Agroecology and In Situ Conservation of Native Crop Diversity in the Third World

Source: ncbi.nlm.nih.gov

Published: June 29, 1988

MIGUEL A. ALTIERI
Associate Professor, Division of Biological Control, University of California, Berkeley

LAURA C. MERRICK
Graduate Research Assistant, Department of Vegetable Crops, University of California, Davis, and L. H. Bailey Hortorium, Cornell University, Ithaca, N.Y.

Today, the foundation and health of agriculture in industrial countries largely depend on their access to the rich crop genetic diversity found in Third-World countries. Yet the very same germplasm resources most sought after for their potential applications in biotechnology are constantly threatened by the spread of modern agriculture. On the one hand, the adoption of high-yielding, uniform cultivars over broad areas has resulted in the abandonment of genetically variable, indigenous varieties by subsistence farmers (Frankel and Hawkes, 1975; Harlan, 1975). The new varieties are often less dependable than the varieties they have replaced when grown under traditional agricultural management (Barlett, 1980). On the other hand, the planting of vast areas with monocultures of genetically uniform cultivars makes agricultural productivity extremely vulnerable to yield-limiting factors, as illustrated by the southern corn leaf blight epidemic in the United States in 1969–1970 (Adams et al., 1971). Agroecosystems established far from centers of origin tend to have simpler genetic defenses against pathogens and insect pests, rendering crops more vulnerable to epidemic attack—a situation that rarely occurs in an unmodified traditional agroecosystem (Segal et al., 1980).

Concern for this rapid loss of genetic resources and crop vulnerability consolidated at the international level about 13 years ago with the establishment of the International Board for Plant Genetic Resources (IBPGR), which coordinates a global network of gene banks to provide plant breeders with the genetic resources necessary to develop better crops. International efforts have so far placed more emphasis on increasing yield than on maintaining stable harvests (Plucknett et al., 1983)—an emphasis that has provided the justification for technological innovation and transfer in a manner not reflecting indigenous social, ecological, and ethnobotanical considerations. Landraces[1] and wild relatives of major crops are collected from their native habitats, and the seed or vegetative material is placed in gene banks for storage or breeding collections for evaluation and potential use (Frankel and Bennett, 1970). Although ex situ conservation methods have contributed to the improvement of certain crops and the storage of the germplasm of a variety of major crops (Frankel and Bennett, 1970), they do not provide a panacea for conserving natural sources of crop genetic resources (Oldfield, 1984). A major problem is that seed storage freezes the evolutionary processes by preventing new types or levels of adaptations or resistance to evolve, because plants are not allowed to respond to the selective pressures of the environment (Simmonds, 1962). In addition, ex situ methods remove crops from their original cultural-ecological context (Nabhan, 1985)—the human-modified systems in which they evolved.

As Wilkes (1983, p. 136) stated, “The centers of genetic variability are moving from natural systems and primitive agriculture to gene banks and breeders’ working collections with the liabilities that a concentration of resource (power) implies.” Controversy has already erupted around the control of gene banks, since countries such as Colombia, Cuba, Libya, and Mexico question the free access to genetic resources by industrial countries. In the industrial countries, breeders develop new commercial varieties, often using valuable genes derived from landraces or wild species originally collected in the Third World. Then, the new commercial varieties are sold back to the Third World at considerable profit (Wolf, 1985).

A number of scientists have emphasized the need for in situ conservation of crop genetic resources and the environments in which they occur, since in situ conservation allows for continued, dynamic adaptation of plants to the environment (Nabhan, 1985; Prescott-Allen and Prescott-Allen, 1982; Wilkes, 1983). For agriculture, this phenomenon is particularly important in areas under traditional farming, where crops are often enriched by gene exchange with wild or weedy relatives (Harlan, 1965). However, most researchers consider that in situ preservation of landraces would require a return to or the preservation of microcosms of primitive agricultural systems—to many, an unacceptable and impracticable proposition (Ingram and Williams, 1984). Nevertheless, we contend that maintenance of traditional agroecosystems is the only sensible strategy to preserve in situ repositories of crop germplasm. Although most traditional agroecosystems are undergoing some process of modernization or drastic modification, conservation of crop genetic resources can still be integrated with agricultural development, especially in regions where rural development projects preserve the vegetational diversity of traditional agroecosystems and depend upon the peasants' rationale to utilize local resources and their intimate knowledge of the environment (Alcorn, 1984; Nabhan, 1985; Sarukhan, 1985).

