The Sociocultural and Food Security Impacts of Genetic Pollution via Transgenic Crops of Traditional Varieties in Latin American Centers of Peasant Agriculture

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The introduction of transgenic crops into centers of diversity or areas dominated by traditional agriculture threatens genetic diversity as well as indigenous knowledge and culture. It is further argued that the impacts go beyond genetic changes in heterogeneous native crop varieties to embrace effects on evolutionary processes such as gene flow between native crops and wild relatives, and erosion of local knowledge systems such as folk taxonomies and selection of varieties that thrive in marginal environments in which resource-poor farmers live.

Keywords: *Transgenic crops; crop diversity; genetic pollution; food security; Latin American agriculture*

Controversy erupted in early 2001 after a peer-reviewed article published in *Nature* (Quist & Chapela, 2000 **2001 IN REF.**) reported that farmers' traditional maize varieties in two remote Mexican states, Oaxaca and Puebla, had been contaminated with DNA from genetically modified (GM) maize. These findings were later corroborated by independent studies commissioned by Mexico's Ministry of Environment. Many scientists, members of environmental and farmers organizations raised the alarm about this case of so-called genetic pollution, both because it is illegal to grow transgenic maize in Mexico and especially because Mexico is the primary center of maize genetic diversity. Maize varieties developed over millennia by indigenous farmers represent one of the world's most valuable reservoirs of genetic material—the foundation for global food security. Although there is considerable disagreement on the significance of this event, several people consider that native maize diversity and its ecological and cultural functions are now under threat by genetic pollution (Stabinski & Sarno, 2001). It is herein argued that the introduction of transgenic crops into centers of diversity or areas dominated by traditional agriculture will further accelerate the loss of genetic diversity and of indigenous knowledge and culture. The impacts go beyond genetic changes in heterogeneous native crop varieties to embrace effects on evolutionary processes such as gene flow between native crops and wild relatives and erosion of local knowledge systems, such as folk taxonomies and selection of varieties that thrive in marginal environments in which resource-poor farmers live. Simplification and homogenization of diverse agricultural systems and genetic materials usually equals a loss in mechanisms that confer traditional farming systems high levels of tolerance to changing socioeconomic and environmental conditions confronting poor farmers, as diverse systems buffer against natural or human-induced variations in production conditions (Brush, 2002).

Genetic diversity is a key component of traditional sustainable farming systems to manage risk and reduce reliance on agrochemicals. In today's globalized world, impoverished rural populations must maintain low-risk agroecosystems that are primarily structured to ensure local food security; given current economic trends that adversely affect small farmers (Mander & Goldsmith, 1996), most poor farmers have no option but to continue producing food for their local communities in the absence of modern inputs. It is compelling that the cultural and agroecological pro-

Bulletin of Science, Technology & Society, Vol. 23, No. X, Month 2003, 1-
DOI: 10.1177/0270467603259774

cesses that underlie the genetic diversity and sustainability of traditional agriculture remain intact and protected against the side effects of biotechnology. To achieve this, key regions must remain geographically isolated from any possibility of cross-fertilization or genetic pollution from uniform transgenic crops. These islands of traditional germplasm within specific agroecological landscapes will not only act as extant safeguards against the potential ecological failure of the second green revolution but will also serve as reservoirs of traditional crops with unique traits that may be in demand in regional and global markets, thus allowing farmers to exploit special economic niches.

