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Geographies of Risk and Difference in Crop Genetic Engineering and Agrobiodiversity Conservation

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NOTE to CAPRi CONFERENCE PARTICIPANTS:

I am in the process revising this paper for publication in a geography journal. I will appreciate your comments and suggestions. The present draft has four parts:

The data and arguments in Section 1 are maybe familiar to most of you, who may wish to go directly to Sections II – IV.

Kathy

Geographies of Risk and Difference in
Crop Genetic Engineering and Agrobiodiversity Conservation

OVERVIEW

Genetic engineering is often depicted as a breakthrough solution to hunger and environmental problems in agriculture, one which is best developed and allocated by private firms, market mechanisms, and IPR. Such claims encourage the further shift of resources toward molecular sciences, the neglect of public science and the private appropriation of its products (public goods), the global standardization of property rights to knowledge and germplasm, and the elimination of regulations specific to genetically modified products. However, while some genomic technologies may prove useful for the global South, most "high" agro-biotechnology focuses on germplasm as a laboratory and test-plot object, decontextualized, denatured, and disembedded from its eco-social habitats.

Advocates of transgenic crops too commonly disregard the material and social geographies of food production and trade, overlooking significant differences between regions where agriculture is most fully industrialized and those where most of the world's food producers reside. But these differences make it impossible to extrapolate, even from a best-case scenario for GM crops and associated IPR in the global North, to a positive prognosis for their effects in most of the South:

1. Differences in the role of genetic and crop diversity in various farming systems, including:
(a) differences in the connections between ecological, cultural, and genetic diversity, (b) differences in economic vulnerability, and (c) differences in the level of risk near to and far from regions of agrobiodiversity.

2. Differences in the degree to which food and seed production and access is based upon commodity relations, and related differences in conservation strategies, in economic options, and in regulatory needs and effectiveness in different types of agro-food systems.

3. Differences in the ability of food and input producers to derive benefits from tradable property rights (whether individual, corporate, or collective) to genetic resources and to biotechnology products, due both to economic and power asymmetries and to incompatible paradigms for valuation, access and use rights, exchange, and conservation of crop genetic resources.

The response should *not* be to eliminate the differences that make IPR and transgenic crops, at least in their present form, irrelevant for most small-scale farmers and possibly hazardous for some. The various cultural, institutional, and discursive practices by which "traditional"[1] farmers manage genetic and other food-producing resources may be actually or potentially more sustainable and efficient as livelihood strategies than adoption of seed varieties that require costly inputs, are encumbered by IPR, or cannot be replanted because of hybrid characteristics or GURTs. Certainly many of these characteristics of agricultural biodiversity conservation New scholarship in political ecology and ethnolandscape research, as well common-property resources, offers useful insights, but farmer/community institutions and practices require more investigation and documentation focused specifically on agrobiodiversity, and as well as external validation and support. Promising approaches include farmer-centered, multidisciplinary research, agroecology (as a science *and* a social movement), and information exchanges and alliances among farmer-scientists, NGOs, and their allies in multilateral and academic institutions.

I LIMITATIONS OF GENETIC ENGINEERING AS A SOLUTION TO HUNGER

It is commonly asserted that new agricultural biotechnologies can prevent a looming crisis of global agricultural productivity. Crop genetic engineering, say its advocates, is essential to produce sufficient food for a burgeoning world population without immense

ENDNOTES

[1] The term "traditional" can be misleading insofar as it connotes static complexes of planting materials and agricultural and cultural practices, isolated from markets, new varieties, and sources of innovative methods and ideas.

ecological damage. Not only US government and agribusiness interests, but also influential international agencies, including the United Nations Food and Agricultural Organization, the United Nations Development Program, and the World Bank, view crop genetic engineering as central to agricultural development policy. Molecular biotechnology has become a priority of the Consultative Group for International Agricultural Research (CGIAR), the institutional base of the green revolution, which remains the primary international network of seed banks and centers of research on agriculture for the global South.

Most arguments for a biotechnology-centered approach to food security, even those that acknowledge possible ecological risks of genetically modified (GM) crops and the difficulties of transferring technology to low-income countries, are built upon unwarranted assumptions about the superiority and universal applicability of European and US technology, regulatory institutions, and food-producing systems. I have written elsewhere that such arguments commonly rely upon idealized conceptions of molecular biology (McAfee 2003a). I contend here that *approaches to food security that are centered on molecular-biotechnology to fail to appreciate crucial differences between the ecological, cultural, institutional, and economic contexts of farming and food systems of most countries of the global South compared to those of the U.S. and Europ*e.

The first fallacy in the proposition that "biotechnology will feed the world" has been widely noted: it does not address food distribution and access. Close to a billion people are undernourished in today's food-surplus world economy. Certainly there are regions where increased local food production could help alleviate hunger, and places where better planting materials can help to increase productivity. However, the obstacles to increasing the production of food that will actually reach the hungry are not primarily technological ones that can be solved by improved seeds. Greater obstacles are lack of access to or control over food-producing resources (land, water, planting materials, other inputs, and credit) by farmers and would-be farmers, inadequate storage, transport and marketing infrastructure, depressed farm-product prices, lack of incomes and entitlements to food, and lack of political power among small and medium-scale food producers and poor consumers.[2]

[2] Even Rockefeller Foundation experts in charge of an ambitious new program to develop molecular biotechnology applications for Africa acknowledge that such applications, if successful, will be but one

Many resource-poor farmers might benefit from modern biotechnologies, including crop varieties produced with the aid of genomic and recombinant-DNA methods, especially if these are developed with farmer input and experimentation and adapted to local situations. However, enthusiastic reports of biotechnology's promise typically emphasize laboratory-devised technologies. They rarely mention the knowledge-intensive technologies that are already employed by farmers in crop-variety development and in farm-resource management, which is as least as important to productivity as is germplasm quality. Industry and World Bank publications depict genetic engineering as more efficient and precise than so-called "informal" plant-breeding. They describe GM crops as "genetically enhanced", as if they are somehow innately superior to varieties developed by other means. This discursive maneuver occludes the intricate relationships of agro-food systems to local cultural practices and institutions and the intimate connections of both to ecosystems and biodiversity, which are various and place-specific by definition.

During the 1940s, geographer Carol O. Sauer stressed these connections when he questioned the basic paradigm of what was to become the green revolution. In his capacity as a consultant to the Rockefeller Foundation, Sauer warned against using "agricultural science to recreate the history of US commercial agriculture in Mexico" (Sauer 1941, quoted in
Bebbington and Carney 1990). Sauer worried that

> A good aggressive bunch of American agronomists and plant breeders could ruin the
> native resources for good and all by pushing their American commercial stocks. The little agricultural work that has been done by experiment stations here [in Mexico] has been making that very mistake, by introducing US forms instead of working on the selection of ecologically adjusted native items…. Mexican agriculture cannot be pointed toward standardization on a few commercial types without upsetting native economy and culture hopelessly ...This thing must be approached from an appreciation of the native economies as being basically sound.

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element, perhaps not the most important one, of a strategy to address hunger in the continent (Toenniessen and deVries 2001).

(Letter from Sauer to Joseph Willits, Director of the Rockefeller Foundation Division of Social Science, quoted in F. Apffel-Marglin and S. Marglin 1996)

Sauer's faith in the self-reliance and acumen of small-scale farmers did not convince many green-revolutionaries, who generally focused on achieving net production increases for urban and rural consumers by means of mechanization, irrigation, and the heavy application of chemical fertilizer to new, high-response crop varieties designed to produce well under those conditions.[3] My intention is not to call for a return to a Sauerian world view, even if its anti-modernist elements resonate with fashionably poststructuralist critiques of development. I simply suggest that Sauer's appreciation of farmer knowledge, the importance of *in situ* agro-biodiversity, and the close linkages between successful agriculture, ecological specificity, and cultural particularism offer a still-timely corrective to overconfidence in globally-applicable, high-technology prescriptions for agriculture. (Also see Bebbington and Carney op. cit.)

Sauer's warning of the damage that could be done in Mexico by "a good bunch of aggressive American[s]" would surely ring true to peasant producers in the Southern Mexican highlands. Many farmers there were told in 2001 that their local maize varieties may be "contaminated" with genetic material that has escaped from transgenic corn produced in the United States and engineered to produce insecticides (McAfee 2003c). Whether, how, and how much transgene flow may endanger maize biodiversity in Mexico, the primary region of genetic diversity for corn, is not yet known. What is clear is that the farm communities whose maize plots are, in effect, being experimented upon are already in a crisis that has been deepened by the actions of forceful American officials and their Mexican counterparts.

