Do Folk Crop Varieties Have a Role in Sustainable Agriculture?

Incorporating folk varieties into the development of locally based agriculture may be the best approach

David A. Cleveland, Daniela Soleri, and Steven E. Smith

Recently there has been increasing attention to the importance of biodiversity in agriculture (NRC 1993), especially for ecological sustainability (NRC 1992, Pimentel et al. 1992). The role of folk crop varieties, and their wild and weedy relatives, has been especially well publicized (Keystone Center 1991, Plucknett et al. 1987). Folk varieties, also known as landraces, traditional varieties, or primitive varieties, have been defined as "geographically or ecologically distinctive populations which are conspicuously diverse in their genetic composition both between populations and within them" (Brown 1978, p. 145) and as the product of local selection by farmer-breeders (Harlan 1992, NRC 1993).

The level of international attention achieved by crop genetic resources, folk varieties, and farmer-breeders was reflected at the 1992 Earth Summit in Brazil. Agenda 21 of the Earth Summit calls for programs and policies for establishing or strengthening in situ conservation of crop genetic resources in farmers' fields and local ex situ conservation in farm communities (e.g., community seedbanks) for the development of sustainable agriculture (UNCED 1993). However, as a basis for program policy and development, there is little scientific data on selection and maintenance of folk varieties by farmer-breeders or on the basic biology and genetics of folk varieties in comparison with other crop varieties. Therefore, the danger exists that, as in the past, much of the debate on the value and use of folk varieties for the future of agriculture may get bogged down in a confusion between statements of value and statements based on empirical evidence. Our purpose in this article is to examine the available data on the current and potential role of folk varieties in the development of sustainable food production, especially for small-scale, indigenously based agriculture.

Farmer management of selection supports long-term yield stability adapted to local conditions and cultural values

David A. Cleveland and Daniela Soleri are co-directors of the Center for People, Food and Environment, 344 South Third Avenue, Tucson, AZ 85701. Cleveland is also an assistant professor in the Department of Anthropology and in the Environmental Studies Program, University of California, Santa Barbara, CA 93106-3210. Soleri is also a graduate student in the Arid Lands Resource Sciences Program, College of Agriculture, University of Arizona, Tucson, AZ 85721. Steven E. Smith is an associate professor in the Department of Plant Sciences, College of Agriculture, University of Arizona, Tucson, AZ 85721.

The loss and conservation of folk varieties

The loss of folk varieties, their evolution through selection, and the adoption of new folk varieties from the outside are part of the ongoing change of dynamic, small-scale, indigenous farming systems. The rate of loss of folk varieties has increased with the modernization and internationalization of agriculture, especially the introduction of modern crop varieties after 1920. However, the details of folk variety loss are difficult to discern, in part because there often is not adequate quantitative documentation of past folk variety diversity to serve as a baseline (see Brush et al. 1992, Vaughan and Chang 1992). To date there has been no comprehensive documentation of the reduction in numbers of folk varieties within a region in relationship to loss of farms, farmers, and farm communities. Likewise, there has been little description of loss of genetic diversity within folk varieties. Such loss may result from a reduction in size of plantings or limited farmer opportunities for selection, management, and exchange of folk varieties.

Researchers have been forced to rely on measures of diversity, such as names or numbers of folk varieties or areas planted, that are likely to be inadequate (Brush et al. 1992, Soleri and Cleveland 1993). Most studies use the number of named varieties to represent genetic diversity. However, although it is not valid to assume that varietal names are proxies for distinct genetic makeup, varietal names often reflect phenotypic differences at the population level, which may be the result of significant genetic differences. One study of potato, a vegetatively propagated crop, found a high level of agreement between folk variety names and genetically distinct varieties identified by isozyme markers (Quiros et al. 1990). More research is needed on the genetic distinctness of named varieties, especially in outcrossing species, because varietal names are frequently the only information available.

Despite the lack of a comprehensive database, there is ample evidence suggesting that the rate of loss of folk varieties increased with the modernization and internationalization of agriculture. For example, in the Mekong Delta, increasing irrigation and commercialization since the nineteenth century have resulted in loss of rice folk varieties and, due to loss of habitat for noncultivated rice, decreased potential for gene exchange with a wild relative (Vaughan and Chang 1992). Japan's goal at turning Taiwan into a source of rice for the Japanese market led to a campaign against rice diversity that reduced the number of folk varieties being grown from approximately 1200 in 1910 to approximately 400 in 1920 (Juma 1989). The development of modern, formal plant breeding after 1920 resulted in modern varieties (crop varieties developed to have relatively high yields under optimal growing conditions, which often include relatively high levels of inputs), which probably led to an increase in the rate of loss of folk varieties. Until the 1950s, this loss was probably much greater in industrialized countires than in the Third World, though there are some exceptions (Plucknett et al. 1987).

Beginning in the 1930s, there has been an increasing number of observations and studies indicating a dramatic increase in the rate of loss of folk varieties due primarily to the spread of modern varieties and the industrialization of agriculture. After World War II, the spread of the Green Revolution in the Third World increased the rate at which modern varieties replaced folk varieties (Belcher and Hawtin 1991, Fowler and Mooney 1990, Frankel and Soulé 1981, Harlan 1992, Keystone Center 1991, Plucknett et al. 1987). International concern for this loss of genetic diversity led to the establishment of the International Board for Plant Genetic Resources in 1974 (since 1993 the International Plant Genetic Resources Institute) and to the increased collection and conservation in genebanks of many folk varieties.

Much of the loss of folk varieties may have occurred as a result of the spread of modern varieties of cereals, especially wheat, rice, and maize. Cereals dominate world food production, providing 73% of total edible dry matter from plant products in 1986 (Evans 1993), and they are the crops where most plant-breeding efforts to increase yields have been focused (Anderson and Hazell 1989). It has been estimated that in the Third World by 1982–1983, 50.7 million hectares were planted to modern varieties of wheat and 72.6 million hectares were planted to modern varieties of rice—slightly more than 50% of the total areas planted to each of those crops (Dalrymple 1986). For maize it is estimated that out of a total of 79.1 million hectares planted in the Third World in 1985–1986, 51% (40 million hectares) were planted to modern varieties (38% in hybrids and 13% in open-pollinated varieties; Timothy et al. 1988).

Comparable summary data are not available, however, on the extent to which folk varieties may continue to be planted in areas dominated by modern varieties. When this incidence occurs in cross-pollinated crops such as maize, the result may be intervarietal hybridization, leading to progressive dilution of the unique genetic constitution of the folk varieties. This dilution would likely be more extreme when the modern varieties are hybrids, because new seed is typically purchased each season for hybrids, which would in effect result in the removal from local seedstocks of progeny from the hybridization of modern and folk varieties each year.