Ecological and Cultural Diversity in Traditional Agriculture

One of the salient features of traditional farming systems located in centers of origin is their high degree of biodiversity. These traditional farming systems have emerged over centuries of cultural and biological evolution and represent accumulated experiences of peasants interacting with the environment without access to external inputs, capital, or scientific knowledge (Chang, 1977; Grigg, 1974). Using inventive self-reliance, experiential knowledge, and locally available resources, peasants have often developed farming systems that generate sustained yields (Wilken, 1987). In Latin America alone, more than 2½ million hectares are under traditional agriculture in the form of raised fields, polycultures, and agroforestry systems, documenting the successful adaptation of a set of farming practices to difficult environments (Altieri et al., 1987). Many of these traditional agroecosystems, still found throughout the Andes, Meso America, and the lowland tropics, constitute major in situ repositories of both crop and wild plant germplasm. These plant resources are directly dependent on management by human groups; thus, they have evolved in part under the influence of farming practices shaped by particular cultures and the forms of sophisticated knowledge they represent (Klee, 1980 **PLS. PROVIDE REF./DELETE**). It is no coincidence that countries containing the highest diversity of cultivated plant forms also contain the greatest number of ethnic groups (McNeely & Scherr, 2002 **2003 IN REF.**).

The existence of such genetic diversity, particularly in centers of origin, has special significance for the maintenance and enhancement of productivity of agricultural crops in developing countries characterized by variable agroclimates and heterogeneous environments. Such diversity provides security to farmers against diseases, pests, droughts, and other stresses and also allows farmers to exploit the full range of agroecosystems existing in each region but that differ in soil quality, altitude, slope, water availability, and so forth. A wide variety of plant species represent an important resource for subsistence farming communities as they form the foundation to sustain current production systems and biological systems essential for the livelihoods of local communities (Clawson, 1985). Folk crop varieties, also known as landraces or traditional varieties, are also valued by farmers because of the cultural values with which they are imbued, such as their symbolism in religious ceremonies or their use as gifts in weddings or rewards in community work projects. At the same time, such folk varieties are extremely important for industrial agriculture because they contain a vast amount of genetic diversity, including traits needed to adapt to evolving pests and changing climates and soils, as well as for sustainable forms of agriculture that maintain yields while reducing external inputs that usually cause environmental degradation (Brush, 2000).

Although these traditional varieties are considered part of the common heritage of humankind, they have been subjected to a process of misappropriation (biopiracy) by many Westerners without properly rewarding rural communities that served as stewards of this patrimony. The perception of folk varieties as so-called raw material to be freely used for the breeding of modern crop varieties and now transgenic varieties directly collides with indigenous notions of intellectual property rights (IPR), leading to conflicts with indigenous communities who claim rights of control over their own folk varieties against those of industrial-world plant breeders or corporations (Cleveland **CLAVELAND IN REF.** & Murray, 1997). This is a relevant consideration in the context of Mexico and the Andean region, in which important indigenous movements (i.e., Zapatistas, Ecuadorian, and Bolivian Indian movements) have a very different view of the value and proper use of genetic resources. When such farmers share seeds with outsiders, it cannot be assumed to be because of lack of a concept of IPR in their folk varieties but may rather reflect an implicit assumption that those who receive the seeds will treat them with the same respect as the farmers who gave them and not use them for commercial purposes. Manipulation of these folk varieties by plant breeders or molecular biologists from public and private institutions composes a direct violation of any implicit IPR right with indigenous farmers. This has been strongly manifested by various Mexican peasant unions in a recent statement **(PLS. PROVIDE CITE AND REF.)** denouncing the contamination of local varieties by transgenic crops in the Sierra Juarez de Oaxaca:

> The contamination of our traditional maize undermines the fundamental autonomy of our indigenous and farming communities because we are not merely talking about our food supply; maize is a vital part of our cultural heritage. The statements made by some officials that contamination is not serious because it will not spread rapidly, or because it will increase our maize biodiversity, are completely disrespectful and cynical. (p. **PLS. PROVIDE PAGE NUMBER**)