"Free trade" reforms led to a 12-fold increase from 1995 to 2001 in Mexican imports of US-grown corn, both conventional and GM (USDA, cited in Vaughan 2002). The cheaper US corn has weakened local markets for thousands of small producers, but

[3] The green revolution was a political project, too. Its anti-communist aim of stabilizing post-colonial societies may have accorded with Sauer's mistrust of centralized state authority and homogenizing bureaucracy (Entrikin 1984). A case can be made, however, that Sauer's philosophy was at odds with the grand ambition of social engineering which lay at the heart of the Rockefeller Foundation's program of molecular biology for agriculture and medicine (Kay 1993).

without reducing hunger in Mexico: the price of the tortillas, Mexico's basic corn staple, rose 483 between 1994 and 1999 (Nadal 2002). The same liberalization policies cut state support for farm prices, inputs, and markets, forcing ever-more *campesinos* to give up farming and migrate Northward (Weiner 2002; Rodarte 2003). Now, US trade negotiators are pressing Mexico to legalize the planting of genetically engineered corn. This policy change is opposed by Mexican peasant movements and civil-society organizations who fear the loss of valuable local maize varieties, the demise of Mexico's own seed companies, and dangerous dependence on patented seeds, which farmers would be forbidden to share or replant.

As the Mexican crisis illustrates, *assessing the promise or peril of crop genetic engineering and associated intellectual property rights requires simultaneous consideration of ecological, economic, political, and cultural factors*. A strictly technological analysis, or a dualist approach that talks of "technology's impact on society" as if the two were separable, will not suffice. Crop varieties—like all technologies, but perhaps especially visibly—are a co-creation of people and nature, a dynamic nexus of agrarian communities and the particular ecosystems of which they are part. The universalism and hubris of green-revolution science that worried Sauer also characterize much of contemporary agrobiotechnology. Its risks are magnified by the unprecedented power of molecular-genetic engineering to alter organisms and ecosystems irrevocably. Additionally, control over food-producing resources is now far more concentrated, crop science more is privatized, and the products of crop science are more standardized and actively marketed worldwide, a situation with the potential to amplify the impacts of biotechnology's unpredictable "side effects".

Multilateral conflicts over the value and regulation of agro-biotechnology

The promotion of biotechnology is an aspect of the re-regulation of the international economy by powerful economic actors: in this case, transnational pharmaceutical and agrochemical/ biotechnology conglomerates, and by the states that foster their global reach. Governments and transnational firms act directly, through bilateral contracts and treaties, and indirectly, through supranational agencies such as the World Trade

Organization, to promulgate institutional reforms that support trade in biotechnology and its products.

With unabashed zeal, US government officials work to convince publics and prime ministers that GM products are the only rational response to hunger.[4] Their hyperbolic depictions of biotechnology wonders are part of a broader strategy to promote worldwide exports of US grains, processed foods, and agricultural inputs, placating influential agribusiness interests and keeping balance-of-payments deficits under control (McAfee 2003b). They see no contradiction between the claim that biotechnology will save Africa's poor and the industry's actual focus, which is on engineered varieties of heavily-traded crops for large farms in the world's main food-exporting regions.

These officials entertain no doubts about the superiority of the US agriculture, both technologically and economically, or about the benefits of agro-food globalization. In their imagined system of global "free trade", the (presumably) less efficient producers will import grains and other staples from countries and firms with more advanced agricultural systems. The agricultural comparative advantage of most countries where there is hunger, they say, lies not in basic food production but in exports of high-value crops that cannot be grown in temperate regions. According to the US Agency for International Development (AID), would-be developing countries should grow avocados and other tropical fruits, cocoa, coffee, and tea, and winter cauliflower, asparagus, and snow peas, so that they can import rice, maize, and wheat and processed foods.[5]

[4] The US Trade Representative, Robert Zoellick, condemned as "Luddite" and "immoral" the policies of African governments that decline donations of US GM maize and European governments that support the African position. The US has asked the World Trade Organization to rule against the European Union's moratorium on GM foods (Becker 2003; USDA 2003). US Agriculture Secretary Ann Veneman told delegates to the FAO's second World Food Summit that new technologies "will reinvigorate productivity growth in food and agriculture production and make agriculture more environmentally sustainable. Agricultural biotechnology…offers the opportunity of economic self-sufficiency for subsistence farmers in developing countries." (FAO 2002) US President Bush has told African presidents that Africans are starving unnecessarily because they are failing to utilize the science of genetic modification (Fleisher 2003). In June 2003, in cooperation with biotechnology and agrochemical firms, US AID, and the US departments of State and agriculture hosted a Technology Expo where government ministers from more than 100 developing-countries, their expenses paid, were addressed by biotechnology researchers, industry representatives, the Agriculture Secretary, and President Bush.

[5] This has been AID's rationale since 1970s, when it began promoting the use of developing-country agricultural resources for growing avocados and other non-traditional fruits, and vegetables during Northern winters, while funding "educational" activities to promote acceptance transgenic grains and other genetically engineered imports.

Other proponents of crop genetic engineering are less inclined to pin the food security of cash-poor countries on their purchasing power in global markets or on the generosity of food donors. They argue that Southern countries need their own biotechnology: a genomic "second green revolution", and advocate publicly-funded efforts to create it (Conway 1997; Juma et al. 1994). Some favor greater precaution in the application of biotechnology and more research on its unknown effects, especially in tropical regions. (NAS 2000; Serageldin and Persley 2000; Royal Society 2002,). These caveats notwithstanding, the FAO, World Bank, UNDP, and CGIAR have all placed the creation of new, engineered varieties of food, animal-feed and fiber crops high on their agricultural agendas. (IIDD 1999, UNDP 2001; World Bank OED 2003).[6]

After much debate, directors of the CGIAR system of 16 agricultural research centers agreed in 1999 to invest substantial new resources in biotechnology. A major expense has been establishment of in-house expertise to handle the cumbersome intellectual-property negotiations needed to gain access to genetic-transformation technologies, many of which are patented, and to prevent the system's own, expected biotechnology inventions from being privatized by others. In a recent evaluation of the CGIAR's 31-years performance, the World Bank complained that the CGIAR, the primary channel of direct Bank support for farming research for the poor, still spends too little on biotechnology (World Bank OED 2003). The Bank made clear that its own priority for the CGIAR is the improvement of crop germplasm by means of new molecular technologies as well as conventional methods.[7] One alterative —or arguably, complementary— approach, favored by some CG scientists but apparently not by the Bank, would prioritize integrated

[6] According to a controversial 2001 report by the U.N. Development program, "Biotechnology offers the only or the best 'tool of choice' for marginal ecological zones—left behind by the green revolution but home to more than half of the world's poorest people, dependent on agriculture and livestock" (UNDP 2001, p 35). FAO Director Jacques Diouf told a conference of international scientists, "All our efforts must be directed to ensure that the potential benefits of biotechnology, with the necessary safeguard measures for health and the environment, are brought to within the reach of everybody, including the poor and the most disadvantaged" (FAO 2001).

[7] The World Bank "Meta-Evaluation" opined that CGIAR centers have been working too closely with farmers, which should be the job of national research agencies, and paying too much heed to "improving policies" and "protecting the environment" at the expense of work to increase crop productivity. According to the Bank, the system's focus on producing new varieties has been diluted as a result of "the unpopularity of germplasm improvement research … due to negative perceptions of the Green Revolution initially and of biotechnology more recently", "the rise of environmentalism and environmental advocacy", and awareness of the negative environmental effects of the green revolution. (World Bank OED 2003, p 7)

natural resource management (INRM), a multidisciplinary methodology that considers social, physical, human, natural and financial aspects of complex agro-ecosystems.

Biotechnology is prominent in the Convention on Biological Diversity, peculiarly so in light of the fact that the CBD was originally conceived as a conservation treaty. The transfer to developing countries of biotechnology, the sharing of its profits, and the handling of its safety risks have sparked rancorous controversy in the Convention and in its subsidiary treaty, the Cartagena Protocol on Biosafety (CPB). Biotechnology issues emerged early in the CBD negotiations when the US delegation, at the urging of pharmaceutical and agrochemical interests, insisted on a provision recognizing intellectual property rights (IPR) (UNEP/CBD 1994, Article 16; McConnell 1996; Drahos 1999). Developing countries opposed it, but then conceded in exchange for wording that recognizes national sovereignty over biotechnology's genetic-resource raw materials and calls for the "sharing of the benefits of [their] commercial utilization" (UNEP/CBD 1994, Articles 1, 3, and 15). Grounds for the CPB were established in 1991, when developing countries and NGOs managed to include language in the CBD to address risks related to biotechnology (UNEP/CBD 1994, Article 19). The Protocol became international law on September 11, 2003. The United States had tried for a decade to block the Protocol, then tried unsuccessfully to insert language that would have subordinated it to the WTO (McAfee 2003b).[8] It continues to work against the treaty's implementation.

