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In Situ Conservation of Crop Genetic Resources through Maintenance of Traditional Farming Systems[1]

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A strategy is suggested for in situ conservation of crop genetic resources whereby conservation efforts are linked to rural development projects in Third World countries. We describe development projects that emphasize preservation of traditional farming systems and succeed in sustaining production by relying on the maintenance of biological and genetic diversity in these systems. Basing agricultural development efforts on indigenous knowledge, technology, and social organization can provide important guidelines for the design of cropping systems that allow low-income farmers to produce subsistence and cash crops without dependence on external inputs and seed supplies. By incorporating landraces and wild relatives of crops into these cropping systems, major achievements in the conservation of crop genetic resources can be obtained.

The loss of crop genetic resources in the Third World can be linked to the spread of modern agriculture in two major ways. First, the adoption of high-yielding, uniform cultivars over broad areas has resulted in abandonment of genetically variable, indigenous varieties by subsistence farmers (Frankel and Bennett 1970; Frankel and Hawkes 1975; Harlan 1975a). The new varieties are often less dependable than the varieties they replaced when grown under traditional agricultural management (Barlett 1980). Second, the planting of vast areas with genetically uniform cultivars, a characteristic of modern agricultural systems, 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; National Academy of Sciences 1972). 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 (Browning 1974), a situation that rarely occurs in an unmodified traditional agro-ecosystem (Rick 1973; Segal et al. 1980).

Concern for this rapid loss of genetic resources and crop vulnerability consolidated at the international level about 13 yr 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 for developing crops more resistant to diseases, insect pests, poor soils, and harsh weather, thus enabling farmers to maintain high yields (Plucknett et al. 1983). Landraces 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

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Economic Botany, 41(1), 1987, pp. 86–96

Bennett 1970). Although ex situ conservation methods have contributed to the improvement of certain crops and the storage of germplasm of important major crops (Frankel and Bennett 1970; Frankel and Hawkes 1975; Wilkes 1983), they do not provide a panacea for conserving natural sources of crop genetic resources (Oldfield 1984). A variety of problems with reliance on ex situ conservation strategies has been acknowledged, such as inadequate sampling procedures during field collection, and lack of representation in gene banks of the whole range of diversity of a given crop and its close genetic relatives. Difficulties also arise from genetic changes due to storage conditions and grow-out procedures, and with programs that give minimal emphasis to conservation of minor crops and wild species with known or potential future value for sources of nutrition, for germplasm enhancement (disease resistance, wider adaptation, increased yield, among others), or for nonfood purposes such as fuel, medicine, or industrial use (Frankel and Bennett 1970; Frankel and Hawkes 1975; Frankel and Soulé 1981; Prescott-Allen and Prescott-Allen 1981, 1983; Wilkes 1983). Storage of seeds involves the freezing of evolutionary processes, thus preventing new types or levels of resistance to evolve, because plants are not allowed to repond to the selective pressures of the environment (Simmonds 1962). In contrast, in situ conservation allows for continued, dynamic adaptation of plants to the environment (Prescott-Allen and Prescott-Allen 1982). For crop plants, this phenomenon is particularly important in areas under traditional agriculture, where crops are often enriched by gene exchange with wild or weedy relatives (de Wet and Harlan 1975; Harlan 1965). In addition, ex situ methods remove crops from their original cultural-ecological context (Nabhan 1979), the human-modified systems in which they have evolved.

Many scientists have emphasized the need for in situ conservation of crop genetic resources and the environments in which they occur (Iltis 1974; Nabhan 1979, 1985b; Prescott-Allen and Prescott-Allen 1982; Wilkes and Wilkes 1972). 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 (Frankel and Soulé 1981; Ingram and Williams 1984). We contend, nevertheless, that maintenance of traditional agroecosystems is the only sensible strategy to preserve in situ repositories of crop germplasm. Although most traditional agroecosystems are under 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 are anchored in the peasants' rationale to utilize local resources and their intimate knowledge of the environment (Alcorn 1984; Nabhan 1985b; Sarukhán 1985).