In alternative strategies, the conservation of plant genetic resources and agricultural development by peasants can be considered simultaneously. In a recent article (Altieri and Merrick, 1987), we suggested the best ways in which traditional varieties, agroecological patterns, and management systems can be integrated into rural development programs to salvage crop genetic resources. These are reviewed below.

Peasant Agriculture and Crop Germplasm Resources

The stability and sustainability of traditional agriculture are based on crop diversity (Altieri and Merrick, 1987; Chang, 1977; Clawson, 1985; Egger, 1981; Harwood, 1979). The peasant's strategy of hedging against risk by planting several species and varieties of crops in different spatial and temporal cropping systems designs is the most effective long-lasting means of stabilizing yields. Although improved varieties are distributed throughout Third-World countries, they have made serious inroads in areas strongly linked to commercial agriculture and the national market, where they have hastened the disappearance of wild relatives and traditional varieties of crops (Brush, 1980). Thus today, the rural landscapes consist of mosaics of modern and traditional varieties and technologies (Figure 41-1). As areas become more marginal in natural resources and in infrastructural support, however, the use of improved varieties declines; farmers abandon them because of the risk and expense and rely on their century-tested, regionally adapted stocks (Figure 41-2). In Peru, for example, as altitude increases, the percentage of native potatoes in the field increases steadily (Brush, 1980). In Thailand, rice farmers plant the modern semidwarf varieties in part of their land during the dry season and sow traditional varieties during the monsoon season. They have thus established a system that allows them to take advantage of the productivity of irrigated modern varieties during dry months and the stability of the traditional varieties in the wet season when pest outbreaks are common (Grigg, 1974).

FIGURE 41-1

A traditional small farm system in Tlaxcala, Mexico, exhibiting a corn-alfalfa strip-cropping pattern, borders of Maguey and Capulin trees, and a number of wild plants both within and around the crop area. Photo by M. A. Altieri.

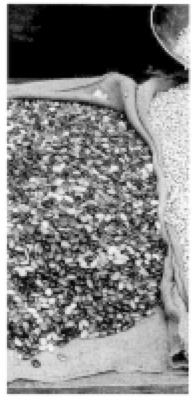

FIGURE 41-2

Bean seeds of different colors expressing high genetic diversity. Harvested from a single field in a rain-fed traditional cropping system in Tlaxcala, Mexico. Photo by M. A. Altieri.

As the economic crisis deepens in most developing countries, and rural populations become increasingly impoverished, a sizeable portion of the peasantry is renewing use of the traditional varieties and low-input management practices needed for subsistence agriculture (Altieri and Anderson, 1986). Opting for less crop uniformity may mean lower yields for farmers, but it gives them the extra margin of resistance to pests, diseases, and other environmental hazards—an important consideration when working under conditions of economic uncertainty. In many areas, unfortunately, the return of some peasant communities to native varieties has been difficult because of genetic erosion.

Several factors have contributed to this loss of crop genetic resources (Nabhan, 1986): decrease in the number of growers, decrease in crop size per field, decrease in planting frequency, loss of seed-saving and seed-collection skills, and changes in the crop's vulnerability to pests and weeds. In such regions, the implementation of in situ crop genetic conservation will be more complex, since both the folk science and the genetic heritage necessary to nurture such programs can only be retrieved very slowly (Altieri and Merrick, 1987).