Several WTO sub-agreements advance the global consolidation of agro-food systems and establish the legal and discursive frameworks, under the rubric of "free trade", for international markets in genetic resources and biotechnology products. The most important of these are the Agreement on Agriculture (AoA) and the Agreement on

[8] The US also failed to convince Southern and European governments to drop Protocol language that permits a precautionary approach to biotechnology regulation. It was unable to defeat a provision that allows countries to decline imports of living GM organisms that would have negative socioeconomic consequences. The US did succeed, however, in excluding from the Protocol products not intended for release into the environment, such as processed foods or grain meant to be consumed by people or animals. Although the US is unlikely to join the Protocol, this exclusion (Article 11) may make it more difficult for countries to decline US agricultural imports or food aid that may contain transgenic grain. The rationale for this provision is that organisms that will not reproduce in the importing country cannot pose environmental risks. However, as explained below, the distinction between grain for eating and grain for planting does not apply in the same way in much of the global South as it does in the United States.

Trade-related Intellectual Property Rights (TRIPs).[9] Achieving these accords has not been easy, and interpretation and implementation of both TRIPs and the AoA were still being contested among the US, EU, and developing-country blocs.[10] The WTO AoA calls for the phased elimination of most subsidies, quotas, and tariffs that many countries have used to maintain domestic farming sectors, and in many cases, to reward agricultural elites. US agribusiness firms want a version of the AoA that will open foreign markets to their products without eliminating the categories of state subsidies that now enable them to export many of their crops at prices below the economic costs of production. Some of these crops —about 40 percent of corn, 76 percent of soy, and 73 of cotton— are now genetically engineered (Gersema 2003), and other GM crops, such as wheat, may soon be commercialized. US agro-industry spokespeople contend that it is too costly to keep them separate from conventional varieties during transport and processing.

The WTO TRIPs Agreement requires WTO member countries to recognize and enforce private property rights "in all fields of technology". The aim of the coalition of biotechnology firms that initiated TRIPs was to prevent public agencies and private enterprises from distributing their own versions of drugs, therapies, research tools, and crop varieties, as well as computer, media, and other technological inventions, to which private firms claim intellectual-property rights: patents, trademarks, trade secrets, or plant-breeders' rights. The US government pushed hard for the adoption of TRIPs and has sponsored even stronger requirements for IPR enforcement in its regional and bilateral trade treaties (GRAIN 2001).

The capacity builders

From the perspective of the major international development institutions and private foundations, some Southern governments, and many national and international crop-research agencies, the main problem with molecular biotechnology is that the global North has it but most of the South does not. Biotechnology advocates hope to bridge this

[9] Other WTO sub-agreement with ramifications for food and biotechnology trade are the Codex Alimentarius, the accord on Sanitary and Phytosanitary Measures, and the general Agreement on trade in Services.

[10] African governments, especially Kenya and Ethiopia, have led a broad alliance of developing and "like-minded countries in opposing globalized IPR. See, for example African Group 2003.

gap by "building the biotechnological capacity" of technology-poor countries.[11] This capacity building is aimed at the formal scientific and regulatory institutions, many of which are weak and have been further hollowed out by structural-adjustment austerity. It is meant to help Southern scientists and administrators understand genetic engineering, access the latest technology packages or engineer plant and livestock varieties appropriate to their soils, climates, and markets, and manage the risks of releasing newly-invented, reproducing organisms into the biosphere. Trainees are encouraged to work with the universities and firms that already dominate the field.

Capacity-building programs often portray "partnerships" with private enterprises as the main way that public institutions and the farmers they serve can gain access to advanced biotechnology tools, data, and germplasm. Transnational corporations and universities have patented of many of the "enabling technologies" and genetic data needed to engineer new crop varieties, as well as plants and animals. (Barton and Berger 2001, Wright 2000; Boyd 2003). Many Southern NGOs and officials have challenged the legitimacy of these proprietary claims, especially when the privatized organism is variety of a staple crop, or when the inventive activity required by patent law —or its liberal interpretation— consists of no more than characterizing and consistently reproducing a crop variety obtained from peasant farmer-breeders, or when the "innovation" involves purifying a plant extract and proposing a novel use for it, which has been sufficient grounds for obtaining utility patents in the United States. Biotechnology capacity-builders must therefore convince skeptics of the morality and the practical value of these private, exclusionary property rights.

Some capacity-building programs include training in intellectual property instruments such as the licenses and material transfer agreements that are negotiated when patent holders permit restricted use of their property. Currently, many countries do not have laws or mechanisms to enforce proprietary claims on plant varieties; some forbid private ownership of living things. Advocates of global standardization of IP globalization contend that such countries will miss the opportunity to participate in the market-mediated sharing of the benefits of biotechnology. Private firms, they say, will be unwilling to sell their products or establish joint ventures there, while public agencies

[11] Capacity building more generally is a widely-used phrase that connotes the cultural and institutional modernization that is the core of the post-colonial development project.

which use privately-patented methods or materials to develop products for the poor will risk suits or other reprisals by patent-holders or governments if they release such products in countries where their sale or reproduction is not "protected".

Biotechnology capacity building, supported by government, multilateral, and industry organizations, has become a minor growth industry for international consultants and lawyers.[12] By June 2003, participants from 117 countries were enrolled a joint effort of the UN Environment Program and the Global Environment Facility, taught by European experts and a scientist previously responsible for drafting US biotechnology regulations (UNEP/GEF 2003). The Foreign Agriculture Service of the US Department of Agriculture sponsors seminars and short courses worldwide "to build regulatory and institutional capacities and educate a variety of foreign audiences on issues surrounding agricultural biotechnology production, consumption, and trade" (FAS 2003). US AID monitors developing-country policies on GM imports and sponsors a $14.8 million program "to enhance biosafety policy, research, and capacity" in Bangladesh, India, Indonesia, the Philippines, and East and West Africa, and other countries (USAID 2002).

Capacity-building may also involve training in how to manage the environmental hazards of GM organisms, typically based on methods and criteria modeled on those used in the United States or Europe. Both the 1993 WTO agreement and the new Biosafety Protocol (CPB) contain language requiring that countries that choose not to accept imports of particular products must justify their policies on the basis of "sound science".[13] Countries and companies that export transgenic crops therefore have a stake in convincing Southern scientists and civil servants that their task is to bring their domestic laws and practices "up" to US and EU standards, and that the latter are unassailably rigorous and universally applicable. However, US standards and procedures for estimating potential hazards and monitoring the environmental and health effects of

[12] In anticipation of the Cartagena Protocol, at least 54 "Biosafety Capacity Building Projects" were already completed or underway by February 2002, covering topics of public awareness, national policies, institutional strengthening, risk assessment, data management, scientific and technical collaboration, technology transfer, and identification of living modified organisms (UNEP/CBD 2002).

[13] The WTO TRIPs agreement allows exceptions in cases of dangers to public order and morality, and the CPB permits countries to decline to import genetically modified living organisms for socioeconomic reasons, but this far, no countries have attempted to use these provisions.

transgenic crops and products have been widely criticized, including by staff of the US EPA and by the US National Academy of Science (NAS 2002).[14]

Promises and perils of GM crops

Significantly, campaigns on behalf crop genetic engineering focus less on existing products than on future, hoped-for applications. One reason is that nearly all commercially-planted GMs crop do not produce more food and have not been designed to do so. Yields from these crops have generally been lower than those of their conventional counterparts, except in a few places in years when certain pest infestations have been unusually heavy (Benbrook 1999; Carpenter, 2001; Benbrook, 1999; Elmore R. W. et al. 2001; Hyde et al., 1999)). GM crops have not resulted in reduced use of pesticides, except in the case of Bt cotton in some regions, nor have they generally saved farmers money (Benbrook 2001).

Industry, government, and multilateral-agency publicity therefore highlights anticipated new crops with nutritional or disease-resistance traits that —it is hoped— will benefit farmers and consumers, not just agrochemical and seed firms. Most of these applications, including the highly-touted "golden rice" containing pro-vitamin A, are still in the development stage or are merely hypothetical. It is unlikely that private firms will have much incentive to develop specialized varieties for the various needs of small-scale or subsistence producers, since these farmers will rarely provide profitable markets. Nevertheless, the World Bank and other agencies reproduce uncritically the discursive ammunition of biotechnology enthusiasts: for example, by routinely referring to GM organisms as "genetically enhanced" instead of the more neutral phrase "genetically modified". This bolsters the impression that genetic engineering is already providing superior crops and that countries that neglect them will be left (farther) behind.