Currently, folk varieties continue to disappear at an increasing rate along with the on-going transformation of indigenous cultures and their ecosystems. The replacement of folk varieties by modern varieties is seen by some as a criterion of agricultural development (Srivastava and Jaffee 1993). Marketing and promotion of modern varieties in areas still rich in folk varieties continues, such as in Ethiopia (Seedling 1992) and the Philippines (Cromwell et al. 1993). While national governments, international development agencies, and agribusiness may be foremost in this activity, they are not alone. In a review of 18 nongovernmental organizations working with local seed systems and farm communities, 50% of the organizations report that they concentrate on modern varieties (Cromwell et al. 1993).

In addition, in surviving farm communities where farmers continue to cultivate folk varieties after the introduction of modern varieties, there may be a decrease in folk variety genetic diversity due to a decrease in the number of different folk varieties being grown or due to a severe reduction in population sizes if the area planted to each folk variety becomes small (Frankel and Soulé 1981, Soleri and Cleveland 1993). For example, data collected in one valley in Peru in 1985 indicate that expansion of area planted to potato modern varieties in the early stages of adoption has a significant effect on the number of potato folk varieties grown. With a 1985 average of 2.1 hectares and 10.1 folk varieties per farm, analysis suggests that an increase of 1 hectare in area planted to modern varieties is associated with a decrease of five folk varieties per farm (Brush et al. 1992). That is, as the proportion of land in a household's farm devoted to modern varieties increases, the number of folk varieties being grown drops.

While the loss of the genetic diversity in folk varieties is alarming to many involved in agriculture, the reasons for their concern and their suggestions to save the diversity vary widely. Some experts assume that modern varieties are superior to folk varieties under most conditions and that the main value of folk varieties is their contribution of genetic diversity as an essential raw material for modern plant breeding, especially as industrial agriculture moves toward lowering inputs. They believe that conservation ex situ in genebanks to make genetic diversity available to modern agriculture is the only practical way to reliably maintain the genetic diversity present in folk varieties (Frankel and Soulé 1981, Lipton and Longhurst 1989, Marshall 1989, Plucknett et al. 1987) or that in situ conservation in farmers' fields can be a backup or complement to ex situ conservation (Vaughan and Chang 1992, Williams 1991).

Another viewpoint, supported by evidence that farmers often maintain folk varieties even when modern varieties are available, is that folk varieties can be valuable for local farmers themselves for agronomic, social, and cultural reasons. Advocates say that the potential value of folk varieties for the development of sustainable agriculture is not only the genetic information encoded in the DNA of these varieties but also the knowledge about selecting, propagating, seed saving, growing, and using the crop, and the cultural values embodied in folk varieties (Amanor et al. 1993, Berg et al. 1991, CLADES et al. 1994). However, due primarily to lack of research, this viewpoint is usually not well supported by scientific evidence (Cromwell et al. 1993, Hodgkin et al. 1993). This lack of evidence has contributed to the assumption by some that folk varieties do not have a role to play in the development of sustainable agriculture. However, an even more important determinant of the role of folk varieties in sustainable agriculture may be the way in which sustainable agriculture is defined.

Figure 1. Folk varieties are often adapted to difficult, local growing environments. Hopi blue maize is adapted to growing in an arid area with a short growing season. Photo: D. Soleri.

Diversity, stability, and sustainable agriculture

Sustainability is a key concept in agricultural development today. Defining sustainable agriculture is not a scientific process but rather an exercise in reaching consensus on values (Cleveland 1993). However, once a definition is agreed on, empirical data can be used to measure sustainability in a given system. Most definitions to date include conservation of natural resources for future generations, economic efficiency and profitability, and social criteria, such as satisfying "changing human needs" (NRC 1989) or providing "acceptable livelihoods," especially for the poor (Plucknett 1993). In addition, stability of yields and food supply are often considered key components (Netting 1993, UNCED 1993). Stable production means crop yields that fluctuate relatively little from year to year. Yield instability contributes to malnutrition and social inequity, especially where storage and transportation infrastructures are small or nonexistent (Anderson and Hazell 1989).

There is growing recognition of the contribution of diversity to yield stability in agricultural systems (Anderson and Hazell 1989, Ceccarelli et al. 1992, Cleveland 1993, Cooper et al. 1992, Pimentel et al. 1992). Diversity may exist at many levels within small-scale, low-input, indigenously based agriculture, including regions, fields, the species of crop plants grown, and the varieties within crop species. This kind of agriculture is usually more socially, biologically, and ecologically diverse than large-scale, high-input industrial agriculture (Amanor et al. 1993, Oldfield and Alcorn 1987). The diversity present in much of small-scale indigenous agriculture appears to be important in providing greater yield stability compared with more homogeneous, large-scale indigenous or industrial agriculture (Amanor et al. 1993, NRC 1993) and to have been in many cases sustained for a much longer period.

In contrast, large-scale industrial agriculture has often degraded the natural resources on which future production depends (NRC 1989) and alienated local communities from their resources (Durning 1990). Industrial agriculture has not emphasized reducing yield instability per se but rather increasing yields for maximal economic returns through control of the environment and breeding of crop varieties that are high-yielding in response to high levels of inputs (Evans 1993). This focus on yields as compared with yield stability can mean choosing between managing resources for short-term gains in food supply compared with long-term food production capability (Gersha et al. 1994, NRC 1989, Pimentel et al. 1992).

The diversity-stability relationship is well documented at the crop variety level; plant breeders recognize that there is often a tradeoff between yield and stability in response to environmental stress (Blum 1988, Ceccarelli et al. 1992, Rosielle and Hamblin 1981). Folk varieties developed by farmers in their role as plant breeders are typically selected for adaptation to local physical, social, and cultural environments. Although not always a conscious intent of the farmer-breeder, the result may be varieties that are genetically heterogeneous compared with homogeneous modern varieties (Borojevic 1990). This variation may be present as a large number of alleles at a locus, as variation in frequency of alleles between populations of one or more folk varieties, or as a high proportion of loci with more than one allele in an individual plant (high levels of heterozygosity; Hodgkin et al. 1993). This variation is probably due to the nature of the selection process—primarily mass selection.

Mean yields of folk varieties are affected relatively less by genotype-by-year interactions than are modern varieties, or as Harlan states, "genetic variability provides some built-in insurance against hazards" (Harlan 1992, p. 148). However, there has been little research on the actual performance of folk varieties in comparison with modern varieties (Hodgkin et al. 1993). Existing evidence does suggest that folk variety yields may be less affected by environmental stress such as drought or salinity (e.g., Weltzien and Fishbeck 1990), and resistance to pests and pathogens is believed to be high as a result of horizontal resistance based on genetic diversity, compared with vertical resistance of modern varieties based on one or a few resistance genes (Ceccarelli et al. 1992, Simmonds 1991b, Thurston 1992). Due to this resistance, within their area of adaptation, yields of folk varieties are more stable than modern varieties from year to year in a given field or among fields within a single year (Evans 1993). Therefore, folk varieties may often have lower mean yields in optimal environments compared with modern varieties but have higher mean yields in the marginal environments to which they are specifically adapted.