Toward a Strategy for in Situ Crop Genetic Conservation

Recommendations for in situ conservation of crop germplasm have emphasized the development of a large system of village-level landrace custodians (a farmer-curator system) whose purpose would be to continue to grow a limited sample of endangered landraces native to the region (Nabhan, 1985). To preserve crop-plant diversity, Wilkes (1983) has suggested that the governments set aside carefully chosen 5-by-20-kilometer strips at as few as 100 sites around the world where native agriculture is still practiced, areas where both indigenous crops and their close wild relatives may interbreed periodically. The idea of setting aside parks for crop relatives and landraces is obviously a luxury in countries where farmland is already at a premium, but to some this may be less costly than allowing native crop varieties to disappear (Brush, 1980; Wolf, 1985). In many areas, the urgent short-term issue is survival, and it would therefore be totally inappropriate to divert the limited land available to peasants for conservation purposes per se so that the germplasm could be used by industrialized nations. Such a position could be viewed as an undesirable form of neocolonialism.

Supporters of in situ strategies argue that farmers should be incorporated into conservation programs by creating biosphere reserves where peasants can continue their traditional agriculture under subsidy (Wilkes, 1983). Once identified, these areas would be designated as germplasm centers and would qualify for special agricultural assistance aimed at promoting the cultivation of native varieties. Industrialized countries using this germplasm would subsidize farmers cultivating native varieties and would help them in marketing the produce. Brush (1980) believes that these support programs could also include the machinery and financial aid needed to compensate for monetary losses incurred by farmers who maintain germplasm and do not reap the rewards of growing improved varieties. Some means of computing the opportunity cost of maintaining these cultivars must be established.

Although Nabhan (1985) agrees with the creation of centers of traditional agriculture, he believes that conservation measures will be most effective when native farmers are cognizant of, and involved in, their planning and implementation. Such efforts are likely to succeed, he argues, as long as members of a culture identify their own reasons for maintaining their crop heritage and persevere in conducting the practices for nurturing these plants. An obvious incentive for resource-poor peasants is to enhance harvest security and to make them independent of the market for seeds and inputs. It is for this type of farmer that preservation efforts should be linked to the overall rural development agenda. Design of sustainable farming systems and appropriate technologies aimed at upgrading peasant food production for self-sufficiency should incorporate locally adapted, native crops, and wild and weedy relatives, to complement the various production processes (Altieri and Merrick, 1987).

At present, there are a number of assistance programs temporarily directed at meeting the subsistence needs of peasants (Altieri and Anderson, 1986; Altieri and Merrick, 1987). These efforts are intended to minimize dependency on purchased inputs and industrialized technology; improve the efficiency with which local resources, including local vegetation, is used; achieve the production goals needed to satisfy home consumption; and favor peasant organization to enhance their capacity for economic reproduction (de Janvry, 1981). The approaches consist generally of taking existing peasant production systems and technologies as starting points and then using modern agricultural science to improve, progressively and carefully, on the productivity of these systems (Altieri, 1983).

Thus, proposed agricultural models are based on the peasants' skills in utilizing the environment and their ability to cope with change, as well as their knowledge of the plant resources and the general biology of the area. The programs have a definite ecological bent and rely on resource-conserving and yield-sustaining production technologies. Through the design of crop associations and regionally adapted patterns, functions of nutrient recycling, natural pest control, and soil conservation can be optimized (Altieri, 1983; Gliessman et al., 1981). As subsistence needs are met, most programs emphasize channeling of excess production to local markets. Income generation is also achieved by promoting nonagricultural activities (e.g., basketry) within the villages.

When valuable crop genetic resources are incorporated into farming systems designed to encourage self-sufficiency of the rural poor, important conservation gains can be achieved. This is illustrated by the efforts by Nabhan (1984) and associates to improve arid land agriculture for native Americans in the U.S.-Mexico borderlands and by a number of groups in Latin America (Altieri and Anderson, 1986; Altieri and Merrick, 1987).