[14] European standards are not as different as they may appear; Wright (1994) has shown how initially more stringent British criteria for detecting hazards of recombinant-DNA technologies were gradually softened to resemble the more narrowly conceived US notion of risk. One continuing point of contention between US and British and E.U. regulators is whether the products of genetically engineered crops are "substantially equivalent" to products of conventional crops. Since 1982, the US Food and Drug Administration and US negotiators have held that held that the process by which foods and other products are produced is irrelevant so long as no "substantial" differences between conventional and transgenic-crop products are detected.

Meanwhile, eight years' experience with GMOs has cast doubt on early, reassuring endorsements of their safety and predictability. Regulators on both sides of the Atlantic have had to revise their recommendations for planting and field testing of GM plants in light of evidence that pollen from crops such as rapeseed (canola) and maize can travel farther than they had assumed, transferring synthetic DNA to related crops in nearby and sometimes in distant fields. Other little-researched and unresolved issues concern the effects of transgenics on "non-target" organisms: not only butterflies and other wild species, but also beneficial insects and soil microorganisms that keep agroecosystems healthy. Because research on GM crops, like most agronomic research, focuses mainly short-term yields and on one crop at a time, scant attention has been paid to the agro-systemic interactions of GM organisms, the longer-term effects of their toxic properties, or the possible hazards of the antibiotic genes and bacterial and viral constructs that are used to engineer transgenic crops and are reproduced along with them (McAfee 2003a).

One troubling consequence of the widespread planting of transgenics, pest resistance, is widely recognized. Weeds and insects can evolve in just a few years to tolerate the pesticides that are used in tandem with GM plants or that are produced by the plants themselves. Approximately 76 percent of currently-marketed GM crops are herbicide-tolerant (HT), engineered to withstand spraying with glyphosate, familiar in the United States as Monsanto's Roundup. Glyphosate kills non-HT crops and any other plant it reaches, including weeds, which is convenient for some farmers and can reduce the need to till erosion-prone soils. These advantages may be only temporary, however. Since HT crops were introduced, several species of weeds have already become resistant to glyphosate, causing serious problems for farmers and threatening to make glyphosate useless in many places in the future (Pollack 2003).

Another 23 percent of planted GM crops carry genetic instructions from a bacterium, *Bacillus thuringiensis* (*Bt*), that causes them to produce insecticides in their tissues. About seven percent have both *Bt* and HT traits. To slow the development of insect pests that are resistant to *Bt* toxins, the US EPA tells farmers to plant 20 percent of their corn acreage in non-*Bt* crops, but this requirement has been laxly enforced (CPSI 2003). Genetic engineers are developing varieties that produce more than one form of toxin, a tactic that may postpone but is unlikely to solve resistance problems.

Pest resistance points to an important characteristic of agro-biotechnology that is commonly overlooked: thus far, *crop genetic engineering represents a continuation of rather than an alternative to some of the most problematic aspects of industrial agriculture.*

Modern monocultures, designed to maximize short-term crop yields, actually create and worsen pest and disease problems. Their high concentrations of nutrients, physical uniformity, and large scale make them ideal grounds for pest organisms to move, breed, and evolve. Lack of genetic diversity in monocrop agro-ecosystems makes them particularly vulnerable when pests gain an edge. These greatly-simplified ecosystems often lack the beneficial microbes, insects that prey on pests, and other organisms involved in the regulatory mechanisms that help keep more complex farming systems productive. Use of insecticides United States rose 10-fold over 44 years, but the proportion of crops lost to insects nearly doubled in the same period (Wargo 1998 [1996], p 7). This pesticide treadmill is equally problematic in green-revolution farming, which also involves pest-attracting monocultures and in which higher crop yields typically depend upon substantial chemical inputs. To date, most genetic-engineering research in universities and the private sector has been conceptualized within this conventional-agriculture paradigm. Industry organizations avoid drawing attention to the problem, which is not surprising given that the leading seed-distribution firms are also major producers of pesticides.

Biotechnology and the problem of genetic erosion

Industrial technology-centered agriculture, and genetic engineering in particular, add momentum to the trends of agrobiodiversity loss, genetic homogeneity, and diminished farmer choices of crops and varieties to plant. This is happening or may soon happen in at least three ways.

First, in the context of low farm-commodity prices and intense transnational competition, biotechnology has helped to speed the consolidation of seed and agrochemical enterprises. Mergers and buy-outs among chemical, pharmaceutical, and seed firms were driven in the 1980s and 1990s by the race to acquire biotechnology tools and intellectual property rights to use them. A small number of mega-firms now dominate agro-industry and food and agriculture trade worldwide (Heffernan and Hendrickson 2002; Murphy 2002; OECD 2000). IPR portfolios are the most valuable asset of some of these firms (Barton and Berger 2001; Boyd 2003). The high cost of genetic engineering and related IPR raises barriers to entry against new companies, smaller companies, and domestically-based companies in Southern countries. Transnational firms market a relatively small number of crop varieties, of which transgenics comprise a growing proportion, as well as the inputs that these varieties require. Agrochemical sales have been the main source of profit for the industry giant, Monsanto. This, added to the preferences and contractual requirements for particular varieties by agro-processing and transport firms, means that fewer seed varieties are marketed, planted, and conserved worldwide.

A second way that genetic engineering can speed genetic erosion is by contributing to social differentiation among farmers. Although this has not yet been documented, it is likely to occur for the same reason that green-revolution technology has frequently had this effect. Only some producers are able to afford higher-priced GM seeds and accompanying technology packages. As more poor, part-time, or older farmers and those in more isolated places or varied ecological and cultural settings are unable to continue, many more crop types and local land races will no longer be cultivated.

A third possible threat to agro-biodiversity from genetic engineering is more direct. Most of the major seed/agrochemical firms are developing genetic-engineering methods to prevent farmers from saving seeds of premium-variety crops for planting. A range of different genetic-use restriction technologies (GURTs)—or “terminator” technologies, as they are called by their critics—are being designed to ensure that farmers must either purchase new seed for each planting or buy chemical keys to activate engineered crop traits. The rationale advanced by GURTs defenders is that companies need to recoup high expenditures on research, development, regulatory requirements, acquisitions, and IP management. One effect, should such technologies be widely employed, will be to impede the continued creation of crop biodiversity by farming communities. Farmers have long been improving their traditional varieties by selecting seeds from their best plants or plants with particular, desired traits, often exchanging seeds with family and communities, sometimes across long distances, and experimenting with different varieties under different growing conditions. Many farmers also encourage modern varieties to interbreed with local landraces to produce plants with new combinations of traits, selecting the seeds of promising specimens. "Terminator" technologies would inhibit this important process of innovation and adaptation. And, should genetic constructs that cause plants to produce sterile seeds find their way into populations of wild crop ancestors and local land races, the results could be even more damaging.

II GEOGRAPHIES OF DIFFERENCE IN FARMING AND FOOD SYSTEMS

Most biotechnology capacity-building programs take for grated that crop genetic engineering will generate net benefits, and that those benefits will be distributed, even if unevenly, to all of humanity. For the sake of argument, let us set aside the problems noted in Section I of this paper. Let us presume that with new discoveries, greater attention to ecological processes, and more enlightened and better-enforced regulation, crop genetic engineering will indeed increase food production and ameliorate environmental damage from industrial farming in advanced capitalist nations. *On the basis of this supposition, can we logically conclude that genetic engineering is the foundation of a strategy to end hunger and strengthen food security in the global South?* Can we agree with the World Bank that molecular science to improve crop germplasm is essential to sustainable rural livelihoods in the would-be developing world? Can we expect that capacity-building to promote adoption of advanced biotechnology will achieve these ends? Will the global standardization of intellectual-property regimes foster conservation, appropriate technology transfer, and the equitable sharing of values of crop genetic resources and the profits from biotechnology?