In this paper we attempt to integrate the various genetic, ecological, and socio-economic issues that interplay when, simultaneously, one considers plant genetic resource conservation and peasant agriculture development. By assembling relevant literature we address the following questions: to what extent does traditional agriculture constitute a repository of crop germplasm and wild/weedy relatives? What ecological, socio-economic, and management factors determine the persistence of these genetic resources in traditional agroecosystems? What plant resources and vegetation manipulation techniques should be retained in the course of agricultural modernization? How can traditional vegetation patterns and management systems be best integrated into a rural development program to salvage genetic resources?

TRADITIONAL AGROECOSYSTEMS AS CROP GERMPLASM REPOSITORIES

Traditional agroecosystems represent centuries of accumulated experience of interaction with the environment by farmers without access to scientific information, external inputs, capital, credit, and developed markets. Such skills, using locally available resources, have often translated into farming systems with sustained yields (Egger 1981; Wilken 1977). A salient feature of traditional farming systems is their degree of plant diversity in time and space in the form of polycultures and/or agroforestry patterns (Chang 1977; Clawson 1985). These systems represent a strategy to promote diversity of diet and income source, stability of production, minimization of risk, reduced insect and disease incidence, efficient use of labor, intensification of production with limited resources, and maximization of returns under low levels of technology (Harwood 1979). Traditional, multiple cropping systems are estimated still to provide as much as 15–20% of the world's food supply (Francis 1985). Traditional agroforestry systems throughout the tropics commonly contain well over 100 plant species per field, species used for construction materials, firewood, tools, medicine, livestock feed, and human food (Wiersum 1981). In Mexico, for example, Huastec Indians manage a number of agricultural and fallow fields, complex home gardens, and forest plots totalling about 300 species (Alcorn 1984). Small areas around the houses commonly average 80–125 useful plant species, mostly native medicinal plants. Manipulation of the noncrop vegetation by the Huastecs in these complex farm systems has influenced the evolution of individual plants and the distribution and composition of the total crop and noncrop communities (Alcorn 1981). Similarly, the traditional *pekarangan* in West Java commonly contains about 100 or more plant species. Of these plants, about 42% provide for building materials and fuelwood, 18% are fruit trees, 14% are vegetables, and the remainder constitute ornamentals, medicinal plants, spices, and cash crops (Christanty et al. 1986). High diversity of crop and associated plant genetic resources are not restricted to tropical agroecosystems. Existing desert Papago fields in the Sonoran desert have been found to include 132 wild and weedy species and 14 domesticated species (Nabhan 1983).

Many traditional agroecosystems are located in centers of diversity, thus containing populations of variable and adapted landraces as well as wild and weedy relatives of crops (Frankel 1973; Harlan 1975b; Vavilov 1951). 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, some lines being resistant or tolerant to certain races of pathogens and some to other races (Harlan 1975b). This is a fairly effective defense against serious epiphytotics (Browning and Frey 1969). For example, wild-oat populations in Israel are protected by a complex interplay of resistance mechanisms, and although only one-third of the population may be resistant to the most virulent race of rust, the entire population is protected (Segal et al. 1980). In the Andes, farmers cultivate as many as 50 potato varieties in their fields (Brush 1982).

Similarly, in Thailand and Indonesia farmers maintain in their paddies a diversity of rice varieties adapted to a wide range of environmental conditions, and they regularly exchange seeds with neighbors (King 1927). The resulting genetic diversity confers at least partial resistance to diseases specific to particular strains of the crop and allows farmers to exploit different microclimates and derive multiple nutritional and other uses from within-species genetic variation (Clawson 1985; Harlan 1975b). Clawson (1985) described a number of systems in which traditional tropical farmers plant multiple varieties of each crop, providing both intraspecific and interspecific diversity and thus enhancing harvest security.