In Mexico, for example, researchers designed for peasants production modules based on the pre-Hispanic traditional *chinampas* (a meadow or garden developed from a reclaimed lake or pond) and multilayered, species-rich kitchen gardens that once characterized the original agroecosystems of Tabasco, Mexico. Diverse arrays of crop and noncrop species were utilized in the various modular systems. In a parallel project, integrated farms were established in Veracruz to help farmers make better use of their local resources (Morales, 1984). In unique designs based on the *chinampas* and on Asiatic systems, vegetable production and animal husbandry, including aquaculture, were integrated through the management and recycling of organic matter. The intensive cultivation of corn, beans, and squash for local consumption and of vegetables with high commercial value, e.g., Swiss chard (*Beta vulgaris cicla*), cilantro (*Cordiandrum sativum*), chilies (*Capsicum* spp.), and cabbage (*Brassica oleracea capitata*), provided abundant plant wastes and cuttings used as cattle and horse feed; all animal wastes were reintegrated as fertilizer for the fields (Altieri and Merrick, 1987).

In the highlands of Bolivia, the project AGRUCO is attempting to maintain the ecological diversity of the Andean agropastoral economy by helping peasants recover their production autonomy. To replace the use of fertilizers and meet the nitrogen requirements of potatoes and cereals, intercropping and rotational systems utilizing a native species, wild lupin (*Lupinus mutabilis*), have been designed. Wild lupin has been cultivated in the high Andes for several thousand years (Smith, 1976). It can fix 200 kilograms of nitrogen per hectare, part of which becomes available to the associated or subsequent potato crop, thus significantly minimizing the need for fertilizers (Augstburger, 1983).

In Chile, where lately the peasantry has been subjected to a process of systematic impoverishment, the Centro de Educacion y Tecnologa (CET) is helping peasants become self-sufficient, thus reducing their dependence on credit demands and fluctuating market prices. CET's approach has been to establish several 0.5-hectare model farms where most of the food requirements for a family with scarce capital and land can be met (Altieri, 1983). Peasant community leaders live in CET farms for variable periods, thus learning through direct participation farm design, management technologies, and resource allocation recommendations. CET farms are composed of a diversified combination of crops, trees, and animals. The main components are vegetables, staple crops (corn, beans, potatoes, fava beans), cereals, forage crops, fruit trees, forest trees (e.g., *Robinia*, *Gleditsia*, *Salix*), and domestic animals all assembled in a 7-year rotational system designed to produce the maximum variety of basic crops in six plots, taking advantage of the soil-restoring properties of the legumes included in the rotation (Altieri, 1983). Most species are locally adapted varieties traditionally grown and consumed by rural populations (Altieri and Merrick, 1987).

The Future

A number of people have stressed the importance of in situ preservation of crop genetic resources but have failed to suggest practical avenues to achieve this goal in Third-World countries (Prescott-Allen and Prescott-Allen, 1982). If the conservation of crop genetic resources 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 to food self-sufficiency and market participation. Any attempt at in situ crop genetic conservation must struggle to preserve the agroecosystem in which these resources occur (Nabhan, 1985, 1986). In the same vein, preservation of traditional agroecosystems cannot succeed if not tied to the maintenance of the sociocultural organization of the local people (Altieri, 1983). The few examples of grassroots rural development programs currently functioning in the Third World suggest that the process of agricultural betterment must utilize and promote autochthonous knowledge and resource-efficient technologies; emphasize the use of local and indigenous resources, including valuable crop germplasm and essentials such as firewood resources and medicinal plants; and be based on self-contained villages and the active participation of the peasants (Altieri and Anderson, 1986; Altieri and Merrick, 1987). The subsidizing of a peasant agricultural system with external resources (e.g., pesticides, fertilizers, improved seeds, irrigation water) can bring high levels of productivity through dominance of the production system, but these systems are sustainable only at high external cost and depend on the uninterrupted availability of commercial inputs. An agricultural strategy based on native crop diversity can bring moderate to high levels of productivity through manipulation and exploitation of the resources internal to the farm and can be sustainable at a much lower cost and for a longer period.

