesticides, it has not served nearly as well resource-poor areas that are highly diverse, rain fed, and risk prone, and that currently hold most of the world's poor. (Global Report, p. 481)

Focusing [agricultural knowledge, science and technology] systems and actors on sustainability requires a new approach and worldview to guide the development of knowledge, science and technology as well as the policies and institutional changes to enable their sustainability. It also requires a new approach in the knowledge base; the following are important options:

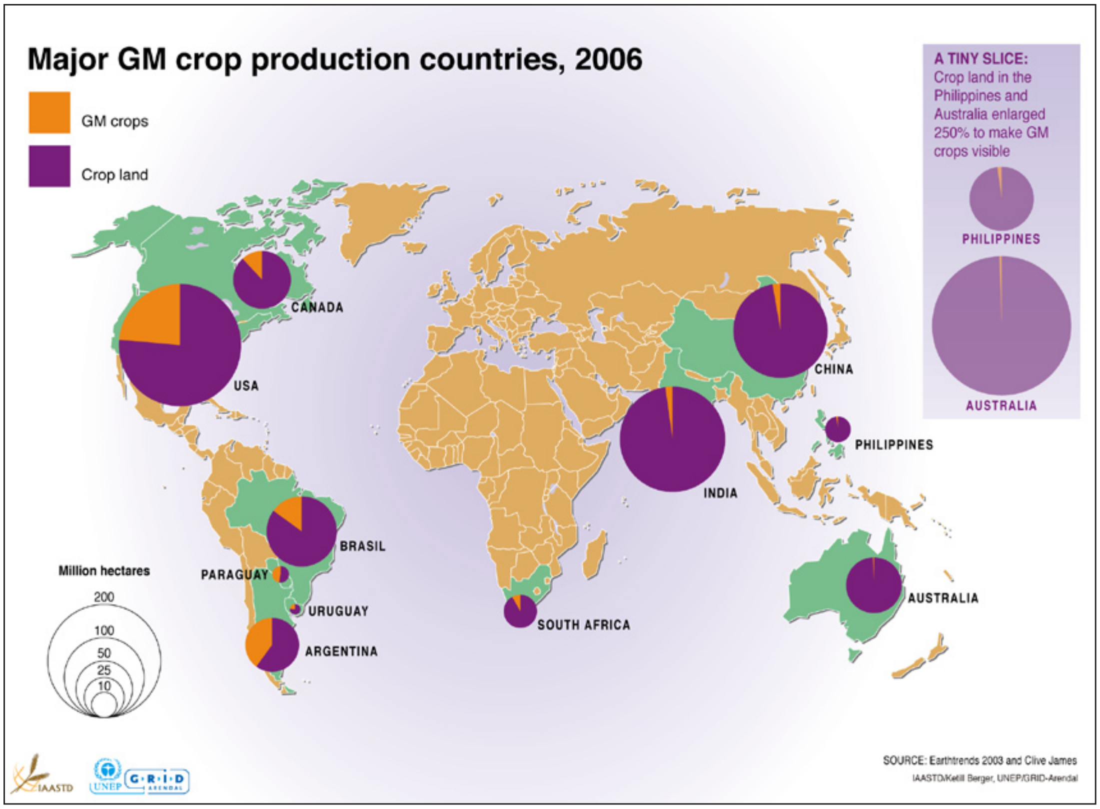
- The revalorisation of traditional and local knowledge and their interaction with formal science;
- Interdisciplinary (social, biophysical, political and legal), holistic and system based approaches to knowledge production and sharing. (Synthesis Report, p. 30)

It is (the) continuing *indigenous capacity for place-based innovation* that has been almost entirely responsible for the initial bringing together of the science, knowledge and technology arrangements for what have become over time certified systems of agroecological farming [...] Systems such as these are knowledge-intensive, tend to use less or no externally supplied synthetic inputs and seek to generate healthy soils and crops through sustainable management of agroecological cycles within the farm or by exchange among neighboring farms. (Global Report, p. 67)

Biotechnology and GMOs

The IAASTD examined a wide range of agricultural knowledge, science and technologies for their potential and proven impacts on equitable and sustainable development. Of these, perhaps the most controversial were the biotechnologies. The IAASTD defined biotechnology as does the Convention on Biological Diversity, namely as "any technological application that uses biological systems, living organisms, or derivatives thereof, to make or modify products or processes for a specific use. "