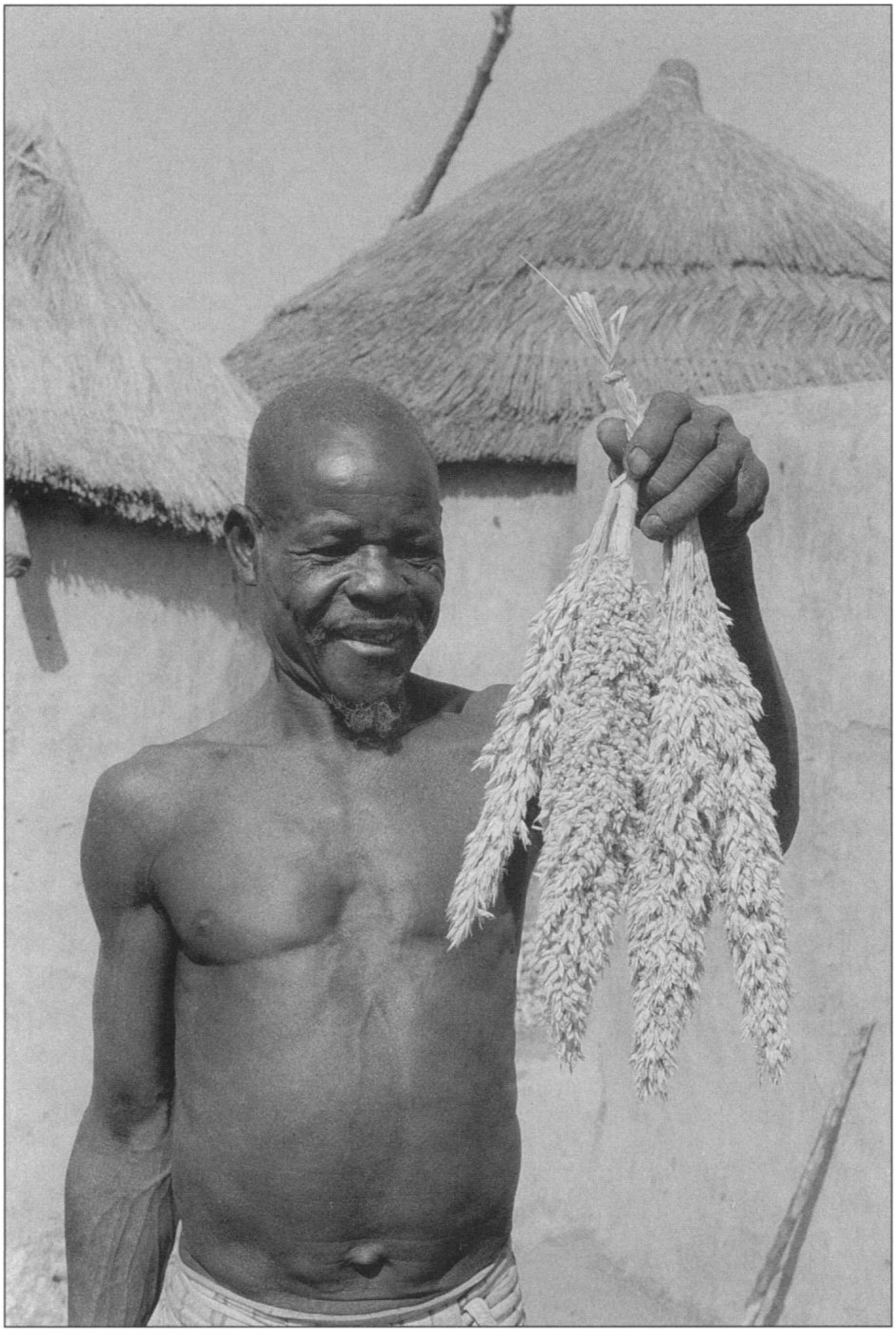

Figure 2. Often many different folk varieties of crops are maintained. Kusasi farmer with a sorghum variety planted in northeast Ghana. Photo: D. A. Cleveland.

The greater genetic diversity of small-scale indigenous compared with large-scale industrial agriculture also exists at the species level, where many more folk varieties of a crop are typically planted; at the field level, where many more species and varieties are planted together; and at the regional level, where there are more varieties of more species in more diverse environments. Farmers typically grow many different varieties of major crops, which they distinguish from each other (Frankel and Soulé 1981). Examples include Mende farmers in Sierra Leone who in one area were growing 70 varieties of rice (Richards 1986) and a sample of 50 Hopi farmers growing 21 varieties of maize including 17 folk varieties (Figure 1) and 13 varieties of common bean including 10 folk varieties (Soleri and Cleveland 1993).

Figure 3. Folk varieties are often selected for intercropping. Kusasi farmers harvesting long-season sorghum in northeast Ghana. Earlier the same field produced a harvest of short-season pearl millet. Photo: D. A. Cleveland.

Stability at regional and national levels can be influenced by the degree of diversity in environments and input sources. In modern industrial agriculture a relatively small number of crop varieties are usually developed for production over a large area of relatively more uniform environments and are often dependent on purchased inputs and an energy- and capital-intensive infrastructure to deliver these inputs, in order to produce high yields. Folk varieties are usually not dependent on such inputs or infrastructure. When there is an interruption in input supply (e.g., lack of irrigation water or lack of fuel for vehicles delivering agrochemicals) due to resource shortages, drought, social conflict, or other factors, modern varieties characteristically show a reduction in yield that is greater and covers wider areas, compared with folk varieties. Therefore, because of increasing homogeneity of plants, cropping practices, and input supply sources over large geographical areas, the extent to which yields in different regions and nations vary in synchrony both within and between years may increase with the introduction of modern varieties and the industrialization of agriculture (Anderson and Hazell 1989, Barker et al. 1981).

Clearly, there is much more to learn about the forms and determinants of stability. A simplistic contrast between sustainable indigenous and unsustainable industrial agriculture is unfounded. For example, large-scale, centrally controlled indigenous societies, such as those of antiquity, may also severely limit local farmer management and other agricultural diversity in an attempt to control large, locally dense populations and bolster the power of a small elite, potentially leading to the destruction of the resource base and the collapse of production (Adams 1978). The role of diversity, however, does appear to be critical. The contrast between more diverse, locally adapted, small-scale indigenous agriculture and less diverse, widely adapted, large-scale industrial agriculture as two extremes of a continuum enables us to better analyze the implications of the strongly contrasted policy options under discussion.

Folk varieties' role in sustainable agriculture

Depending on the definition used for sustainable agriculture, the assessment of the loss of folk varieties, approaches for their conservation, and their role are likely to be different. If sustainable agriculture is defined as the continuing pursuit of higher yields through refining the industrial model, then folk varieties are seen primarily as a source of genetic raw material for the development and maintenance of modern crop varieties, and conservation efforts are likely to focus on ex situ conservation in genebanks. If sustainable agriculture is defined as optimizing long-term diversity and stability, including an important role for small-scale indigenous farmers, then folk varieties are seen as resources to be used directly by farmers, and in situ conservation is essential, although ex situ conservation remains important (Soleri and Smith 1994).