The answer, unfortunately, is that we cannot take any of these optimistic assumptions for granted. There are important geographies of difference that make it impossible to extrapolate, even from a best-case scenario for the biotechnology in the global North, to positive prognosis for the effects of GM crops in most of the global South. These spatial dimensions of difference fall into three main categories:

1. **Differences in the role of genetic and crop diversity in various farming systems.**

2. **Differences in the degree to which production is based upon commodity relations.**

3. **Difference in the ability of food producers to capture benefits from property rights to genetic resources.**

1. Differences in the role of crop and genetic diversity

Differences in the risk to agrobiodiversity in regions of the global North and South

The risks of negative consequences from the release of living GM organisms are greater in many parts of the global South than in the United States, Argentina, Canada, and China, where most transgenic crops have been grown. None of these countries are centers of natural genetic diversity for the crops that are now grown there in transgenic forms[15]. Most of today's staple crops were first domesticated in parts of Asia, Latin America, and Africa. A vast wealth of traits are conserved in these regions in the genomes of crops and the wild plant types from which early farmers derived them.[16] Also important are secondary centers of agrobiodiversity, where farmers have developed myriad local varieties (landraces) suited to their particular growing conditions and farming practices: for example, maize varieties in parts of Africa and rice landraces in South Asia.

Farmers who save and exchange seeds still draw upon this genetic diversity to maintain the vigor of their crops and to cope with environmental fluctuations, pests, and diseases. Crop breeders in formal institutions, whether using conventional or molecular means, also employ genetic material from unique landraces and crop wild relatives to develop new varieties. The plant samples and seeds conserved by the CGIAR and other gene banks are precious potential sources of traits that may help with pest and plant-physiology problems and climatic stress. Varieties cultivated by small and medium-scale farmers are at least as valuable, particularly to the farmers. Moreover, while little is

[15] The United States is the world's largest producer and exporter of transgenic crops: mainly, corn, soy, cotton, and rapeseed (canola). Argentina, which grows transgenic soy and corn is second, followed by Canada, which exports genetically engineered rapeseed and grains. China has experimented with transgenic tobacco and cotton and is working on other crops, but placed a moratorium on transgenic plantings in 2002. About 15 other countries have permitted limited planting and field testing of transgenics (ISAAA 2002).

[16] Centers of genetic diversity of food and beverage crops are found in Mexico and Central and America (maize, beans, tomato, squash, peppers, avocados, sweet potatoes, potatoes, peanuts, pineapples, cassava, lima beans, and cacao, as well as cotton, rubber and tobacco), Southeast Asia and the South Pacific (rice, bananas, citrus, taro, yams, coconut, sugar cane, mangos, breadfruit, yam, taro, breadfruit), China (soy, types of millet, peaches, oranges, tea), South Asia (rice, eggplant, cucumber), Africa (African rice, sorghum, pearl and finger millet, tef, cowpeas, oil palm, watermelons, African yams, coffee), West and Central Asia and the Mediterranean (wheat, barley, oats, grapes, figs, olives, dates, sesame, broad beans, chick peas, lentils, onions, carrots), Europe (rye, apples, sugar beets, cabbage), and North America (sunflower and cranberry) (Kloppenburg and Kleinman1987; FAO 1998).

known about many of the samples stored in seeds banks, information about how different living varieties perform is available from farmers themselves. The acceleration of genetic erosion —the loss of this agricultural biodiversity— is one of the negative consequences of the green revolution and of agricultural modernization more generally.

Is this vital agricultural genetic diversity threatened by genetically altered crops? Many researchers believe that the possibility is great enough to warrant postponing the release of GM varieties, especially in regions of genetic diversity, until much more is known about their effects over space and time. There is no doubt that engineered genetic material can be transferred via pollen, even from plants that are usually self-pollinating, to fields of conventional crops and wild relatives of these crops (Ohio State 2002). Recent studies suggest that genetic engineering itself may, in some cases, cause plants to produce more seed or spread their pollen more widely. (Ellstrand, 2001; Snow et al. 2002).[17]

There is growing evidence that engineered genetic constructs may also be transferred “horizontally”, from one species to another, with the aid of naturally-occurring microbes or by the viral vectors that bio-engineers use to force “foreign” DNA into living cells. Horizontal gene transfer is even less understood than gene flow via pollen. Other poorly-understood phenomena are the multiple, unpredicted outcomes of genetic engineering in both experimental and commercially planted GM crops (Meyer et al., 1992; Halsberger 2003). These include silencing of the expression of genes apparently unrelated to the construct inserted by genetic engineering and the appearance of unexpected traits in response to changes in growing conditions. (See McAfee 2003a for a summary of some early research on these and other crop-biotechnology problems). Some researchers have advanced plausible although far from definitive reasons why the genetic-engineering process might stimulate the emergence of new pathogens.

In November 2001, University of California researchers reported in *Nature* that they had detected transgenic material in corn kernels collected from mountainside maize plots in Oaxaca, Mexico, where planting GM corn is illegal (Quist and Chapela 2001). Other scientists cast doubt upon some of the diagnostic methods used in the initial *Nature*

[17] Although gene flow between crop populations is common, gene-flow problems of GM crops were initially underestimated by regulators and ignored by industry. Now some biotechnology advocates argue that “terminator” technologies are needed to reduce GM gene flow.

study and on the authors' interpretation of their results (Kaplinksi et al. 2002; Matthews 2002).[18] Nevertheless, few researchers deny that that transgenic material probably has been or soon will be incorporated into the genomes of local maize varieties wherever GM corn is planted. Many believe that engineered DNA might also be taken up by wild plant relatives, such as teosinte,[19] the wild ancestor of maize. It is not yet known whether this introgression is likely to cause the loss genetic or varietal diversity in corn or teosinte or in different crops and wild plants in other regions. This could occur if engineered genetic material confers a survival advantage to some varieties, which might out-compete related plants with potentially-valuable characteristics that would then become extinct. Some researchers think that such effects will not be significant: this is the official position of the CGIAR's International Maize and Wheat Improvement Center. Nevertheless, CIMMYT has taken pains to ensure that its seed collections are not "contaminated" by transgenic varieties (CIMMYT 2001).

What is indisputable is that *if gene flow from transgenic crops does cause any of the problems mentioned above, the risk of harm to crop genetic resources is orders-of-magnitude greater in centers of crop genetic diversity and in regions where domestic-crop ancestors still thrive than it is in the major food-exporting countries*, where most commercial crops now grown were unknown 400 years ago. There is already little genetic diversity in these modernized agro-ecosystems. In contrast, in the global South, many farmers benefit from and depend upon both inter-species and intra-species diversity.

Differences in the role of agro-biodiversity in different kinds of agro-food systems

Inter- and intra-species genetic diversity is economically inefficient in some agro-food systems but critically important in others. In capitalist agriculture, the values of crop varieties, like other factors of production, depend upon their contribution to the profitability of the enterprise, usually calculated over one harvest cycle or just a few

[18] An equivocal statement about the Quist and Chapela report by *Nature*'s edited, widely described reported in the press as a "disclaimer", and campaign to discredit Chapela and his article by affiliates of the industry leader, Monsanto, contributed to the widespread perception that worries about transgene flow had been laid to rest.

[19] *Zea mays* ssp. Parviglumis, also called teocintle.

years.[20] For large farming operations and agribusiness firms, genetic uniformity has advantages related to the exigencies of mechanization and large-scale production and marketing. Identical plants that ripen simultaneous can be harvested, quality-checked, transported, and processed in bulk.[21] Genetic variation is a hindrance in such farming systems, except, of course, when crops are devastated by diseases to which none of the individual plants have retained resistance.

In contrast, in more "traditional" farming systems in the global South and elsewhere, crop variety and genetic diversity may be advantageous for multiple reasons, not all of them directly economic. The values of different crops and traits are related to the manifold functions of agricultural landscapes. They are place-specific and particular to various eco-social systems. Especially where certain foods are grown for subsistence, where food, labor, and inputs are exchanged among family and community members and migrants, and where local markets and festivities are important, different crops and land races may be preferred for different purposes. Traits that affect local marketability, tastes and colors, cooking and storage qualities, and symbolic significance can be important to cultural cohesion as well as to nutrition.

In addition, genetic homogeneity may be dangerous for ecological and agronomic reasons. Especially where peasants must use marginally arable land, it is common to plant different varieties at different altitudes or in soils and micro-climates with different characteristics, or to plant landraces with different traits, in order to increase the chances of an adequate harvest if the growing season turns out to be particularly dry, wet, hot, or cold. Moreover, as noted above, small-scale farmers not only select their best seeds for planting, but may also allow their own varieties to hybridize with modern or wild varieties in order to improve or reinvigorate their crops. If they have access to fewer traditional and new varieties, and especially if the new varieties carry genetic instructions for seed sterility, these economically and culturally vital processes will be stifled.

[20] Genetically engineered varieties have not generally been more profitable for individual farm enterprises; so far their benefits to farmers, if any, have been the convenience of simplified regimens for pesticide applications.

[21] Transgenic crops are not necessarily more genetically uniform than many hybrid and other premium varieties sold to modern farms; in this respect they offer no particular benefit or disadvantage. However, as explained above, molecular biotechnologies have speeded the corporate consolidation which accelerates the trend toward the use of fewer and more homogenous varieties.