The term biotechnology can thus include traditional and local knowledge, organic and agroecological practices, conventional breeding, the application of tissue culture and genomic techniques, marker-assisted breeding and gene splicing. "Modern biotechnology" is defined in the Cartagena Protocol on Biosafety and is commonly understood as "the manipulation of genetic material and fusion of cells beyond normal breeding barriers," with the most common example being genetic engineering (GE) in which genes are inserted or deleted through transgenic technologies to create genetically modified (GM) organisms (GMOs). The IAASTD notes that the use of the term "modern" is by convention only, and does not in any way suggest that these



A Tiny Slice: GM Crop Production by Country, 2006
(IAASTD Synthesis Report, p. 41)

techniques are more sophisticated or relevant than other biotechnologies with longer histories.

> Biotechnology has made tremendous contributions to agriculture, with some biotechnologies as old as agriculture itself. Free-to-the-public technologies and extension services are important to farmers. In contrast, modern biotechnology has a poor track record of relevance to the poor and subsistence farmer and its control by a relatively small number of large multinational companies means that adopting modern biotechnologies could also require accepting significant social changes and adopting agricultural models that may not result in poverty reduction or sustainable practices, while also increasing the dependency of local farmers on technological exports from the wealthy countries. (Heinemann, p. 7)

The impacts and potential or actual contributions of GMOs to sustainable and equitable development were rigorously examined by the IAASTD. The report found conflicting evidence put forward by proponents and critics of the technology, with conflicts often dependent upon whether the potential agronomic benefits of yet-to-be developed GMOs (the '"in-the-box" design) were highlighted or whether the broader societal and environmental impacts of GMOs on social equity, livelihoods, culture, biodiversity and farmers' rights, were addressed.

> Crops derived from GE technologies have faced a myriad of challenges stemming from technical, political, environmental, intellectual-property, biosafety, and trade-related controversies, none of which are likely to disappear in the near future. Advocates cite potential yield increases, sustainability through reductions in pesticide applications, use in no-till agriculture, wider crop adaptability, and improved nutrition. Critics cite environmental risks and the widening social, technological and economic disparities as significant drawbacks. Concerns include gene flow beyond the crop, reduction in crop diversity, increases in herbicide use, herbicide resistance (increased weediness), loss of farmer's sovereignty over seed, ethical concerns on origin of transgenes, lack of access to IPR held by the private sector, and loss of markets owing to moratoriums on GMOs, among others. (Global Report, p. 95)

While focusing mainly on transgenic *crops* because there are no widespread commercial applications of GM animals, the report did note that gene flow from GM fish could be of significant concern and would need to be stringently monitored, particularly given how little is understood about marine ecosystems.

In general, the IAASTD found little evidence to support a conclusion that modern biotechnologies are well suited to meeting the needs of small-scale and subsistence farmers, particularly under the increasingly unpredictable environmental and economic conditions that they face.

Key findings are presented on the following pages.

GMOs in the Field

The IAASTD observed that the evidence regarding GMO impacts on yield is sparse, highly variable and mostly anecdotal. Yield declines have been consistently recorded in GM soybeans and maize, while yield gains have been reported in some situations and no yield effects at all in others. In many cases, yield benefits observed in GMOs derive from the developer's use of high-yielding modern varieties developed over time through local and conventional breeding, rather than from the genetic engineering technology itself.

> Modern biotechnology and its products have not reliably increased yields of crops. If GMOs are being considered for inclusion in an overall national strategy on agriculture, then their proposed benefits to the agroecosystem require new evidence. (Heinemann, p. 10)

> Although the promoters of transgenic crops argue that this technology benefits small producers, and that it is a sound tool for fighting poverty and hunger in the world, there are very few empirical studies that verify these assertions for [Latin America]. […] [Benefits have] accrued largely due to the financial and technical support provided by the government and by the implementation of other plant health programs.

> The economic benefits have been accompanied by social changes such as the displacement of small producers and the consequent migration to the cities, the concentration of lands and agribusinesses, and the loss of food sovereignty (Latin America Report, p. 38-9).