Some observers see the increasing instability in world crop yields as an inescapable consequence of agricultural modernization (Anderson and Hazell 1989, Barker et al. 1981, Duvick 1992). Different definitions of sustainable agriculture lead to different approaches to yield instability. The response that dominates international agricultural development is to continue increasing production levels by introducing new technology—while mitigating any resulting yield instability through centralization of markets and increasing government coordination to link individual farmers with the rest of the world—and continuing development and supply of modern varieties (Anderson and Hazell 1989, Evans 1993, Lipton and Longhurst 1989, Plucknett et al. 1987).

Genetic diversity is the raw material required for development and maintenance of modern varieties, and folk varieties are theoretically an important source of this diversity, especially for unique traits not present in existing cultivars or breeding materials (Plucknett et al. 1987). Yet, in practice there is substantial diversity already available in highly selected germplasm (e.g., across inbred lines of maize, wheat, and rice), and relatively little use is made of the folk varieties available in genebanks (NRC 1993, Shands and Wiesner 1991, 1992, Williams 1991), much less of evolving folk varieties available only in farmers' fields. However, there are many specific examples of the contribution of folk varieties to the development of modern industrial varieties (Shands and Wiesner 1991, 1992).

Interest in folk varieties as a

source of genetic diversity for creating modern varieties has grown recently (e.g., Ceccarelli et al. 1992). One reason is that as the rates of yield increase have leveled off and food production moves to more marginal environments, researchers seek to reduce required inputs and their economic costs and to minimize adverse environmental effects (NRC 1989, Plucknett 1993). This new direction in agricultural research calls for a change in plant-breeding strategies (Smith and Zobel 1991). In addition, recent developments in plant biotechnology greatly increase the potential to identify, isolate, and transfer genes for specific traits (NRC 1993). For these reasons, some proponents of conserving the genetic diversity in folk varieties and their wild relatives stress their potential contribution to the future of industrial agriculture and the need to look for diversity beyond the breeders' highly selected materials (Plucknett et al. 1987, Shands and Wiesner 1991, 1992).

An alternative approach to achieving long-term stability emphasizes the need for biological diversity (NRC 1992, Pimentel et al. 1992), locally diverse and specific management strategies (Cleveland 1991, Ghersa et al. 1994, Richards 1986), indigenous knowledge (NRC 1992, Thurston 1992), recognition of the productivity of small-scale farmers (Netting 1993), and the rights of small-scale farmers to control their crop and farm resources (Cooper et al. 1992, Soleri et al. 1994). This approach is based on the stability of a diverse agriculture composed of many locally adapted farming systems and folk varieties and the value of folk varieties to local farmers.

Figure 4. Hopi farmer Jerry Honawa plants Hopi blue maize 25 cm below the soil surface in his field in the high desert of southwestern North America. Photo: D. Soleri.

Why farmers maintain folk varieties

Indigenous farmers often retain folk varieties even when they experiment with and adopt some modern varieties (Figure 2). The causes for retaining folk varieties are not well researched but may include storage, cooking, nutritional, and processing qualities; historical and cultural reasons such as dietary diversity and the use of folk varieties in traditional foods or religious ceremonies and filling unique market niches. Another cause may be for agronomic reasons: some folk varieties are considered more suited to traditional intercropping patterns (Figure 3), have longer or shorter growing cycles, or are more resistant to local biotic and abiotic stresses (Bellon 1990, Brush 1991, Brush et al. 1992, Dennis 1987, Ferguson and Mkandawire 1993, Longley and Richards 1993, Soleri and Cleveland 1993, Soleri et al. 1994, Thurston 1992, Zimmerer 1991).

Yield stability is also an important reason for retaining folk varieties. Many farmers are aware of the relationship between diversity and stability, and stability is an important criterion in their varietal selection. For example, African farmers "often favor yield stability...more than maximum yields" (Haugerud and Collinson 1990).

Farmers deliberately plant varietal, or even special, mixtures to improve or stabilize production. For example, farmers in Uttar Pradesh, India, plant rice varieties that differ in drought resistance and grain quality, and farmers in the Sri Lankan highlands plant an awned rice variety that protects an unawned but higher yielding variety (Vaughan and Chang 1992). Farmers in Malawi cite yield stability as a major reason for deliberately maintaining numerous varieties of common bean (*Phaseolus vulgaris*) in their planting stock (Ferguson and Mkandawire 1993). Susu farmers in Sierra Leone intermix African and Asian rice (*Oryza glaberimma* and *Oryza sativa*) varieties to optimize yields over good and bad years (Longley and Richards 1993). Mende farmers in Sierra Leone maintain a large and constantly changing collection of rice folk varieties selected primarily for adaptation to a variety of moisture regimes and for different growing cycles (Richards 1986).

Mexican farmers in one farm community in Chiapas maintain both modern varieties and folk varieties of maize on their farms to reduce risks in sloping and flat field plots (Bellon 1990). While they avidly experiment with varieties from any source, Hopi farmers in Arizona in the United States still plant primarily folk varieties of field crops. They state that one major reason for this choice is the relatively greater yield of these varieties when drought stressed (Soleri and Cleveland 1993). For example, the ability of Hopi blue maize to emerge from seeds planted as deep as 25 cm (Figure 4) is a specific adaptation to the arid climate and the soils of the Hopi homelands.

Research with Hopi farmers sponsored by Native Seeds/SEARCH (Soleri and Cleveland 1993) supports the conclusion of many researchers that the mix of folk varieties maintained by farmers is not random but a result of changing adaptation and constant experimentation (Harlan 1992, Richards 1986). Folk varieties tend to be lost when changes in the local biophysical or sociocultural environment reduce the importance of their adaptation. When biophysical and sociocultural changes make folk variety replacement possible, actual replacement appears to be determined by the availability of seed of new varieties that are similar to folk varieties or of alternatives to products made with folk varieties.

The interaction between these factors in determining the fate of a particular folk variety may be complex, as illustrated in the case of Hopi maize folk varieties and vegetables grown by Hopi gardeners. Hopis retain their blue maize folk varieties because they are adapted to drought and the short growing season and meet cultural requirements (blue maize is important in religious ceremonies). However, the Hopi data suggest that the several folk varieties of blue maize are being collapsed into one (Soleri and Cleveland 1993). One reason may be that today many farmers have full-time jobs in addition to farming. Thus, they do not have the time to maintain so many different varieties, which involves planting out separate fields or blocks to control cross-pollination and requires more careful selection and storage of planting seed for the different varieties. Another reason may be that the importance of the varieties' unique grain characteristics is diminished by social changes. For example, the introduction of machine grinding reduced the importance of the softer blue corn variety, while the cash economy reduced the desirability of the better storage qualities of the harder blue corn varieties because storing two years' harvest against crop failure is no longer necessary.