A number of plants within or around traditional cropping systems are wild or weedy relatives of crop plants. The ecological amplitudes of wild relatives may exceed those of the crops derived from or otherwise related to them, a feature exploited by plant breeders to enhance the resistance or adaptive range of crops (Frankel and Bennett 1970; Harlan 1976; Prescott-Allen and Prescott-Allen 1983). In these settings, landraces and wild and weedy relatives have co-existed and co-evolved over a long period of time with each other and with human cultures. Cycles of natural hybridization and introgression have often occurred between crops and wild relatives, increasing the variability and the genetic diversity available to farmers (Harlan 1975b). Through the practice of non-clean cultivation, farmers have inadvertently increased the gene flow between crops and their relatives (e.g., sorghum: Doggett and Majisu 1968; rice: Oka and Chang 1961; tomato: Rick 1958; *Chenopodium*: Wilson and Heiser 1979; wheat: Zohary and Feldman 1962). For example, farmers in Mexico allow teosinte to remain within or near maize fields so that when the wind pollinates the maize some natural crosses occur (Wilkes 1977). Although crosses such as these are not immediately evident, the following year when the new maize crop is planted from last year's seeds, the maize-teosinte seeds produce hybrid plants. Such hybrids and their descendants are phenotypically distinct and fertile and thus capable of passing on their genetic traits. The teosinte is said to increase corn yields (Wilkes 1977). In northwestern Mexico, farmers recognize that exchange of traits occurs between sympatric cultivated and wild/weedy squashes (Merrick and Nabhan 1984; Nabhan 1984b) and suggest that a similar pattern occurs for other local crops as well (Merrick and Nabhan, unpubl.). The process of natural hybridization may be perceived as enhancement (for example, increased pungency in cultivated chilies due to hybridization with wild chiltepines) or contamination (bitter, unpalatable flesh in domesticated squashes due to hybridization with wild gourds) (Merrick and Nabhan, unpubl.). The encouragement of specific weeds by peasant farmers in their agroecosystems may represent progressive domestication, a process described by Davis and Bye (1982) for *Jaltomata,* a herbaceous perennial used by the Tarahumara in Mexico. Farmers derive other benefits from the presence of tolerable levels of weeds in their fields. Certain weeds are directly used for medicinal and culinary purposes (Datta and Banerjee 1978), and in many cases weed communities are managed within crop fields, resulting in increased biological insect-pest control (Altieri et al. 1977) and enhanced organic matter accumulation and soil conservation (Chacon and Gliessman 1982).

Through this continual association, relatively stable equilibria among crops, weeds, diseases, cultural practices, and human habits have developed (Barlett 1980). In fact, the great variety of primitive crop cultivars corresponds well with the heterogeneity of the social and ecological environment (Brush 1982). The majority of close wild/weedy relatives of crops are recognized to be adapted to survival in habitats disturbed by humans (de Wet and Harlan 1975). Some species or races of weeds are entirely restricted in distribution to agricultural environments, called *agrestals,* after Baker (1965), *agroecotypes,* after Barrett (1983), or *arvenses* (in Spanish), after Hernández (1985). These plants are highly specialized in terms of adaptations to agricultural fields as a result of evolution in conjunction with particular crops grown under specific cultural conditions (Barrett 1983). Agricultural weeds may or may not be closely related genetically to crops growing in the same location; however, the management of conservation strategies of genetic resources of weeds differs from that of truly wild species due to the adaptation of weeds to survival under conditions of human disturbance. The stabilized equilibria in traditional agroecosystems are complex and very difficult to modify without upsetting the balance and risking loss of genetic resources, not to mention negative effects on the social organization (Grossman 1984). In fact, it is here argued that many landraces and wild/weedy relatives can be preserved only in agroecosystems under traditional management and, furthermore, only if this management is guided by the local intimate knowledge of the plants and their requirements (Alcorn 1984). On this basis we resist the implementation of top-down rural development approaches (i.e., those derived exclusively from decisions of policymakers and researchers external to the community of local farmers) (Brown 1983) that do not reflect indigenous social, ecological, and ethnobotanical considerations.