The vast majority of commercially available transgenic crops have been engineered to contain either herbicide-tolerant or insecticidal traits (or a combination thereof), with no widespread commercialization of crops containing other GM traits. Despite much recent public and private sector publicity around the goal of bringing forward "climate-ready", drought- or salt-tolerant transgenic crops, no stress-tolerant GMOs have yet been commercially developed, even after 25 years of research. This is likely because the physiology of stress tolerance derives not from a single gene but from multiple interactions of many genes in complex, changing environments. In contrast, participatory and conventional breeding and marker-assisted selection can and have achieved stress tolerance in plants and animals, relatively quickly and at low cost.

Pesticides

Impacts of GMOs on pesticide use are complex and require close examination over time. With the introduction of GM plants engineered to contain insecticides (Bt), some farmers have at least initially decreased their application of chemical insecticides. However, as pest resistance to Bt develops and as secondary pests have emerged, some farmers are resorting to the use of older and more toxic insecticides. Furthermore, the total amount of insecticide present in fields has likely increased due to the presence of insecticides in GM plant biomass.

> 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. This illustrates the frequently documented gap between the reality of how a technology is used (taken up in a given social context) and its 'in the box' design. (Global Report, p. 95)

Meanwhile, the introduction of herbicide-resistant crops—engineered to be used in tandem with proprietary herbicides produced by the manufacturer of both the GM seed and the herbicide—has led to a massive increase in herbicide use. This increase far outweighs the limited and temporary reductions in chemical insecticide use on Bt crops. The by-design surge in herbicide use has contributed to herbicide resistance, the spread of increasingly difficult-to-control herbicide-resistant weeds and a sharp decrease in the diversity of pest management techniques in GM crops, with increasing reliance on a single chemical product.

courtesy of Syngenta

Transnational corporations benefit the most from GM crops, 98% of which are engineered to be herbicide-resistant and used with proprietary herbicides, and/or to contain insecticides. In contrast, small-scale farmers in Oaxaca, Mexico, who maintain diverse maize-beans-squash agroecosystems reap a diversity of foods and herbs for home consumption and local markets.

> In the case of transgenic soybean, a dramatic increase has been reported in the use of herbicides, especially glyphosate; the evolution of resistance to glyphosate has already been reported in some weeds, limiting the possible benefit of the technology. The massive use of Bt crops affects other organisms and some ecological processes, and can lead to resistance […] threatening not only the future utility of these crops, but also annulling one of the most useful tools available to the organic producers for fighting pests. (Latin America Report, p. 39).

> Modern biotechnology may have indirect benefits through reduction in the quantity or type of pest control agrochemicals that are used on GM crops. These benefits are contested and likely not sustainable. Moreover, these benefits fare poorly overall in comparison with agroecological farming approaches. (Heinemann, p. 11)

Biodiversity

Genetic engineering can affect biodiversity in multiple ways. Most obviously, the large-scale cultivation of GM crops in monoculture drastically reduces both natural and agricultural biodiversity. The rapid pace, large scale and sometimes even the possibility of converting natural ecosystems into agricultural systems is unique to the management practices accompanying GMOs. The resulting loss of biodiversity in turn has been implicated in the loss of cultural knowledge of locally adapted flora and fauna, and loss of skills in facilitating complex agroecosystem interactions that maintain biodiversity, ecosystem function and agricultural output ("agricultural deskilling").

> Transgenic crops have also had a negative impact on biodiversity due to the conversion of forest areas and natural savannahs to transgenic plantations, in particular soybean. In Brazil and Argentina the expansion of transgenic soybean has affected directly and indirectly on the deforestation of unique ecosystems such as the tropical forest of the Amazon region and the Cerrado in Brazil, and the Yungas forest in Argentina. […] The widespread adoption of homogeneous transgenic varieties inevitably leads to genetic erosion and the loss of local varieties developed and used traditionally by thousands of small-scale producers. (Latin America Report, p. 39).

Direct impacts of GMOs on biodiversity within fields depends in part on whether a comparison is being made between a GMO field and a conventional high-pesticide use field (in which case if synthetic chemical insecticides have in fact been reduced in GMO-planted fields, then an increase in non-target insects as well as secondary pests may result) or whether the comparison is with agroecologically managed or organic farms (the latter support greater biodiversity than do GMO-planted fields).