Fruit and vegetable crops represent a different story for two reasons. First, at Hopi these crops are grown in irrigated gardens where adaptation to drought and soils is not as important as it is for field crops. Second, although desirable foods, these crops do not have the same traditional religious and social importance in the Hopi culture as do the many Hopi maize folk varieties. In the study, of the 21 households cultivating chilies, only 2 grew Hopi chilies, while the rest grew modern chili varieties. All of the other vegetables planted in the irrigated gardens were commercial (Soleri and Cleveland 1993).

The specific reason for farmer maintenance of folk varieties can vary depending on both their biophysical and sociocultural environments. While they may often give more reliable yields and be better adapted to meeting local needs than many modern varieties, there may still be room for improving folk varieties' performance in the eyes of farmers.

Can folk varieties be further improved?

Farmers play an active role as plant breeders in creating and maintaining crop genetic diversity. Many plant breeders agree that since the beginning of agriculture indigenous farmer-breeders have made more total improvement in most crops than have Western scientific, or formal, plant breeders during the period of modern plant breeding (e.g., Simmonds 1979). Farmers plan, execute, and evaluate experiments with new varieties based on a wide range of sociocultural and environmental criteria (Berg et al. 1991), although much of the evidence for this data is anecdotal. The limited data so far from Africa (Ferguson and Mkandawire 1993, Longley and Richards 1993, Richards 1986), the Americas (Benz et al. 1990, Soleri and Cleveland 1993, Zimmerer 1991), and Asia (Dennis 1987, Vaughan and Chang 1992) show that farmer-breeders manage existing varieties and create new ones through a variety of techniques. These techniques include collection and domestication of wild plants, hybridization with wild species, planting of patterns to regulate cross-pollination, removal of unwanted plants in the field, and selection of seeds for replanting. They also obtain new varieties from spontaneous mutations in their fields and from neighbors, extension agents, and markets.

An important question is whether the ongoing evolution of folk varieties in response to rapidly changing needs can be enhanced by collaboration between farmer-breeders and formal plant breeders. The plant-breeding and seed-supply activities of the modern, formal sector and those of small-scale indigenous farmers have operated largely in isolation from each other (Amanor et al.

1993, Cromwell et al. 1993). A new approach is required to determine whether or not it is possible to improve folk varieties that were developed over many generations for a particular location. Collaboration with formal plant-breeding programs may be most useful in cases where farmers' selection and experimentation have deteriorated as a result of social and environmental changes or when there is a lack of genetic diversity.

Plant-breeding experience has shown that selection and testing in the environment where a crop variety is to be grown is the most effective way to create varieties specifically adapted to that environment (Hill 1975, Simmonds 1991a). Nevertheless, financial and other constraints generally force plant breeders to define the target environments for the use of their varieties as broadly as possible resulting in an emphasis on regional rather than local adaptation (Simmonds 1979), with selection and occasionally evaluation conducted entirely on experiment stations (Simmonds 1991a, Smith and Zobel 1991).

There is, however, increasing appreciation of the plant-breeding skills of indigenous farmers; of the value of folk varieties as a basis for breeding varieties for specific, especially marginal, local environments; and of the potential for enhancement of indigenous plant breeding and folk varieties by collaboration with formal plant breeding. Berg et al. (1991) find that while farmers' traditional plant breeding is quite similar to recurrent selection in multiple populations as used by formal plant breeders, farmer-breeders could improve their efficiency by increasing the size and genetic diversity of the original population and using statistical techniques to improve selection efficiency and methods. They advocate that formal plant breeders provide advanced, genetically diverse material to local farmers, followed by farmer selection of varieties in the field (Berg et al. 1991). Ceccarelli et al. (1992) describe the plant-breeding goals of the International Center for Agricultural Research in the Dry Areas (ICARDA) as based on increasing stability of yield, reducing inputs, exploiting the genetic variability of folk varieties, and considering the value of specific varieties from the farmer's point of view within local farming systems.

The cooperative enhancement of local folk varieties by farmer-breeders and formal plant breeders is already underway in some areas, although detailed results are not yet available. In Malawi, the Bunda College of Agriculture is using folk varieties as the foundation of its breeding program for common beans and has so far released nine varieties (Ferguson and Mkandawire 1993). They have also been encouraging crop diversity by releasing several varieties with different characteristics at the same time and encouraging farmers to integrate them with their existing varieties.

In Zimbabwe, the Indigenous Seeds Project coordinated by the Zimbabwe Seeds Action Network (ZSAN; composed of four Zimbabwean nongovernmental organizations) encourages farmer conservation of both local folk varieties and those from similar ecogeographic areas and selection to improve quality (Mushita 1992). The MASIPAG (*Mga Magsasaka at Siyentipiko para sa Pagpapaunlad ng Agham Pankagrikultura*, or Farmer-Scientist Participation for Development) program in the Philippines, established by scientists at the University of the Philippines in 1986, has been working with local farmers, especially in rice-growing regions that lost much of their genetic diversity in the last 20 years (Salazar 1992). A collection was made of 210 rice varieties from all over the country, including 127 folk varieties and 83 improved varieties, and the varieties were crossed and selections were made under low-input conditions with farmers' participation. In this work, yields of folk varieties were equal to or more than the improved varieties, and folk varieties were preferred by farmers as parents for crosses. Collaborating with MASIPAG in the Philippines is the Mindoro Institute for Development, which has 180 rice folk varieties from which technical consultants and farmers have selected 10 varieties that produce good yields with low inputs (Cromwell et al. 1993).

The Plant Genetics Resources Center/Ethiopia (PGRC/E) operated by the national government, collaborates with farmers in selection based on what they refer to as farmers' "judgment and long established skills" and in evaluation of selections based on farmers' comparisons with original folk variety seedstock. PGRC/E also works with farmers in selecting pure lines from wheat folk varieties supplied by PGRC/E and adapted to different environmental stresses, probably due to their original selection environment. These selections are then bulked and redistributed to farmers. Preliminary results show that yields of these elite folk variety lines "surpass those of commercially released varieties" (Worede 1992).

Local conservation of folk varieties

Farmer maintenance and selection conserves folk varieties in situ as part of local farming systems, yet there has been little research on indigenous seed supply networks or seed conservation (Cromwell et al. 1993; Figure 5). Many factors, including increasing population pressure, environmental destruction, promotion of modern varieties and industrial agriculture, and social and cultural changes suggest that this traditional approach alone may no longer be adequate.

For example, as local communities become more assimilated into mainstream industrial society, traditional markets or kinship networks that served to distribute seeds may change in ways that make it difficult to find seeds of folk varieties, especially for young people who wish to start farming (Ferguson and Mkandawire 1993, Soleri and Cleveland 1993). Widespread famine and political turmoil in Ethiopia has meant that particular folk varieties have been wiped out by crop failure or by farmers being forced to eat their seedstocks (Worede 1992).