Resource-Poor Farmers, Poverty, and Genetic Diversity

It is a paradox that the sources of greatest varietal diversity tend to be the poor isolated and often marginal areas in the developing world, and the farmers who usually conserve the most diverse traditional crop germplasm are likely to be the poorest. Although estimates of the number and location of resource-poor farmers vary considerably, it is estimated that about 1.9 billion to 2.2 billion people remain directly or indirectly untouched by modern agricultural technology (Pretty, 2002). Despite the increasing industrialization of agriculture, the great majority of farmers are peasants, or small producers, who still farm the valleys and slopes of the rural landscapes (mostly semiarid and hillsides that are ecologically vulnerable) with traditional and subsistence methods. Their agricultural systems are small-scale, complex, and diverse and exhibit somewhat stable yields with a minimum of external inputs (Beets, 1982). In Latin America, peasant production units reached about 16 million in the late 1980s, occupying close to 60.5 million hectares, or 34.5% of the total cultivated land. The peasant population includes 75 million people representing almost two thirds of Latin America's total rural population (Ortega, 1986 **PLS. PROVIDE REF./DELETE**). Average farm size of these units is about 1.8 hectares, although the contribution of peasant agriculture to the general food supply in the region is significant. In the 1980s, it reached approximately 41% of the agricultural output for domestic consumption and is responsible for producing at the regional level 51% of the maize, 77% of the beans, and 61% of the potatoes (Altieri, 1999).

In Brazil, there are about 4.8 million family farmers (about 85% of the total number of farmers) that occupy 30% of the total agricultural land of the country. Such family farms control about 33% of the area sown to maize, 61% of that under beans, and 64% of that planted to cassava, thus producing 84% of the total cassava and 67% of all beans. In Ecuador, the peasant sector occupies more than 50% of the area devoted to food crops such as maize, beans, barley, and okra. In Peru, about 52 ethnic groups, a population of more than 9 million people, practice a diversity of types of agriculture rich in native genetic resources. In Mexico, peasants occupy at least 70% of the area assigned to maize and 60% of the area under beans (Ortega, 1986 **PLS. PROVIDE REF./DELETE**). In addition to the peasant and family farm sector, there are about 50 million individuals belonging to some 700 different ethnic indigenous groups who live and utilize the humid tropical regions of the world. About 2 million of these live in the Amazon and southern Mexico. In Mexico, half of the humid tropics is utilized by indigenous communities and "ejidos" featuring integrated agriculture-forestry systems with production aimed at subsistence and local-regional markets (Toledo, Carabias, Mapes, & Toledo, 1985).

Although many of these systems are undergoing major changes pushed by political and economic forces, the stubborn persistence of millions of hectares under traditional agriculture in many parts of the Latin America are living proof of a successful indigenous agricultural strategy and composes a tribute to the "creativity" of small farmers (Wilken, 1997 **1970 or 1987 IN REFS.**). These microcosms of traditional agriculture offer promising models for other areas as they promote biodiversity, thrive without agrochemicals, and sustain year-round yields.

The Complex Nature of Indigenous Knowledge

Traditional agroecosystems are the result of a complex coevolutionary process between natural and social systems, which resulted in ingenious strategies of ecosystem appropriation. In most cases, the indigenous knowledge behind the modification of the physical environment is very detailed. Ethnobotanies and folk taxonomies are perhaps the most complex of all forms of indigenous knowledge (Brokenshaw, Warren, & Werner, 1980).

Many systems used by indigenous people to group together plants have been documented (Berlin, Breedlove, & Raven, 1973). In general, the traditional name of a plant or animal usually reveals that organism's taxonomic status. Researchers have found that, in general, there is a good correlation between folk taxa and scientific taxa (Alcorn, 1984). The ethnobotanical knowledge of certain *campesinos* in Mexico is so elaborate that the Tzeltal, P'urepecha, and Yucatan Mayans can recognize more that 1,200, 900, and 500 plant species, respectively (Toledo et al., 1985). Many traditional agroecosystems are located in centers of crop diversity, thus containing populations of variable and adapted land races as well as wild and weedy relatives of crops. Clawson (1985) described several systems in which tropical farmers plant multiple varieties of each crop, providing both intraspecific and interspecific diversity, thus enhancing harvest security. For example, in the Andes, farmers cultivate as many as 50 potato varieties in their fields and near Ayacucho, indigenous people from Quispillacta maintain an average of 11 crop species and 74 ecotypes within their small plots (Brush, 1982). Similarly, in Thailand and Indonesia, farmers maintain a diversity of rice varieties in their paddies adapted to a wide range of environmental conditions, and they regularly exchange seeds with neighbors (Grigg, 1974). The resulting genetic diversity heightens resistance to disease that attack particular strains of the crop and enables farmers to exploit different microclimates and derive multiple nutritional and other uses from genetic variation within species (Wilken, 1987).