2. Differences in the degree to which production is based upon commodity relations

Greater economic risks for self-provisioning farmers and tropical smallholders

The effects of crop genetic engineering, at least as it is currently carried out, are substantially different for capitalist agriculture than for farming in which the processes, inputs, and products of production are not primarily based on commodity relations. One reason is that farmers in commoditized, industrial-agriculture systems purchase new seed frequently, often annually, while the majority of Southern-country farmers save seeds for planting. Widespread use of seed-sterility technologies could prove immensely more harmful in such regions, where it would rupture the cycle of agrarian life and survival.

Moreover, the consequences of crop failure are more likely to be severe, threatening livelihoods and lives, in places where farmers lack other sources of incomes and food. Where seeds are saved and planted, transgenic or other traits are more likely to be dispersed, with consequences that are less predictable in the case of transgenics. As we have seen, transgenic crops that require pesticides or that produce pesticides, like pesticides more generally, can speed the evolution of resistant weeds and pests. Potentially-resistant predators are often more numerous and varied in tropical zones and in regions of crop genetic diversity, where pests have co-evolved with domesticated crops and their wild relatives. While resistance causes costly problems in modernized farming, its consequences may be much more serious for smallholders in the global South.

Contrasts in regulatory needs and effectiveness in different kinds of agro-food systems

Most agencies that facilitate biotechnology capacity-building take for granted that US or European regulatory institutions are models for developing countries. Some worry that regulatory bodies in the global South are subject to political pressures or are excessively compliant (Cohen 1999). While this may often be true, prescriptions to solve that problem by replicating US regulatory models are disingenuous or blind. In the United States, biotechnology and trade policies are strongly linked to the political clout of agribusiness and pharmaceutical interests (McAfee 2003a, 2003b) and there is ample evidence of pro-industry bias and laxity in biosafety testing and resistance-management regulation. A National Academy of Sciences panel found that USDA procedures for determining the safety of new crops are in consistent and not sufficiently transparent, nor rigorous enough (NAS 2002). A 2003 investigation found USDA data indicating that nearly one in five farmers in corn-producing states have not been complying with US Environmental Protection Agency (EPA) rules meant to slow the evolution of insecticide-resistant pests and that industry reports greatly underestimate the problem (Jaffe 2003).[22] Faith in US regulatory practices, industry self-monitoring, and government transparency is as ill-founded in the global North as in the South.

But North-South differences raise additional concerns. *Even if US safety measures were stringent, thorough, and honestly enforced, models developed for industrialized farming are not appropriate for much of the global South. That is because the meanings and practices that surround the seed are greatly different agro-food systems that are fully integrated into national and international markets and in those in which a significant proportion of farming is for subsistence and local exchange.* The model that US AID and the USDA are try trying to export presumes a system of commercialized agriculture in which varieties are uniform, seed is a commodity sold for planting, and harvested grain is an entirely different commodity, sold for consumption. But in Mexican and other partially self-provisioning peasant economies, the same seed may be the source of life both in the sense of the next day's meal and the next season's planting material. Agricultural production and consumption are phases of a cycle that is both more local and more closed.

In modern societies and agro-food systems, society-nature relations are mediated by markets, and conceptual dualism prevails. Seed for planting, feed for animals, and food for people are perceived and regulated differently, even when the same grain variety is the source of all three. The contamination in 2001 of US corn food products and exports with GM Starlink corn, which had been restricted to sale for animal feed because of its potential allergenicity, showed that such distinctions are hard to maintain.

[22] One of the few risks of transgenic crops that has been widely studied is the rapid evolution of insect pests that are not harmed by *Bacillus thuringiensis* (Bt) toxins, which is produced in the tissues of about a quarter of the transgenic crops currently planted. Because such resistance could render useless an important, relatively benign insecticide, the EPA requires that 20 percent of corn acreage be planted in non-Bt varieties. The CSPI study found that a majority of farmers were unaware of or misinformed about the simple EPA rule, and that reports by industry overestimated farmer compliance with this safety measure by 40 percent. The latter is significant because the EPA and other US regulatory agencies rely primarily on industry self-reporting when they assess the safety of transgenic crops and other potential environmental and health hazards.

Nevertheless, during the Biosafety Protocol negotiations, the United States insisted upon the appropriateness for all societies of the conceptual separation of "food", "feed", and "seed". US negotiators were adamant about excluding from the treaty's purview any GM organisms not meant "for intentional introduction into the environment", including those meant "for direct use as food or feed, or for processing" (Article 7). They also demanded the exclusion of living modified organisms[23] "in transit" or "destined for contained use" (Article 6). The US purpose was to make it more difficult for countries to decline to import US agricultural products on public-health or environmental grounds. The rationale offered was that such organisms would not reproduce and therefore could pose no conceivable ecological risks.

The *Nature* report of gene flow in Oaxaca and the ensuing controversy illustrate the folly of this reasoning and the error of modeling developing-country GMO management on US regulations. EPA rules and USDA guidelines have underestimated or ignored the dispersal of transgenic artifacts by natural means, such as wind-born pollen and possible horizontal (interspecies) gene transfer, even though traveling transgenes have already made it impossible for some growers of "GM-free" canola and organic corn in the US and Canada to market their products. As we have seen, transgene flow may have graver consequences in centers of genetic diversity.

But in addition, seeds are not only "natural". *Those who would base biosafety rules on Northern models fail to appreciate the meanings, multifunctionality, and mobility of corn, and of all seeds, as cultural objects* —or as actor-network theorists might put it, as actants— in agricultural eco-social systems. In 1998, the Mexican government banned the planting of transgenic plants with the aim of keeping Mexican crops "GM-free" for the time being. Such a ban might work in a fully commodified agro-food system, but Mexican agriculture does not fit that description, despite the efforts of the last two governments to eliminate the country's "inefficient' peasant producers. Few Mexican observers were surprised to hear that "escaped" transgenic constructs were detected in the Oaxacan sierra, meaning that the official GM moratorium was futile. The origin of the GM constructs, many said, was likely to have been whole-grain, US *Bt* corn, widely

[23] The use in the Protocol text of the term "living modified organism" instead of the more commonly used "genetically modified" or "genetically engineered" organism is a discursive device which helps to create this dubious differentiation: the assumption is that the Protocol need not cover "non-living" material such as seeds intended for consumption, since they will presumably not be brought to life.

marketed as grain to be fed animals or to be ground to make tortillas. Alternatively or in addition, *Bt* corn seeds might have been brought home by seasonal migrants, following the time-honored practice of experimenting with and exchanging seed varieties and encouraging new types to hybridize with local landraces.

In addition, there are important differences in the perceived usefulness of hoped-for genetic-engineering applications intended particularly to benefit the poor when these are seen from the perspectives of the "inventors" purported super-crops, one the one hand, and from the perspectives of peasant agriculturalists, on the other hand. From the view of those accustomed to fully-commoditized agro-food systems, promised crops with enhanced nutritional values, such as "golden" rice that produces beta-carotene and "protatoes" engineered to have slightly higher protein content, appear unquestionably beneficial.

But for many rural communities, modernization and integration into agricultural markets has already been accompanied by a narrowing of the range of foods that they can afford to produce or manage to obtain. For them, such magic-bullet varieties are poor substitutes. A miracle rice or tuber that contained all the nutrients that peasants once obtained from a varied intake of grains, pulses, vegetables, "weeds", and wildlife would make a dull diet indeed, and would leave farm households entirely dependent on their ability to purchase food in markets over which they have little control. Laboratory and test-plot results that focus on single traits in single crops, without reference to the place-specific material, cultural, and economic contexts in which food is planted, harvested, processed, purchased, cooked, and consumed, cannot tell us whether a new variety is "beneficial" or not.

3. Differences in the positions of food producers and enterprises to profit from biotechnology and property rights

In an ideal world of globalized property rights, anyone, anywhere has equal opportunity to innovate and to exclude others from the use of his or her invention. In the real world, there are tremendous historical and structural differences in the abilities of transnational firms, domestic companies, public-sector agencies, indigenous peoples' organizations, and small-scale food producers to make profitable use of property rights to genetic and agriculture resources.