When the population size of outcrossing species of folk varieties is greatly reduced, genetic drift and inbreeding become a risk (Frankel and Soulé 1981). In selfing species, reduction in population size may result in a loss of varietal heterogeneity. Seed admixture or cross pollination with another variety may also effectively eliminate a folk variety—or create a new one. Because of changing conditions and needs, collaboration with outsiders, including formal plant breeders, may be in the best interest of local farmers. When traditional systems of in situ conservation prove inadequate, local ex situ conservation in community seedbanks may be desirable.

There are several arguments supporting the conservation of folk varieties locally both in situ as part of the farming system and ex situ in community seedbanks. These arguments include: folk varieties have adaptations for specific local conditions and can be used directly for local breeding of new varieties (Worede 1992); folk varieties are best conserved for farmers' future needs in the evolving selection environment where they are used and by the farmers who use them (Vaughan and Chang 1992), because ex situ conservation outside of the local growing environment can result in shifts in population structure due to natural selection (Soleri and Smith 1994); and local control of folk varieties is likely to best ensure that they benefit the farmers and communities that developed them (Cooper et al. 1992).

For farmers, these approaches are clearly superior to dependence on ex situ conservation in national or regional genebanks. Although international genebanks have been able to return folk varieties to local farmers and are working, for example, to repatriate germplasm after catastrophic losses in Somalia (Anonymous 1993), there are potential problems. The goal of conventional ex situ conservation is primarily to make genetic diversity, often as individual lines carrying only a single desired trait, available to plant breeders, whereas farmers are interested in the complex suites of traits that characterize each unique folk variety (Harlan 1992). It is widely accepted on theoretical grounds that off-site ex situ conservation results in suspension of genetic changes in response to changing local environments and introduces genetic changes in response to storage and growout in a different environment (Marshall 1989, Vaughan and Chang 1992). There is evidence to support this theory (Breese 1989). If farmers cast loose seed of a folk variety locally, seed reintroduced from a distant genebank may have changed in ways that may be disadvantageous to farmers, as may be the case for Hopi maize (Soleri and Smith 1994).

Figure 5. Farmers select seeds based on fruit and seed characteristics as well as agronomic characteristics. Zuni farmer Lygatie Laate with a Zuni squash from his field saved for seed for next season's planting. Photo: D. A. Cleveland.

Some experts have suggested that incorporating in situ conservation of folk varieties into rural economic development programs would not conserve folk varieties, although the new varieties might retain many folk variety adaptive complexes (Oldfield and Alcorn 1987). Folk variety loss may occur when farmers become more actively involved with formal breeders in improving folk varieties, especially if that improvement includes the introduction of exotic germplasm (Berg et al. 1991). While there could easily be a loss of old folk varieties and of some genetic diversity, the new varieties selected by farmers in their fields could also be considered folk varieties.

Local ex situ conservation in community seedbanks is especially appropriate where rapid modernization, recurrent famine, or widespread political turmoil exists. A number of indigenous African organizations are planning or initiating community seedbanks. For example, KENGO, a nongovernmental organization in Kenya, has been promoting the protection and use of indigenous plants and plans to help establish community seedbanks (Anonymous 1990). In Indonesia, local nongovernmental organizations became involved in promoting community seedbanks to conserve and increase the planting of folk varieties after plant disease outbreaks (Soetomo 1992).

PGRC/E has been using the Ethiopian national collection as a source of folk varieties to resupply local farmers whose seedstocks have been lost due to drought, famine, and conflict. It has also promoted field testing by farmers of folk varieties from other areas and has brought plant breeders to work with farmers on crossing and selection in their own fields (Worede 1992). In Peru, a project has tried to make available certified (mainly virus-free) seed potatoes from a community seedbank (Benzing 1989). Local folk varieties have been collected and multiplied in farmers' fields or village land, with the effects of biotic and abiotic stress, including pest and disease damage, recorded for the use of the farmers and the project. Farmers who work on the trial plots receive the harvest, thus reintroducing local folk varieties and spreading them to new locations.

In addition to supporting in situ conservation and resupplying local folk varieties, community seedbanks may also choose to cooperate with regional, national, or international institutions on various projects. However, the advantages must be weighed against the threat of losing local control of folk varieties for local needs (Altieri 1989, Soetomo

1992), an issue now being discussed in terms of intellectual property rights and the human rights of local groups (Cooper et al. 1992, Soleri et al. 1994). The CGIAR system of International Agricultural Research Centers (IARCs) has been advocated as the best institution to oversee crop genetic resources conservation (Plucknett 1993), including in situ conservation (Brush 1991), while others have questioned the abilities of the IARCs—which spread the Green Revolution and receive a majority of their funding from industrial nations—to safeguard folk varieties for long-term benefit of local Third World communities (Altieri 1989). Recently, however, there is a new spirit of cooperation among local communities, nongovernmental organizations, national governments, the International Plant Genetic Resources Institute, and the IARCs, and joint projects are being proposed that give more respect to the value of biodiversity and local farmers' knowledge and rights (CLADES et al. 1994, Hodgkin et al. 1993).

However, while community seedbanks have become fashionable components of agricultural development projects, their social sustainability depends on whether they grow from the needs of diverse, local communities and how well they are integrated with broader goals of sustainable agriculture. A recent review of 18 community seedbank projects run by nongovernmental organizations found that they tend to set up new seed-supply institutions rather than work with existing social institutions. However, working with existing institutions may not always be the answer because they may not provide equitable benefits (Cromwell et al. 1993).

Conclusions

Current data and theory suggest that farmer control and management of selection is the most practical and effective way of managing genetic resources that support long-term yield stability specifically adapted to the local environment and to local farming systems including social organization and cultural values. If this hypothesis is supported by further research, existing folk varieties are likely to play an important role in the development of sustainable agriculture as we have defined it here. This development includes the improvement of some folk varieties by further farmer-managed selection and the development of new folk varieties through the introduction of new genetic resources, including those of modern varieties.

On the other hand, supporting diverse local farming systems and folk varieties as a basis for sustainable agriculture does not mean a return to an idealized, pristine indigenous agriculture. All small-scale, traditional systems cannot be assumed to have been sustainable in the past. Many may not be adapted to present or future conditions because their social, biological, and physical environments have been so greatly changed by colonialism, international markets, population growth, environmental degradation, climate change, migration, and international conflict. Flexibility is thus essential—including adaptation to diverse local conditions with a major focus on local experimentation—in working for indigenously based sustainable agriculture. It is also essential to use the most current information and techniques from Western scientific plant breeding and agriculture without linking these techniques to the profit-maximizing values and overall organization of industrial agriculture. Perhaps most important is the empowerment of local farmers and communities by supporting their control of their folk varieties, farming systems, and indigenous knowledge (Amanor et al. 1993, Cromwell et al. 1993).