Many plants within or around traditional cropping systems are wild or weedy relatives of crop plants. In fact, many farmers may "sponsor" certain weeds in or around their fields if they serve a useful purpose (Caballero & Mapes, 1985). Through this practice of so-called nonclean cultivation, whether unintentional or intentional, farmers may increase the gene flow between crops and their relatives. For example, in Mexico, farmers allow teosinte to remain within or near corn fields, so that when the wind pollinates corn, some natural crosses occur resulting in hybrid plants (Chacon & Gliessman, 1982).

In the Mexican Sierras, the Tarahumara Indians depend on edible weed seedlings (*Amaranthus*, *Chenopodium*, *Brassica*) from April through July, a critical period before maize, bean, cucurbits, and chiles mature in the planted fields in August through October. Weeds also serve as alternative food supplies in seasons when the maize crops are destroyed by frequent hail storms. In a sense, the Tarahumara practice a double crop system of maize and weeds that allows for two harvests: one of weed seedlings of "quelites" (greens) early in the growing season and another of the harvested maize late in the growing season (Bye, 1981).

Modern Science, the Green Revolution, and Peasant Crop Diversity

Perhaps the greatest challenge to understanding how traditional farmers maintain, preserve, and manage biodiversity is to acknowledge the complexity of their production systems. Part of this complexity involves the recognition that crop genetic resources are more than just a collection of alleles and genotypes of native crops and wild relatives, but also include ecological interactions such as gene flow via cross-pollination among crop populations and species, and human selection and management guided by systems of knowledge and practice associated with genetic diversity, especially complex folk taxonomies and selection about adaptation to heterogeneous environments. Today, it is widely accepted that indigenous knowledge is a powerful resource in its own right and is complementary to knowledge available from Western scientific sources. Agronomists, other scientists, and development consultants have struggled to understand the complexities of local farming methods and their underlying assumptions. Unfortunately, more often than not, they have ignored traditional farmers' rationales and imposed conditions and technologies that have disrupted the integrity of native agriculture. This was prophetically stated by Berkeley geographer Carl Sauer **PLS. PROVIDE CITE AND REF.** after visiting Mexico at the invitation of the Rockefeller Foundation in the wake of the green revolution:

> A good aggressive bunch of American agronomists and plant breeders could ruin native resources for good and all by pushing their American commercial stocks. . . . And Mexican agriculture cannot be pointed toward standardization on a few commercial types without upsetting native economy and culture hopelessly. The example of Iowa is about the most dangerous of all for Mexico. Unless the Americans understand that, they'd better keep out of this country entirely. This must be approached from an appreciation of native economies as being basically sound. (p. **PLS. PROVIDE PAGE NUMBER**)

Part of the problem arises from the fact that the association of genetic diversity with traditional agriculture is perceived in development and scientific circles as negative, and thus linked to underdevelopment, low production, and poverty. Many people involved in international agriculture view on-farm conservation of native crop diversity as opposite to agricultural development (Brush, 2000). Those proponents of the green revolution warned by Sauer assumed progress and achieving development in traditional agroecosystems as inevitably requiring the replacement of local crop varieties for improved ones, and that the economic and technological integration of traditional farming systems into the global system is a positive step that enables increased production, income, and, commonly, well-being (Wilkes & Wilkes, 1972). But as evinced by the green revolution integration brought in addition several negative impacts (Lappe, Collins, & Rosset, 1998; Shiva, 1991; Tripp, 1996):