GENETIC CONSERVATION AND RURAL DEVELOPMENT

Previous recommendations for in situ conservation of crop germplasm have emphasized the development of a wide 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 (Iltis 1974; Kuckuck, quoted in Bennett 1968; Mooney 1983). Carefully chosen strips of 5 × 20 km at as few as 100 sites around the world where native agriculture is still practiced have been suggested to be set aside by governments to preserve crop-plant diversity (Wilkes and Wilkes 1972). Given the increasing impoverishment and lack of income generating alternatives for rural populations in the Third World, a proposition of this kind is clearly naive because the rural poor first need satisfaction of their subsistence needs. In many areas the urgent short-term issue is survival; diverting the limited land available to peasants to conservation purposes per se might prove totally inappropriate. 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 native crops and wild/weedy relatives to complement the various production processes.

There exist at present a number of programs of assistance to peasants temporarily directed at meeting their subsistence needs (Hirschman 1984). These efforts aim (a) to minimize dependency on purchased inputs and industrialized technology, (b) to improve the use efficiency of local resources, including local vegetation, (c) to achieve production to satisfy home consumption, and (d) to favor peasant organization to enhance the capacity of peasants 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 1985). Thus, proposed agricultural models are anchored in the peasants' rationale to utilize the environment and on their ability to cope with change, as well as on their knowledge of plant resources and general biology of the area. The programs have a definite ecological bent and rely on resource-conserving and yield-sustaining production technologies. Through design of crop associations and regionally adapted patterns, the 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 within the villages (e.g., basketry).

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. For example, current efforts by Nabhan (1984a) and associates to improve native Americans' arid land agriculture in the United States–Mexico borderlands are based on cropping systems composed of genera of plants that are adapted to desert conditions and that have with them a diversity of coevolved symbionts. The design of these systems has necessarily drawn from plants domesticated by the Papago and other Indians over millenia—such as tepary beans (*Phaseolus acutifolius*), striped cushaw squash (*Cucurbita mixta*), and devil's-claw (*Proboscidea parviflora* var. *hohokamiana*)—and from plants brought more recently into cultivation that were traditionally harvested locally from the wild—such as agave (*Agave augustifolia*), mesquite (*Prosopis* spp.), jojoba (*Simmondsia chinensis*), Mexican oregano (*Lippia* spp.), and chiltepine (*Capsicum annuum* var. *aviculare*). All require less than half the water needed by introduced crops (Nabhan 1984a, 1985a). Similarly, Gliessman et al. (1981) designed, for peasants, production modules based on the pre-Hispanic traditional *chinampas* and multilayered, species-rich, kitchen gardens (*huertas familiares*) 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 to 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 high commercial value vegetables (e.g., Swiss chard, cilantro [*Coriandrum sativum*], chilies [*Capsicum* spp.], cabbage, etc.) provided abundant plant wastes and cuttings used as cattle and horse feed; all animal wastes were re-integrated as fertilizer for the fields.

In the highlands of Bolivia, the agro-pastoral economy has been radically modified and peasants are becoming more dependent on commercial inputs. The Projecto de Agrobiología de Cochabamba (PAC) is attempting to reverse this trend by helping peasants to 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, *Lupinus mutabilis*

Sweet, have been designed. *Lupinus mutabilis* has been cultivated in the high Andes for several thousand years (Smith 1976). Experiments revealed that *L. mutabilis* can fix 200 kg/ha of nitrogen, which partly 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 Educación y Tecnología (CET) is helping peasants become self-sufficient, thus reducing their dependence on credit demands, fluctuating market prices, etc. The CET's approach has been to establish several 0.5 ha model farms where most of the food requirements for a family of scarce capital and land can be met (Altieri 1983). Peasant community leaders live in CET farms for variable periods of time, 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 yr 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. The various products are used for human consumption, animal feed, green manure, composting, and fuel, among other uses.

The Rural Advancement Fund International has designed a resource kit for non-government organizations and others who wish to work with farmers in the establishment of community-based systems of traditional crop variety preservation. The guide, The Community Seed Bank Kit (Rural Advancement Fund International 1986) is now available in English, Spanish, and French versions. The kit explains how to collect and conserve crop varieties, emphasizing public participation (Rural Advancement Fund International 1985). Nabhan (1985b) described ways in which conservation measures can be more effective when native farmers are aware of, and involved in, their planning and implementation.