Given the continuing threat to the conservation and use of folk varieties by indigenous and small-scale farmers, specific measures to safeguard these varieties for sustainable agriculture at the community level may be needed. Where appropriate such measures could include:

- Documentation of folk varieties by farmers, in collaboration with outsiders where appropriate, including indigenous knowledge about their selection, cultivation and use, and genetic and agronomic characteristics;
- Education of agronomists, formal plant breeders, local communities, and, in some cases, local farmers and students concerning the contribution of folk varieties to food production, yield stability, natural resource conservation, nutrition, history, and culture;
- Increases in the availability and planting of folk variety seeds through the encouragement of seed-exchange networks and seedbanks at the community level and exploration of opportunities for local commercial production of folk varieties for food and planting material;
- Improvement of the maintenance and performance of folk varieties through collaboration with formal plant breeders; and
- Establishment of control by farm communities over their folk varieties and the indigenous knowledge about them, through policies for seed collecting and use of folk variety seeds, food products, names, and knowledge by outsiders.

The incorporation of folk varieties into the development of locally based and locally controlled agriculture may be the best approach not only to conserving the genetic diversity in folk varieties and the farming systems that contain them but to supporting sustainable farming systems grounded in local environments and cultural values.

Acknowledgments

We thank Hopi and Zuni farmers of North America and Kusasi farmers of West Africa for many insights into the role of folk varieties; Steven McLaughlin of the University of Arizona and Anne Ferguson of Michigan State University for reviewing drafts of this article; Walter De Boef of the Centre for Genetic Resources, the Netherlands, and Toby Hodgkin of the International Plant Genetic Resources Institute, Rome, for copies of reports; and the editor, Julie Ann Miller, and the four anonymous reviewers for *BioScience*.

References cited

Adams, R. M. 1978. Strategies of maximization, stability, and resilience in Mesopotamian society, settlement, and agri-

culture. *Proc. Am. Philos. Soc.* 122: 329–335.
Altieri, M. 1989. Rethinking crop genetic resource conservation: A view from the South. *Conserv. Biol.* 3: 77–79.
Amanor, K., K. Wellard, W. de Boef, and A. Bebbington. 1993. Pages 1–13 in W. de Boef, K. Amanor, K. Wellard, and A. Bebbington, eds. *Cultivating Knowledge: Genetic Diversity, Farmer Experimentation and Crop Research.* Intermediate Technology Publications, London, UK.
Anderson, J. R., and P. B. R. Hazell, eds. 1989. *Variability in Grain Yields: Implications for Agricultural Research and Policy in Developing Countries.* Johns Hopkins University Press, Baltimore, MD.
Anonymous. 1990. Seed conservation at the community level in Kenya. *African Diversity* 4: 4–5.
______. 1992. Ethiopia's future: Hybrids or landraces. *Seedling* 9 (November): 11–14.
______. 1993. International efforts to save Somalian genetic resources. *Diversity* 1&2: 20–21.
Barker, R., E. C. Gabler, and D. Winkelmann. 1981. Long-term consequences of technological change on crop yield stability: the case for cereal grain. Pages 53–78 in A. Valdés, ed. *Food Security for Developing Countries.* Westview Press, Boulder, CO.
Belcher, B. and G. Hawtin. 1991. *A Patent on Life: Ownership of Plant and Animal Research.* International Development Research Center, Ottawa, Ontario, Canada.
Bellon, M. R. 1990. The ethnoecology of maize production under technological change. Ph.D. dissertation, University of California, Davis, CA.
Benz, B. F., L. R. Sanchez-Velasques, and F. J. Santana Michel. 1990. Ecology and ethnobotany of *Zea Diploperennis*: Preliminary investigations. *Maydica* 35: 85–98.
Benzing, A. 1989. Andean potato peasants are "seedbankers." *ILEIA Newsletter* 5(4): 12–13.
Berg, T., Å. Bjornstad, C. Fowler, and T. Skroppa. 1991. *Technology Options and the Gene Struggle.* Development and Environment No. 8, NORAGRIC Occasional Papers Series C. Norwegian Center for International Agricultural Development, Ås, Norway.
Blum, A. 1988. *Plant Breeding for Stress Environments.* CRC Press, Boca Raton, FL.
Borojevic, S. 1990. *Principles and Methods of Plant Breeding.* Elsevier, Amsterdam, the Netherlands.
Breese, E. L. 1989. *Regeneration and Multiplication of Germplasm Resources in Seed Genebanks: The Scientific Background.* International Board for Plant Genetic Resources, Rome, Italy.
Brown, A. H. D. 1978. Isozymes, plant population genetic structure and genetic conservation. *Theor. Appl. Genet.* 52: 145–157.
Brush, S. B. 1991. A farmer-based approach to conserving crop germplasm. *Econ. Bot.* 45: 153–165.
Brush, S. B., J. E. Taylor, and M. R. Bellon. 1992. Technology adoption and biological diversity in Andean potato agriculture. *Journal of Development Economics* 39: 365–387.
Ceccarelli, S., J. Valkoun, W. Erskine, S. Weigand, R. Miller, and J. A. G. van Leur. 1992. Plant genetic resources and plant improvement as tools to develop sustainable agriculture. *Exp. Agric.* 28: 89–98.
(CLADES) Latin American Consortium for Agroecology and Development, Community Technology Development Association (COMMUTECH) Zimbabwe, Centre for Plant Breeding and Reproduction Research (CPRO-DLO), Genetic Resources Action International (GRAIN), Norwegian Centre for International Agricultural Development (NORAGRIC), Plant Genetic Resources Centre/Ethiopia (PGRC/E), Rural Advancement Fund International (RAFI), South East Asian Regional Institute for Community Education (SEARICE). 1994. Community Biodiversity Development and Conservation Programme. Proposal to DGIS, IDRC and SIDA for Implementation Phase I—1994–1997. Centre for Genetic Resources, Wageningen, the Netherlands, and Centro de Educación y Tecnología, Santiago, Chile.
Cleveland, D. A. 1991. New crop varieties in a green revolution for Africa: Implications for sustainability and equity. Pages 325–338 in R. E. Downs, D. O. Kerner and S. P. Reyna, eds. *The Political Economy of African Famine.* Gordon and Breach, New York.
______. 1993. Is diversity more than the spice of life? Diversity, stability, and sustainable agriculture. *Culture and Agriculture Bulletin* 45–46: 2–7.
Cooper, D., H. Hobbelink, and R. Vellvé. 1992. Why farmer-based conservation and improvement of plant genetic resources? Pages 1–16 in D. Cooper, R. Vellvé, and H. Hobbelink, eds. *Growing Diversity: Genetic Resources and Local Food Security.* Intermediate Technology Publications, London, UK.
Cromwell, E., S. Wiggins, and S. Wentzel, eds. 1993. *Sowing Beyond the State: NGOs and Seed Supply in Developing Countries.* Overseas Development Institute, London, UK.
Dalrymple, D. G. 1986. *Development and Spread of High-Yielding Wheat Varieties in Developing Countries.* Bureau for Science and Technology, Agency for International Development, Washington, DC.
Dennis, J. V. 1987. Farmer management of rice variety diversity in northern Thailand. Ph.D. Dissertation, Cornell University. University Microfilms, Ann Arbor, MI.
Durning, A. B. 1990. Ending poverty. Pages 135–153 in Lester R. Brown et al. *State of the World 1990.* Norton, NY.
Duvick, D. N. 1992. Genetic contributions to advances in yield of U.S. maize. *Maydica* 37: 69–79.
Evans, L. T. 1993. *Crop Evolution, Adaptation and Yield.* Cambridge University Press, Cambridge, UK.
Ferguson, A. E., and R. M. Mkandawire 1993. Common beans and farmer managed diversity: Regional variations in Malawi. *Culture and Agriculture Bulletin* 45–46: 14–17.
Fowler, C., and P. Mooney. 1990. *Shattering: Food, Politics and the Loss of Genetic Diversity.* University of Arizona Press, Tucson, AZ.
Frankel, O. H., and M. E. Soulé. 1981. *Conservation and Evolution.* Cambridge University Press, Cambridge, MA.
Ghersa, C. M., M. L. Roush, S. R. Radosevich, and S. M. Cordray. 1994. Coevolution of agroecosystems and weed management. *BioScience* 44: 85–94.
Harlan, J. R. 1992. *Crops and Man.* 2nd ed. American Society of Agronomy, Crop Science Society of America, Madison, WI.
Haugerud, A., and M. P. Collinson. 1990. Plants, genes and people: Improving the relevance of plant breeding in Africa. *Exp. Agric.* 26: 341–362.
Hill, J. 1975. Genotype-environment interactions: A challenge for plant breeding. *J. Agric. Sci.* 85: 477–494.
Hodgkin, T., V. Ramanatha Rao, and K. Riley. 1993. Current issues in conserving crop landraces in situ. Paper presented at the On-Farm Conservation Workshop, Bogor, Indonesia, 6–8 December 1993.
Juma, C. 1989. *The Gene Hunters: Biotechnology and the Scramble for Seeds.* Princeton University Press, Princeton, NJ.
Keystone Center, The. 1991. *Final Consensus Report: Global initiative for the security and sustainable use of plant genetic resources.* Oslo Plenary Session. Genetic Resources Communications Systems, Washington, DC.
Lipton, M., with R. Longhurst. 1989. *New Seeds and Poor People.* Johns Hopkins University Press, Baltimore, MD.
Longley, C., and P. Richards. 1993. Selection strategies of rice farmers in Sierra Leone. Pages 51–57 in W. de Boef, K. Amanor, K. Wellard, and A. Bebbington, eds. *Cultivating Knowledge: Genetic Diversity, Farmer Experimentation and Crop Research.* Intermediate Technology Publications, London, UK.
Marshall, D. R. 1989. Genetic resources: Current and emerging issues. Pages 367–388 in A. H. D. Brown, M. T. Clegg, A. L. Kahler, and B. S. Weir, eds. *Plant Population Genetics, Breeding, and Genetic Resources.* Sinauer Associates, Sunderland, MA.
Mushita, A. 1992. Zimbabwean farmers at the starting point. Pages 69–77 in D. Cooper, R. Vellvé, and H. Hobbelink, eds. *Growing Diversity: Genetic Resources and Local Food Security.* Intermediate Technology Publications, London, UK.
Netting, R. M. 1993. *Smallholders, Householders: Farm Families and the Ecology of Intensive, Sustainable Agriculture.* Stanford University Press, Stanford, CA.
National Research Council (NRC). 1989. *Alternative Agriculture.* National Academy Press, Washington, DC.
______. 1992. *Conserving Biodiversity: A Research Agenda for Development Agencies.* National Research Council, Washington, DC.
______. 1993. *Managing Global Genetic Resources: Agricultural Crop Issues and*