- The green revolution involved the promotion of a package that included modern varieties (MVs), fertilizer, and irrigation, marginalizing a great number of resource-poor farmers who could not afford the technology.
- In areas in which farmers adopted the package stimulated by government extension and credit programs, the spread of MVs greatly increased the use of pesticides, often with serious health and environmental consequences.
- Enhanced uniformity caused by sowing large areas to a few MVs increased risk for farmers. Genetically uniform crops proved more susceptible to pests and diseases and, also, improved varieties did not perform well in marginal environments in which the poor live.
- Diversity is an important nutritional resource of poor communities, but the spread of MVs was accompanied by a simplification of traditional agroecosystems and a trend toward monoculture, which affected dietary diversity, thus raising considerable nutritional concerns.
- The replacement of folk varieties also represents a loss of cultural diversity, as many varieties are integral to religious or community ceremonies. Given this, several authors have argued that the conservation and management of agrobiodiversity may not be possible without the preservation of cultural diversity.

It is important to point out that indigenous-traditional farmers are not totally isolated from industrial agriculture, and many appear to be more than willing to experiment with MVs, adopting them when they fulfill complex criteria that include not only higher yield but also local adaptation and cultural value. Once tested, farmers may integrate some MVs into the group of local landraces as done by farmers in Cuzalapa, in the sate of Jalisco, Mexico. In this case, rather than displacing local cultivars, exotic varieties occupy a small proportion of the area planted to maize, but local landraces continue to dominate the agroecosystem (Louette, 2000). Introduced varieties more often have uses and modes of management that are complementary, rather than substitutable for those of the dominant local cultivars.

The Potential Impacts of Transgenic Crops on Traditional Agroecosystems

Concerns have been raised about whether the introduction of transgenic crops may replicate or further aggravate the effects of MVs on the genetic diversity of landraces and wild relatives in areas of crop origin and diversification and, therefore, affect the cultural thread of communities. The debate was prompted by *Nature*'s controversial article reporting the presence of introgressed transgenic DNA constructs in native maize landraces grown in remote mountains in Oaxaca, Mexico (Quist & Chapela, 2001). Although there is a high probability that the introduction of transgenic crops will further accelerate the loss of genetic diversity and of indigenous knowledge and culture, through mechanisms similar to those of the green revolution, there are some fundamental differences in the magnitude of the impacts. The green revolution increased the rate at which modern varieties replaced folk varieties without necessarily changing the genetic integrity of local varieties. Genetic erosion involves a loss of local varieties, but it can be slowed and even reversed through in situ conservation efforts that conserve not only landraces and wild-weedy relatives but also agroecological and cultural relationships of crop evolution and management in specific localities. Examples of successful in situ conservation have been widely documented (Altieri & Merrick, 1987; Bursh **BRUSH IN REF.**, 1986; Jarvis et al., 2000 **PLS. PROVIDE REF./DELETE**).

The problem with introductions of transgenic crops into diversity regions is that the spread of characteristics of genetically altered grain to local varieties favored by small farmers could dilute the natural sustainability of these races. Although many proponents of biotechnology believe that unwanted gene flow from GM maize may not compromise maize biodiversity (and therefore the associated systems of agricultural knowledge and practice along with the ecological and evolutionary processes involved) may pose no worse a threat than cross-pollination from conventional (non-GM) seed. In fact, some industry researchers believe that DNA from engineered maize is unlikely to have an evolutionary advantage, but if transgenes do persist, they may actually prove advantageous to Mexican farmers and crop diversity. But here a key question arises: Can genetically engineered plants actually increase crop production and, at the same time, repel pest, resist herbicides, and confer adaptation to stressful factors commonly faced by small farmers? Thermodynamic considerations suggest they cannot; traits important to indigenous farmers (resistance to drought, food or fodder quality, maturity, competitive ability, performance on intercrops, storage quality, taste or cooking properties, compatibility with household labor conditions, etc.) could be traded for transgenic qualities that may not be important to farmers (Jordan, 2001). Under this scenario, risk will increase and farmers will lose their ability to adapt to changing biophysical environments and produce relatively stable yields with a minimum of external inputs while supporting their communities' food security.