Only the well-endowed can afford to establish and maintain proprietary claims that are legally and internationally defensible, especially to processes or information of potentially substantial commercial value. Accumulation of capital in biotechnology is based on the enclosure of the intellectual commons: private ownership of scientific knowledge of a kind that was formerly shared, and of genes and organisms that were once open-access resources (Press and Washburn 2000; Barton 1998). The great majority of patents on products and processes used around the world, regardless of their origins, are held by Northern corporations and institutions, with those based in the United States well in the lead. A few private firms control a large proportion of the rights to basic genetic-engineering tools (called “enabling” or “platform” technologies) as well as the rights to make use of natural or induced genetic variations. As a result, many academic and public-sector researchers and plant breeders find it difficult or impossible to produce biotechnology-based public goods, such as crop varieties crafted for poor farmers (Barboza 2001).

NGOs, farmer activists, and governments of Southern states point to the injustice of what they call “biopiracy”. This charge is usually aimed at Northern firms and universities when they patent pharmaceuticals, crop varieties, or other products derived from materials and information obtained from Southern ecosystems, farmers, or medicinal practitioners, sometimes with little or no added innovation by the patent holder. Defenders of universalized IPR point out that proprietary claims on medicines and crops cannot prevent the original cultivators or healers from continuing to use those crops or natural products in their original form. They may not, however, sell those crops or medicines in countries where property rights to them are recognized. To those who resources have been “pirated”, that message reads: “It’s fine to keep benefiting from these valuable genetic resources —as long as you agree to remain poor.”

A consortium of Mexican small and medium-scale farmers got such a message when they took NAFTA’s free-trade promise at face value. In 1994, the Rio Fuerte producers union began increasing their exports to the US of a type of yellow bean they had been growing and selling since the 1970s. Their US market disappeared when their distributor was sued for patent infringement by a US bean broker, Pod’ner LLC.

Pod'ner's CEO claimed to have invented the "Enola" bean in 1996, using beans he bought in Mexico in 1994 and then grew for three years in Colorado. He was granted a US patent in 1999 on beans with the same color and other traits also found in the Mexican growers' mayacoba bean (Carlsen 2003).[124] US and EU patents have been granted for other varieties developed and marketed in the global South, including basmati rice, neem plant extracts, quinoa and beans from the Andes, and kava from the South Pacific.

Defenders of a property-rights paradigm for environmental management urge governments and communities in gene-rich regions to assert their own proprietary claims on genetic resources and then trade them internationally. When the CBD was drafted, hopes were high that the sale of such genetic-resource rights under the terms of biodiversity prospecting contracts with pharmaceutical firms would generate incentives and income streams for biodiversity conservation and for indigenous peoples and other local resource providers. These expectations were exaggerated: demand for natural materials is limited, market prices for natural-product samples are minimal, sources for biological materials are man. No community has yet earned significant royalties from a commercialized pharmaceutical under the terms of a bioprospecting contract., not are they likely to.

Benefits to genetic-resource providers, which now commonly take the form of modest, up-front payments used for community-development projects, depend upon the good will or public-relations agendas of pharmaceutical firms and other bio-buyers, not on the legal force of local IP claims. Such bioprospecting deals can aid some communities, but it is illusory to imagine that they can be the basis of a strategy for conservation or for the "equitable sharing" of the "benefits of biodiversity" called for in the CBD. The power relations between buyers and sellers are too hugely asymmetrical. Should a firm develop a highly profitable use for a substance obtained through such

[24] The "Enola" patent requests state that the applicant grew the beans for three years in the field in Colorado. According to University of California researcher Paul Gepts, an expert on crop domestication in the American and a specialist in *phaseolus* genetics, three years is enough to select a pure line from an initial mixture but is not enough to develop a new cultivar through the process of hybridization and selection in the progeny. Pure line selection is prior art. In addition, it is not an inventive step as it is described in text books, usually as a first step in a breeding program. In Gepts' view, the patent does not stand up for at least two criteria: novelty, non-obviousness, and whether it satisfies the enablement (disclosure) criterion is also debatable (personal communication, September 2003).

arrangements, it could use its immensely greater legal and technological resources to interpret the contract or to alter the product in such as way as to limit profit transfers to the raw-material providers. The firm's shareholders would expect nothing less. This problem applies no less to proposed forms of collective IP rights to territorial resources or community knowledge. Under these circumstances, multilateral conservation and direct-compensation instruments may be more effective than bilateral contracts to the exchange of genetic resources as commodities.

Of course, the vast differences in the capacity of economic actors to employ biotechnology and to accumulate capital from property rights do not fall strictly along a North-South divide. State agencies and private firms in India, Brazil, Cuba, South Africa, and some other Southern nations may be able to find export niches for specialized biotechnology products. But even if they do, this is unlikely to the effect the trend toward consolidation of food-producing resources in fewer hands worldwide. Absent global-level policy changes, the combination of food-trade and investment liberalization and IPR globalization will speed displacement of domestic food producers, agro-industries and seed companies— for example, in Brazil, where Monsanto has been poised to take over some of the country's largest seed firms if transgenic crops are legalized.

All three of the dimensions of difference discussed above are consequences of the place-specificity of agro-eco-social systems and the biodiversity they contribute to and depend upon. I have not characterized these differences as "ecological", "economic", and "cultural" because *all three dimensions of difference are simultaneously ecological, economic, and cultural*. At the same time, all three axes of difference are related to the degree to which agro-food systems have become capitalist, modernized, and integrated into wider markets. This does not imply, however, an either-or choice between agro-food systems that are "modern", market-oriented, high-technology, and highly productive (but probably not ecological sustainable) and farming systems that are "traditional", subsistent-oriented, and less productive (even if more sustainable).

IV CODA: LACK OF INCENTIVES FOR GENETIC-RESOURCE CONSERVATION, OR LACK OF MEANS?

Today, many of the Mexican *campesinos* communities whose farming practices Carl Sauer admired continue to develop and conserve a multiplicity of local food-crop varieties. They certainly do not want to be poor, or to survive on self-provisioning alone, nor do they reject new knowledge and crops. But many are struggling for the right to remain farmers, or a least to maintain some agricultural activities and productive land in their extended families and communities. As a principle of human rights and democracy, their choices demand respect.

Moreover, productive rural communities embody and produce multiple benefits for social well-being, food security, biodiversity and environmental sustainability. More often than not, agricultural biodiversity —both multiple crops and multiple varieties— is a crucial component of those benefits. Therefore, the response to the geographies of difference outlined in Section II above should not be to eliminate the differences that make GM crops, at least in their present form, irrelevant for most farmers in the global South and possibly hazardous to some of them.

Self-provisioning farmers who want to continue to use locally unique or adapted varieties (often in addition to new varieties) want to do so because of the particular agronomic, storage, or cooking qualities, and sometimes the symbolic significance and/or the exchange values in local markets, of those local varieties. Thus, they already have incentives to conserve as well as to improve and adopt crop genetic resources. These incentives are not based on the abstract value of local varieties as “agrobiodiversity”, nor on the potential value of genetic resources as tradable, IP-protected commodities. Rather, incentives to conserve are inseparable from their incentives to survive as food producers and to maintain family, community, and cultural traditions and identities.

The obstacle to crop diversity conservation is often less a lack of incentives than it is the lack of means, especially in the face of policy changes that undermine agrarian economies.

For example, agricultural genetic-resource loss in a real danger for Mixtec communities in the greater municipality of Nochixtlan in Oaxaca, Mexico. Farmers there have names for at least 14 locally-planted wheat varieties (the ancestors of which are non-indigenous), 31 types of beans and pulses (most but not all of American origin), and 10 main groups of maize varieties (which perhaps carry traits derived from formal plant breeding in addition to farmer selection), as well as about 200 horticultural and medicinal plants that they cultivate or collect. Households and family networks prize their particular red, blue, yellow, white, and multicolored maize strains, some of which are remarkably productive and drought-tolerant and might provide plant breeders and other farmers with valuable traits for hardier varieties.

The farmers I interviewed are well aware of the value of these maize landraces for their own survival and enjoyment, and want to continue planting them: they do not lack "incentives" in this sense. Tenure rights and land shortage are not the major obstacles facing these particular farmers at present. Land degradation is a very serious problem, but, building upon communal structures of leadership and accountability, some of these communities are successfully rescuing farmland by rebuilding terraces and reforesting thousands of hectares, visibly transforming the landscape with limited outside assistance. Wildlife is returning and dry springs have come back to life.

However, farmers in the Mixteca Alta are having great difficulty maintaining their crop and livestock genetic resources because of the effects of trade liberalization and integration of their region into transnational agro-food systems. The flooding of local markets with cheaper, imported US corn —considered vastly inferior in taste and cooking quality by these farmers— has meant that they cannot sell their maize harvests in nearby towns or the state capital at a price high enough to recover their production costs. They face similar problems with markets for their livestock and for their beans, which are now undersold by "Michigo" (Michigan) black beans. In addition, now that grain commerce has become internationalized and organized on a larger scale, buyers are affiliated with the grain-trade giant, Cargill, and are demanding more standardized products, such as only white maize varieties. According to the farmers, these grain dealers combine their local corn with imported corn and sell the mixture with a deceptive "local" label.