DISCUSSION AND CONCLUSIONS

A number of people, though stressing the importance of in situ preservation of crop genetic resources, have failed to suggest practical avenues to achieve this goal in Third World countries (see Ingram and Williams 1984 and Prescott-Allen and Prescott-Allen 1981 for discussion and proposals focussing on wild relatives of crops). This failure is understandable because preserving crop genetic resources in the midst of agricultural modernization efforts is not only technically complicated, but a politically sensitive issue. There are many economic forces that push farmers to accept newly introduced varieties. This trend not only has resulted in disappearance of indigenous varieties, potentially useful germplasm, but has affected the social organization of peasant groups because the new varieties and their associated technologies have inevitably been accessible only to peasants most favored in terms of access to credit, technical assistance, and markets (de Janvry 1981; Ewell and Poleman 1982; Grossman 1984).

If crop genetic resource 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 and/or market participation. Any attempt at in situ crop genetic conservation must struggle to preserve the agroecosystem in which these resources occur (Nabhan 1979, 1985b). In the same vein, preservation of traditional agroecosystems cannot be achieved isolated from maintenance of the socio-cultural 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 (a) utilize and promote autochthonous knowledge and resource-efficient technologies, (b) emphasize use of local and indigenous resources, including valuable crop germplasm as well as essentials like firewood resources and medicinal plants, and (c) be a self-contained, village-based effort with the active participation of peasants (Altieri 1985). The subsidizing of a peasant agricultural system with external resources (pesticides, fertilizers, 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 a diversity of plants and cropping systems 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 of time.

Ecologists, agronomists, anthropologists, and ethnobotanists have an important yet unrealized role in agricultural development and genetic resource conservation (Alcorn 1981). 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 elements of natural vegetation in the traditional agroecosystems (Alcorn 1984).

Although in recent history it has been the responsibility of governments, genetic resource organizations, and plant breeders, both public and private, to salvage germplasm before it is lost and to assure its introduction into germplasm banks (Brown 1983), it is time to recognize the active role of peasants in genetic resource conservation (Alcorn 1984). Socio-cultural issues make it impossible to view the resources merely as a set of genes that can simply be conserved by sticking them into a gene bank. If isolated from the folk science and traditional uses of the cultures that have nurtured them, they lose part of their value or cultural-historical meaning (Nabhan 1979, 1985b; Sarukhán 1985).

Incorporation of indigenous crops and other native plant germplasm in the design of self-sustained agroecosystems should assure 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 institutions for inputs, rural communities tend to lose control over their production systems.

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Book Review

Underdeveloping the Amazon: Extraction, Unequal Exchange and the Failure of the Modern State. S. G. Bunker. University of Illinois Press, 54 E. Gregory Dr., Champaign, IL 61820. 1985. 280 pp. $24.50.

Numerous books are now appearing on the Amazon, but it is seldom that the problems of this vast tropical region are met and discussed so straightforwardly as in Bunker's treatise. Although he is a sociologist, his outlook and coverage are interdisciplinary and are indicative of extensive experience in the tropics and a mastery of the literature.

The primary thrust of the book concerns the social and ecological disruption of the region by extractive economies that have characterized the manipulation of the Amazon for 350 years and which are still in progress on an even greater scale due to a variety of ill-conceived, often mismanaged and frequently corrupt governmental programmes. He proposed a novel model based on "the use and depletion of energy values in natural resources as the key to understanding the disruptive forces at work in the Amazon basin."

Inasmuch as great emphasis is placed throughout the book on useful plants, Bunker's arguments that extractive economies have degraded both the natural and human environments constantly touch upon economic botany. Specialists in this field will find in his treatment much of a thought-prevoking and practical nature.

The book can be recommended without reservation to economic botanists interested in the development not only of the Amazon but of most humid tropical regions in ways that will conserve the environment and the human element living and exploiting the area.

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