Most scientists agree that teosinte and maize interbreed, but one problematic result from a transgenic maize-teosintle cross would be if the crop-wild relative hybrids would be more successful by acquiring tolerance to pests (Ellstrand, 2001). Such hybrids could become problem weed upsetting farmers' management but also out-competing wild relatives. Another potential problem derived from transgenic crop-to-wild gene flow is that it can lead to extinction of wild plants via swamping and outbreeding depression (Stabinsky **STABINSKI IN REF.** & Sarno, 2001).

But the impacts of transgenic contamination of landraces may not be limited to introgression-mediated changes in the fitness of native crops or wild relatives. Introduction of transgenic crops could also affect the biological balance of insect communities within traditional agroecosystems. In the case of Bt maize, it is known that natural enemies of insect pests could be directly affected through intertrophic level effects of the Bt toxin. The potential of Bt toxins to move through insect food chains poses serious implications for natural biocontrol in agricultural fields. Recent evidence shows that the Bt toxin can affect beneficial insect predators that feed on insect pests present on Bt crops (Hilbeck, Moar, Putzai-Carey, Filippini, & Bigler, 1999). Studies in Switzerland show that mean total mortality of predaceous lacewing larvae (Chrysopidae) raised on Bt fed prey was 62% compared to 37% when raised on Bt-free prey. These Bt prey fed Chrysopidae also exhibited prolonged development time throughout their immature life stage (Hilbeck et al., 1999).

These findings are of concern to small farmers who rely on the rich complex of predators and parasites associated with their mixed cropping systems for insect pest control (Altieri, 1994). Intertrophic level effects of the Bt toxin raise serious concerns about the potential of the disruption of natural pest control. Polyphagous predators that move throughout the crop season within and between mixed crops cultivars subjected to transgenic pollution will surely encounter Bt-containing nontarget prey. Disrupted biocontrol mechanisms may result in increased crop losses due to pests or to increased use of pesticide by farmers, with potential consequent health and environmental hazards (Obrycki, Losey, Taylor, & Jessie, 2001).

Still, the environmental effects are not limited to crops and insects. Bt toxins can be incorporated into the soil through leaf materials, when farmers plow under transgenic crop residues after harvest. Toxins may persist for 2 to 3 months, resisting degradation by binding to clay and humic acid soil particles while maintaining toxin activity. Such active Bt toxins that end up and accumulate in the soil and water from transgenic leaf litter may have negative impacts on soil and aquatic invertebrates and nutrient cycling processes (Donnegan et al., 1999 **1995 IN REF.**).

The fact that Bt retains its insecticidal properties and is protected against microbial degradation by being bound to soil particles, persisting in various soils for at least 234 days (Saxena, Flores, & Stotzky, 1999) is of serious concern for poor farmers who cannot purchase expensive chemical fertilizers. These farmers instead rely on local residues, organic matter, and soil microorganisms for soil fertility (key invertebrate, fungal, or bacterial species), which can be negatively affected by the soil-bound toxin (Saxena et al., 1999). By losing such ecological services, poor farmers can become dependent on fertilizers with serious economic implications.