The IAASTD refers to the Cartagena Protocol on Biosafety's recognition of "the crucial importance to humankind of centres of origin and centres of genetic diversity." Loss of biodiversity caused by genetic contamination of indigenous plants and non-GM crops with pollen and seed containing GM traits remains a grave concern, both for economic and ecological reasons. Impacts of GM crop pollen and plant biomass on a wide range of non-target organisms have not been sufficiently investigated and may have as yet unknown cascading effects through an ecosystem. To prevent biodiversity loss, the IAASTD Latin America report suggests establishing precautionary measures prohibiting the transfer of GMOs among countries that are centers of origin or of genetic diversity, and limiting production in countries where wild relatives exist.

Health

The IAASTD warns of potential adverse health effects associated with biopharmaceutical GMOs, and indicates that a precautionary approach would be appropriate.

> Products of modern biotechnology, for example GMOs made from plants that are part of the human food supply but developed for animal feed or to produce pharmaceuticals that would be unsafe as food, might threaten human health. Moreover, the larger the scale of bio/nanotechnology or product distribution, the more challenging containment of harm can become. (Synthesis Report, p. 42)

Maize is the most widely used crop in biopharmaceutical genetic engineering, and risks to maize-consuming populations (for example in Mexico) of the potential release of a pharmaceutical transgene into the food supply are highlighted.

> The potential dangers of exposure to recombinant compounds by this means would affect practically the entire population of Mexico […] The genetic contamination of maize would be devastating since Mexico is one of the centers of genetic diversification, and Mexican culture is tightly bound to this crop. […] No containment system is infallible. In a case such as this, where there are possibilities of contamination, and where the consequences would be disastrous for millions of human beings, one should apply the precautionary principle. (Latin America and the Caribbean Report, p. 40)

Social Equity

The social, economic and equity impacts of GMOs raise significant concerns. The IAASTD observes that current intellectual property (IP) laws tend to benefit GM crop patent holders (typically large corporate manufacturers) and large-scale producers rather than the rural communities that have developed genetic resources over millennia. Reasons for the inequitable distribution of benefits are closely tied to the political economy of who controls the technology and how institutions governing rights to and control over germplasm have changed dramatically over time.

> Genetic resource management over the past 150 years has been marked by an institutional narrowing [...] This narrowing is illustrated in history by four major trends: (1) a movement from public to private ownership of germplasm; (2) unprecedented concentration of agrochemical, seed corporations, and commodity traders; (3) tensions between civil society, seed corporations, breeders and farmers in the drafting of [intellectual property rights or IPR]; (4) stagnation in funding for common goods germplasm. These trends have reduced options for using germplasm to respond to the uncertainties of the future. They have also increased asymmetries in access to germplasm and benefit sharing and increased vulnerabilities of the poor. (Global Report, p. 87-8)

> There have been positive farm level economic benefits from GMOs for large scale producers, but less evidence of positive impact for small producers in developing countries. […] Institutional factors such as the national agriculture research capacity, environmental and food safety regulations, IPRs and agriculture input markets determined the level of benefits, as much as the technology itself (Global Report, p. 195-6).

Where new technologies and products (such as transgenic seeds) have been developed and protected by IP laws, industry consolidation has taken place rapidly. The rapid pace of corporate concentration — along with enforcement of patents and other IP instruments — has fueled the speed with which control of once-public goods (germplasm) has shifted into an increasingly smaller number of private hands. As a result, farmers have fewer choices for purchasing inputs and selling their products and, forced to become "price-takers," are less able to earn a living from agriculture.

The IAASTD cites threats posed by IP rules to small-scale farmers, particularly to the practice of saving, using, exchanging and selling seed (identified as rights by the International Treaty on Plant Genetic Resources for Food and Agriculture). IP rules that restrict farmers' access to and community control over plant genetic resources, along with misappropriation of Indigenous, women's and local people's knowledge, can severely undermine rural communities' food and livelihood security. Such restrictions can also erode knowledge-sharing and innovation and inhibit community-based participatory plant and animal breeding initiatives, experimentation, impact analysis and *in situ* conservation of agricultural biodiversity by both farmers and independent researchers.

> In developing countries especially, instruments such as patents may drive up costs, restrict experimentation by the individual farmer or public researcher while also potentially undermining local practices that enhance food security and economic sustainability. In this regard, there is particular concern about present IPR instruments eventually inhibiting seed-saving, exchange, sale and access to proprietary materials necessary for the independent research community to conduct analyses and long term experimentation on impacts. (Executive Summary of the Synthesis Report, p. 8)

Furthermore, IP rules create liabilities for farmers whose crops or fields (whether GM or not) may be contaminated with transgenes from other GM crops (and who may then be held liable for patent infringement). Likewise, GM crop farmers may be held liable for transgenic contamination of organic or certified "non-GMO" crops.