Ecologists, agronomists, anthropologists, and ethnobotanists have an important, as yet unrealized role in agricultural development and genetic resource conservation (Alcorn, 1984). Through interdisciplinary efforts they can assess traditional know-how to guide the use of modern agricultural science in the improvement of small farm productivity. Ethnobotanists and ecologists can provide critical information for policy makers about resources needing protection and about the ecological and management factors that determine the persistence of natural vegetation in the traditional agroecosystems (Alcorn, 1984).

It is time to recognize the active role of peasants in genetic resource conservation (Alcorn, 1984), and it behooves the industrial nations interested in the germplasm to provide fair subsidies to the peasants for their ecological service of maintaining native cultivars. Farmers should be made aware that reciprocal exchanges of seeds with gene banks are possible and that they have unconditional access to seed held in gene banks, which they can tap if they lose their remaining seeds. Farmers must also know the reasons why others are interested in their seeds. Agricultural education programs including information from elders on traditional planting techniques, seed saving, and seed selection should also be established (Nabhan, 1985).

Incorporation of indigenous crops and other native plant germplasm in the design of self-sustained agroecosystems should ensure the maintenance of local genetic diversity available to farmers. This approach sharply contrasts with current efforts by international centers that tend to concentrate on fewer varieties, potentially eroding genetic diversity and making farmers increasingly dependent on seed companies for their seasonal seed supply. A major concern is that when impoverished peasants become dependent on distant institution for inputs, rural communities tend to lose control over their production systems (Altieri and Merrick, 1987).

References

- Adams, M. W., A. H. Ellingbae, and E. C. Rossineau. 1971. Biological uniformity and disease epidemics. BioScience 21:1067–1070.
- Alcorn, J. B. 1984. Development policy, forests and peasant farms: Reflections on Haustec-managed forests' contributions to commercial production and resource conservation. Econ. Bot. 38:389–406.
- Altieri, M. A. 1983. Agroecology: The Scientific Basis of Alternative Agriculture. Division of Biological Control, University of California, Berkeley. 162 pp.
- Altieri, M. A., and M. K. Anderson. 1986. An ecological basis for the development of alternative agricultural systems for small farmers in the Third World. Am. J. Alt. Agric. 1:30–38.
- Altieri, M. A., and L. C. Merrick. 1987. In situ conservation of crop genetic resources through maintenance of traditional farming systems. Econ. Bot. 41(1):86–96.
- Augstburger, F. 1983. Agronomic and economic potential of manure in Bolivian valleys and highlands. Agric. Ecosys. Environ. 10:335–346.
- Barlett, P. F. 1980. Adaptation strategies in peasant agricultural production. Annu. Rev. Anthropol. 9:545–573.
- Brush, S. B. 1980. The environment and native Andean agriculture. Am. Indigena 40:161–172.
- Chang, J. H. 1977. Tropical agriculture: Crop diversity and crop yields. Econ. Geogr. 53:241–254.
- Clawson, D. L. 1985. Harvest security and intraspecific diversity in traditional tropical agriculture. Econ. Bot. 39:56–67.
- de Janvry, A. 1981. The Agrarian Question and Reformism in Latin America. Johns Hopkins University Press, Baltimore. 311 pp.
- Egger, K. 1981. Ecofarming in the tropics—characteristics and potentialities. Plant Res. Devel. 13:96–106.
- Frankel, O. H., editor; , and E. Bennett, editor. , eds. 1970. Genetic Resources in Plants—Their Exploration and Conservation. International Biological Programme Handbook #11. Blackwell, Oxford, United Kingdom. 554 pp.
- Frankel, O. H., editor; , and J. G. Hawkes, editor. , eds. 1975. Crop Genetic Resources for Today and Tomorrow. Cambridge University Press, Cambridge, United Kingdom. 422 pp.
- Gliessman, S. R., R. E. Garcia, and M. A. Amador. 1981. The ecological basis for the application of traditional agricultural technology in the management of tropical agroecosystems. Agro-Ecosystems 7:173–185.
- Grigg, D. B. 1974. The agricultural systems of the world: An evolutionary approach. Cambridge University Press, Cambridge. 358 pp.
- Harlan, J. R. 1965. The possible role of weed races in the evolution of cultivated plants. Euphytica 14:173–176.
- Harlan, J. R. 1975. Our vanishing genetic resources. Science 188:618–622. [PubMed]