Most families in the villages I visited in July 2003 continue to plant a range of maize and legume varieties for their own consumption, selling the surplus when and if they can, at least for now. Others have been forced to abandon farming and migrate to the North. Those who remain know that they are "subsidizing" (or robbing) themselves by putting in excessive work hours to cover the costs of purchased inputs and transportation for their crops —a classic example of Chayanovian self-exploitation— or by tapping funds from migrant remittances or household wage income. It is doubtful that they can continue this indefinitely, but their efforts to date suggest that "lack of incentives" to maintain crop diversity is the least of their problems.

Villagers around Nochixtlan are not passively accepting the fate —extinction as agriculturalists— that the Mexican Ministry of Agriculture and the US departments of Agriculture and Commerce envision for them. According to the president of one locally-based farmer organization,

> *Being a campesino is a vocation as important as any profession. Even though the government tells us that we are ignorant, it is we who produce the food…. The government has no solution for us – are we all supposed to go work in maquiladoras? We are resisting that. We want to stay in our homes. We propose that we are valuable. Most of the natural resources are in our hands and we are responsible for their conservation: without us, they'll be exploited and sold off….*
>
> *Our land has been abused, but we're planting more trees —100,000 this year in just this village— and land that was so sad to look at is now green and beautiful again, as you can see. These forests aid the climate and the water for our own fields and for people who live in the city. The forests give us craft and construction materials, fuel wood, fodder and organic matter [for soil improvement]. But our people eat maize, not trees, so we are conserving agricultural land, too, for our survival.*

To this end, some local farmer organizations are encouraging their members to phase out the use of chemical fertilizers in favor of animal and green manures and compost from the eaves shed by the regrowing forests. Taking the value of their own labor time into account, they have calculated that the extra work required to use organic fertilizer costs no more than the expense of purchasing and transporting synthetic inputs. Said another local indigenous leader, whose own bountiful *rancho* demonstrates the wisdom of his words:

> *Chemicals seem like a miracle at first, but we soon see the decline of the soil. After only five years, you can't grow anything without them. Then it takes a while to rebuild the soil, so we have to reduce the chemicals gradually. We also are also using more crop rotations, planting more varieties, and encouraging the beneficial insects. We live in a healthy place, and we have to care for the health of our soil because it's reflected in the health of our plants and of ourselves.*

Even with continued success in these efforts, these farming communities will find it hard to survive the loss of the markets for their crops and markets. Through their local farmer organizations, they have endorsed the demands by other Mexican peasant organizations that the government maintain or reinstate food-import tariffs eliminated by the North American Free Trade Agreement. They are calling for the government to make good on its promises to cushion the economic shocks of trade liberalization. (The $1030 peso per hectare support provided by the federal PROCAMPO program, they say, does not cover the difference between their increased production costs and the reduced market prices for farm commodities.)

Orthodox economic analysis would observe that basic-grains farming is "inefficient" in the Mixteca Alta and in most of Mexico, where small-farmers face a similar cost-price squeeze. Such analysis would conclude that society as a whole, and Mixtecs in the long run, will be better off if Oaxacans purchase their staple foods from cheaper, foreign sources. The Mexican agriculture minister has stated that market signals indicate that these *campesinos* ought to find other work. However, a more multifaceted analysis, with a longer time horizon, would take account of the myriad immediate and long-term values to local communities, to Mexican society, to farmers and plant breeders worldwide, and to humanity that these farmers have helped to create and are maintaining. These include the direct and indirect use-values and the non-use values of watershed and habitat conservation and other ecosystem services in addition to the values of crop genetic resources.

At least as important are the values to the families and communities themselves of the survival and continued development of their agrarian cultures, including the crop diversity that is vitally important to those cultures. These values are impossible to quantify or to compare in cost-benefit equations, or to capture under the terms of biodiversity prospecting contracts. Compensation to farmers and communities for the services to humanity that they provide by conserving and continuing to create useful crop varieties could be important to making that survival and development more possible. However, access and benefit-sharing arrangements conceived within a framework of commodity exchange and property rights (whether individual, corporate, or collective), and based upon the expected *commercial* values of biodiversity, cannot encompass the greater part of these values, nor match the most powerful incentives that already motivate communities such as those in the Mixteca Alta.

CONCLUSION

In 1984, Bebbington and Carney were optimistic that Carl Sauer's concerns with "the agronomic knowledge of resource-poor farmers and the frequent inappropriateness of general technologies coming out of the [CG] centers for such farmers" would be reflected in newer CGIAR research "on farmer participation in technology research" (p 35). They felt that social scientists and geographers in particular could link their theoretical work with practical CGIAR research so that

> Analyses embracing structures, institutions, human agency, and the biophysical environment would contribute to a theoretical enrichment of nature-society studies while offering the potential to identify spaces for successful institutional and local action (p 39)

They hoped this would shed light on "the possibility of broader social change through local practice". They observed that "*the technology project itself influences processes of social reproduction and change via its influence on how resources management decisions are made in institutions*" (Ibid; my emphasis). More than a decade later, it appears that the latter has occurred, but arguably, the influence of "the technology project" has had impoverishing effects within the CGIAR system itself. The advent of rDNA technology and overly sanguine expectations of its potency seem to have outweighed or displaced interest in a more humble but more multifaceted and ultimately more promising CGIAR research agenda.

If this is true, it is most inopportune. Fascination with crop genetic engineering is peaking just at the time when the crop-yield gains of the green revolution have been leveling off and the inherent limitations of standardized, high-external-input agriculture can no longer be denied. At the same time, valuable insights into more sustainable approaches are emerging from farmer-centered and multidisciplinary agronomic research, agroecology (both as a science and a social movement), and alliances between networks of farmer-scientists, peasant activists, and their allies in non-governmental, multilateral, and academic institutions (Altieri 1995; Brookfield 2001; Uphoff 2002).

At present, "high" agro-biotechnology is focused on germplasm as a laboratory object, denatured, decontextualized, and disembedded from its eco-social habitats. For the most part, it is doing more to perpetuate a fundamentally conventional agricultural paradigm than it is doing to help create more sustainable and adaptable options. This has partially to do with the techno-science itself: what I have described as the reductionist discursive practices of molecular-genetic engineering (McAfee 2003a). It is also the consequence of the path taken by applied agro-biotechnology in the context of aggressive export competition and concentration of agricultural and scientific resources in the hands of agribusiness/ biotechnology/ agrochemical oligopolies. This approach will prevail so long as profitability criteria set research agendas, budget cuts and property claims block production of public goods, and policymakers are mesmerized by the mirage of molecular miracles.

Such a path for genomic sciences and rDNA technology is not inevitable. Analysts in academia, government, UN agencies, and the CGIAR system have pointed to potential contributions of molecular biotechnology to agricultural sustainability: decentralized *ex situ* and *in situ* genetic-resource conservation and evaluation, exchange of plant genetic resources and knowledge about them, farmer-focused and participatory crop and livestock breeding, and research and capacity-building for integrated resource management. And, as understanding and experience with crop genomics and transformation has increased, useful guides for the prudent and precautionary use of these powerful tools have begun to emerge (Benbrook 2003).

A truly "modern" agricultural science is one that combines knowledge from genomics, ecology, and local experience to pursue multiple technological options, experimental methods, and learning models that can be adapted with active farmer participation to diverse eco-social situations. Activities with farmers that draw attention to the genetic resources they use, document, validate, and strengthen the practices by which they conserve and develop local varieties, and support expanded access to and exchange of germplasm and information about it can strengthen farmers' incentives to conserve.

However, the idea that markets in genetic resources and genetic-resource property rights are needed to "create incentives" to conserve misses the mark where what farmers lack more than incentives are the *means* to conserve. New, formal activities that supplement existing genetic-resource-management practices can help to provide these means. At least as important are the broader economic and institutional factors that enable or constrain the options of farmers who, given a choice, would prefer to continue a range of local varieties as well as new ones. Because the future of agrobiodiversity is imperiled by expansion of industrialized, monocrop agriculture, agro-food globalization, and rural depopulation, those who support on-farm conservation of crop genetic resources also need to respond to the policies and economic trends that undermine the forms of individual and collective action for *in situ* conservation that already exist. In this, rural social movements and international networks of farmers and non-government organizations working on agroecology, resource rights, and "food sovereignty" may be valuable allies.

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