Increasingly, universities are relying on funding from the private sector — notably from large agrochemical and seed firms — to supplement dwindling public sector financing of agricultural research and education. This funding often carries with it IP conditions set by the company, shifting ownership to the private sector for example and limiting sharing of public good knowledge. Universities have also established programs and professional incentives to stimulate faculty research that could bring in new revenue streams from patents, which can in turn inhibit faculty willingness to share research findings with the academic community and the public. Enforcement of IP laws has also tended to increase the dependency of the public sector on patent-holding transnational companies as when, for example, researchers are required to submit their research plans for approval and obtain permission from corporate patent-holders as a precondition for their purchase and experimental cultivation of GM seed.

> Today in many industrialised countries an increasing percentage of the funding for university science comes from private commercial sources. It tends to be concentrated in areas of commercial interest [...] rather than in applications deeply informed by knowledge of farming practice and ecological contexts. [...] Hence a condition of funding is that the source of funds often determines who is assigned first patent rights on faculty research results. In some cases the right to publication and the uninhibited exchange of information among scholars are also restricted. The assumption under these arrangements that scientific knowledge is a private good changes radically the relationships within the scientific community and between that community and its diverse partners. (Global Report, p. 72)

This institutional coupling between industry and universities has encouraged a steady narrowing of agricultural research agendas to focus on modern biotechnology. Opportunity costs associated with this situation include plummeting resources for agroecology and attrition in the numbers of "next generation" plant and animal breeders, biologists and ecologists available to contribute their scientific and disciplinary expertise to the resolution of increasingly complex agricultural challenges. The increasing influence of agrochemical and seed corporations over public sector agricultural research agendas risks weakening public institutions' ability to fulfill their mandates to serve the public good.

Options for Action

The IAASTD lays out a comprehensive set of options to reorient local and global food systems towards greater social equity and sustainability. These include improvements in the sustainability of farming practices on the ground as well as overhauling the institutions and policies that determine so much of what is possible. Options for effective action include:

Support small-scale farmers

- Strengthen small-scale farmers', women's, Indigenous and community-based organizations, and invest in rural areas.
- Ensure farmers have secure access to land, seeds, water, information, credit, marketing infrastructure and information.
- Build capacity in participatory agroecological research, extension and education and in biodiverse, ecologically resilient farming practices to cope with increasing environmental stress.

Re-think biotechnology

- Engage all stakeholders in open, informed, transparent and participatory debate about new and emerging biotechnologies.
- Introduce long-term environmental and health monitoring programs and conduct comparative technology assessment to better understand the respective risks, benefits and costs of different technologies and production systems.
- Use full-cost accounting to evaluate and compare the social, environmental and economic costs of different agricultural production systems, guide public policy decisions and set research priorities. (By internalizing "externalities," this approach begins to correct the market's failure to price goods and production systems accurately.)
- Use the precautionary approach in decision-making (e.g. as per the Cartagena Protocol on Biosafety), which may entail prohibiting the transfer of genetically modified organisms (GMOs) among countries that are centers of origin or of genetic diversity.
- Limit production of GMO plants in regions that have wild relatives and show botanical characteristics that could contaminate the gene pool.

Build institutions to support social equity and sustainability

- Revise intellectual property laws to prevent misappropriation of Indigenous, women's, and local people's knowledge; establish IP rules that recognize farmers' and independent researchers' rights to save, exchange and cultivate seed, particularly for purposes of livelihood and/or public interest research.

Small-scale organic tea growers in Sri Lanka diversify production with spices such as cinnamon and turmeric and enjoy steady profits through fair trade market outlets.

- Strengthen the capacity of farmers, Indigenous peoples, vulnerable or marginalized communities and developing countries to engage effectively in international discussions and negotiations (for example, around intellectual property, bilateral, regional or global trade, climate change, environment, sustainable development, etc).
- More closely regulate globalized food systems for fairness and to ensure that both rural and urban poor have secure access to food and productive resources at all times.
- Establish and enforce fair competition rules to reverse harmful effects of corporate concentration and vertical integration in the food and agriculture industry.
- Establish equitable regional and global trade arrangements that enable farmers to meet food and livelihood security goals and to diversify production.

Sources

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