- Harwood, R. R. 1979. Small Farm Development—Understanding and Improving Farming Systems in the Humid Tropics. Westview Press, Boulder, Colo. 160 pp.
- Ingram, F. B., and J. T. Williams. 1984. In situ conservation of wild relatives of crops. Pp. 163–178 in J. H. W. Holden, editor; and S. T. Williams, editor. , eds. Crop Genetic Resources. Conservation & Evaluation. G. Allen and Unwin, London.
- King, F. H. 1927. Farmers of Forty Centuries; or, Permanent Agriculture in China, Korea and Japan. Cape, London. 379 pp.
- Morales, H. L. 1984. Chinampas and integrated farms: Learning from the rural traditional experience. Pp. 188–195 in F. De Castri, editor; , F. W. G. Baker, editor; , and M. Hadley, editor. , eds. Ecology in Practice. Vol. 1. Ecosystem Management. Tycooly, Dublin.
- Nabhan, G. P. 1984. Replenishing desert agriculture with native plants and their symbionts. Pp. 172–182 in W. Jackson, editor; , W. Berry, editor; , and B. Colman, editor. , eds. Meeting the Expectations of the Land. North Point Press, San Francisco.
- Nabhan, G. P. 1985. Native crop diversity in Aridoamerica: Conservation of regional gene pools. Econ. Bot. 39:387–399.
- Nabhan, G. P. 1986. Native American crop diversity, genetic resource conservation and the policy of neglect. Agric. Human Val. 2:14–17.
- Oldfield, M. L. 1984. The Value of Conserving Genetic Resources. U.S. Department of the Interior, National Park Service, Washington, D.C. 360 pp.
- Plucknett, D. L., N. J. H. Smith, J. T. Williams, and N. M. Anishetty. 1983. Crop germplasm conservation and developing countries. Science 220:163–169. [PubMed]
- Prescott-Allen, R., and C. Prescott-Allen. 1982. The case for in situ conservation of crop genetic resources. Nat. Resour. 23:15–20.
- Sarukhan, J. 1985. Ecological and social overviews of ethnobotanical research. Econ. Bot. 39:431–435.
- Segal, A., J. Manisterski, G. Fischbeck, and I. Wahl. 1980. How plant populations defend themselves in natural ecosystems. Pp. 75–102 in J. G. Horsfall, editor; and E. B. Cowling, editor. , eds. Plant Disease: An Advanced Treatise. Academic Press, New York.
- Simmonds, N. W. 1962. Variability in crop plants, its use and conservation. Biol. Rev. 37:422–465.
- Smith, P. M. 1976. Minor crops. Pp. 312–313 in N. W. Simmonds, editor. , ed. Evolution of Crop Plants. Longman, London.
- Wilkes, H. G. 1983. Current status of crop plant germplasm. CRC Crit. Rev. Plant Sci. 1:133–181.
- Wolf, E. C. 1985. Conserving biological diversity. Pp. 124–126 in The State of the World. A Worldwatch Institute Report on Progress Toward a Sustainable Society. W. W. Norton, New York.

Footnotes

1 - Landrace populations consist of mixtures of genetic lines, all of which are reasonably adapted to the region in which they evolved but which differ in reaction to diseases and insect pests.