Creating Safeguards Against Homogenization

In today's globalized world, technological modernization of small farmers, through monocultures, new varieties, and agrochemicals, is perceived as a critical prerequisite for increasing yields, labor efficiency, and farm incomes. As conversion from subsistence to cash agricultural economy occurs, the loss of biodiversity in many rural societies is progressing at an alarming rate. As peasants directly link to the market economy, economic forces increasingly influence the mode of production characterized by genetically uniform crops and mechanized and/or agrochemical packages. As adoption of modern varieties occurs, landraces and wild relatives are progressively abandoned, becoming relics or extinct. Greatest loss of traditional varieties is occurring in lowland valleys close to urban centers and markets than in more remote areas (Brush, 1986). In some areas, land scarcity (resulting mostly from uneven land distribution) has forced changes in land use and agricultural practices resulting in the disappearance of habitats that formerly maintained useful noncrop vegetation including wild progenitors and weedy forms of crops (Altieri, Anderson, & Merrick, 1987).

The above situation is expected to be aggravated by the technological evolution of agriculture based on emerging biotechnologies whose development and commercialization is increasingly concentrated and under the control of a few corporations, accompanied by the increased withdrawal of the public sector as major provider of research and extension services to rural communities (Jordan, 2001). The social impacts of local crop shortfalls, resulting from genetic uniformity or changes in the genetic integrity of local varieties due to genetic pollution, can be considerable in the margins of the developing world. In the extreme periphery, crop losses mean ongoing ecological degradation, poverty, hunger and even famine. It is under these conditions of systemic market failures and lack of public external assistance that local skills and resources associated with biological and cultural diversity should be available to rural populations to maintain or recover their production processes.

Diverse agricultural systems and genetic materials that confer high levels of tolerance to changing socioeconomic and environmental conditions are extremely valuable to poor farmers, as diverse systems buffer against natural or human-induced variations in production conditions (Altieri, 2002). Under economic uncertainty, impoverished rural populations must maintain low-risk agroecosystems that are primarily structured to ensure local food security. Farmers in the margins must continue to produce food for their local communities in the absence of modern inputs, and this can be reach by preserving in situ ecologically intact locally adapted agrobiodiversity. For this, it will be necessary to maintain pools of genetic diverse material, geographically isolated from any possibility of cross fertilization or genetic pollution from uniform transgenic crops. These islands of traditional germplasm within specific agroecological landscapes will act as extant safeguards against the ecological failure derived from the second green revolution imposed in the margins.

One way to isolate traditional varieties from exposure to transgenic crops is to declare a country-level moratorium on the field experimentation and commercial release of biotech crops or to clearly define transgenic-free areas in which traditional varieties can be grown without exposure to transgenic crops. But this may not provide sufficient safeguards, as many developing countries receive food aid that is a major entry point for transgenic seeds. It is imperative that such countries demand that shipments of soybean, corn, wheat, and rice are not transgenic or labeled as such, a difficult request when much such aid originates in the United States.

In Situ Conservation, Rural Development in GMO PLS. SPELL OUT ABBREVIATION-Free Centers of Origin

Given the above-described destructive trends, many scientists and development workers have emphasized the need for in situ conservation of local crop genetic resources and the environments in which they occur (Jarvis et al., 2000 **PLS. PROVIDE REF./DELETE**; Prescott-Allen & Prescott-Allen, 1981). However, most researchers consider that in situ preservation of landraces would require a return to or the preservation of microcosms of primitive agricultural systems, an unacceptable and impracticable proposition that condemns farmers to poverty and stagnation. It is here contended, nevertheless, that maintenance of traditional agroecosystems is the only sensible strategy to preserve in situ repositories of crop germplasm and strengthen food security. Any attempt at in situ crop genetic conservation must struggle to preserve the agroecosystem in which these resources occur. In the same vein, preservation of traditional agroecosystems cannot be achieved isolated from maintenance of the sociocultural organization of the local people (Altieri & Merrick, 1987). Ultimately, if biodiversity conservation is indeed to succeed among small farmers, the process must be linked to rural development efforts that give equal importance to local resource conservation and food self-sufficiency market participation (Thrupp, l998).

Preservation efforts should be linked to an overall rural-development agenda that focuses on conservation opportunities rather than exclusively on possibilities to enhance production. In this case, the primary aim of traditional agriculture shifts to one that focuses on productive forms of conservation targeting those populations most at risk from poverty and food insecurity and that are least able to benefit from agricultural modernization, but rather may suffer the unintentional consequences of intensification such as genetic pollution. The idea is to design sustainable farming systems and appropriate technologies aimed at upgrading peasant food production for self-sufficiency by incorporating native crops and wild/weedy relatives within and around production fields to complement the various production processes (Altieri & Merrick, 1987; Brush, 2000). Obviously, farmers can link to local or regional markets in search of income, but they will need political support to protect the price of their products and access to markets.

Since the early 1980s, hundreds of agroecologically based projects have been promoted by nongovernmental organizations (NGOs) throughout the developing world, which incorporate elements of both traditional knowledge and modern agricultural science. A variety of projects exist featuring resource-conserving yet highly productive systems, such as polycultures, agroforestry, and the integration of crops and livestock, and so forth (Altieri, 1999). Such alternative approaches can be described as low-input technologies, but this designation refers to the external inputs required. The amount of labor, skills, and management that are required as inputs to make land and other factors of production most productive is quite substantial. So rather than focus on what is not being utilized, it is better to focus on what is most important and readily available to increase food output: native seeds, labor, knowledge, and traditional management skills (Uphoff & Altieri, 1999).

The analysis of dozens of NGO-led agroecological projects show convincingly that agroecological systems are not limited to producing low outputs, as some critics have asserted (Altieri, Rosset, & Thrupp, 1998). Increases in production of 50% to 100% are fairly common with most alternative production methods. In some of these systems, yields for crops that the poor rely on most—rice, beans, maize, cassava, potatoes, and barley—have been increased by severalfold, relying on labor and know-how more than on expensive purchased inputs, and capitalizing on processes of intensification and synergy (Uphoff, 2002). In a recent study of 208 agroecologically based projects and/or initiatives throughout the developing world, Pretty and Hine (2000) documented clear increases in food production over some 29 million hectares, with nearly 9 million households benefiting from increased food diversity and security. Promoted sustainable agriculture practices led to 50% to 100% increases in per-hectare food production (about 1.71 mg per year per household) in rain-fed areas typical of small farmers living in marginal environments; that is, an area of about 3.58 million hectares, cultivated by about 4.42 million farmers. Such yield enhancements are a true breakthrough for achieving food security among farmers isolated from mainstream agricultural institutions.

More important than just yields, agroecological interventions raise total production significantly through diversification of farming systems, such as raising fish in rice paddies or growing crops with trees, or adding goats or poultry to household operations (Uphoff, 2002). Agroecological approaches increased the stability of production as seen in lower coefficients of variance in crop yield with better soil and water management.

Although in the eyes of development specialists, marginal rural communities represent failure in economic development, to agroecologists, they represent success in relation to diversity conservation. It is precisely this ability to generate and maintain diverse crop genetic resources that offers unique niche possibilities to marginal farmers that cannot be replicated with uniform and highly productive systems in the more favorable lands. As globalization leads to greater homogeneity between and within societies, the difference that remains within marginal environments (i.e., landraces free from transgenic contamination) composes one of the greatest resources of poor farmers. Such difference can be strategically utilized by exploiting unlimited opportunities that exist for linking traditional agrobiodiversity with local markets but also with tourist and international markets as long as these activities are carefully planned and remain under grassroots control.

Basing a rural development strategy on traditional farming and ethnobotanical knowledge not only ensures continual use and maintenance of valuable genetic resources but also allows for the diversification of peasant subsistence strategies including links with external markets. But for peasants to have a truly competitive edge, they will need to be able to produce unique agricultural crops (i.e., GMO-free) for niche markets. Such uniqueness is also crucial for the maintenance of the stability of their local farming systems in times of uncertainty.

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