Policies. National Research Council, Washington, DC.
Oldfield, M. L., and J. B. Alcorn. 1987. Conservation of traditional agroecosystems. *BioScience* 37: 199–208.
Pimentel, D., U. Stachow, D. A. Takacs, H. W. Brubaker, A. R. Dumas, J. J. Meaney, J. A. S. O'Neal, D. E. Onsi, and D. B. Corzilius. 1992. Conserving biological diversity in agricultural/forestry systems. *BioScience* 42: 354–362.
Plucknett, D. L. 1993. International agricultural research for the next century. *BioScience* 43: 432–440.
Plucknett, D. L., N. J. H. Smith, J. T. Williams, and N. M. Anishetty. 1987. *Gene Banks and the World's Food*. Princeton University Press, Princeton, NJ.
Quiros, C. F., S. B. Brush, D. S. Douches, K. S. Zimmerer, and G. Huestis. 1990. Biochemical and folk assessment of variability of Andean cultivated potatoes. *Econ. Bot.* 44: 254–266.
Richards, P. 1986. *Coping with Hunger: Hazard and Experiment in an African Rice-Farming System*. Allen & Unwin, London, UK.
Rosielle, A. A. and J. Hamblin. 1981. Theoretical aspects of selection for yield in stress and non-stress environments. *Crop Sci.* 21: 93–98.
Salazar, R. 1992. Community plant genetic resources management: experiences in Southeast Asia. Pages 17–29 in in D. Cooper, R. Vellvé, and H. Hobbelink, eds. *Growing Diversity: Genetic Resources and Local Food Security*. Intermediate Technology Publications, London, UK.
Shands, H. L., and L. E. Wiesner. 1991. *Use of Plant Introductions in Cultivar Development*. Part 1. CSSA Special Publication Number 17. Crop Science Society of America, Madison, WI.
______. 1992. *Use of Plant Introductions in Cultivar Development*. Part 2. CSSA Special Publication Number 20. Crop Science Society of America, Madison, WI.
Simmonds, N. W. 1979. *Principles of Crop Improvement*. Longman, London, UK.
______. 1991a. Selection for local adaptation in a plant breeding program. *Theor. Appl. Genet.* 82: 363–367.
______. 1991b. Genetics of horizontal resistance to diseases of crops. *Biological Review* 66: 189–241.
Smith, M. E., and R. W. Zobel. 1991. Plant genetic interactions in alternative cropping systems: Considerations for breeding methods. Pages 57–81 in D. A. Sleper, T. C. Barker, and P. J. Bramel-Cox, eds. *Plant Breeding and Sustainable Agriculture: Considerations for Objectives and Methods*. CSSA Special Publication Number 18. Crop Science Society of America and American Society of Agronomy, Madison, WI.
Soetomo, D. 1992. Sowing community seedbanks in Indonesia. Pages 30–37 in D. Cooper, R. Vellvé, and H. Hobbelink, eds. *Growing Diversity: Genetic Resources and Local Food Security*. Intermediate Technology Publications, London, UK.
Soleri, D., and D. A. Cleveland. 1993. Hopi crop diversity and change. *J. Ethnobiol.* 13(2): 203–231.
Soleri, D., and D. A. Cleveland, with Donald Eriacho, Fred Bowannie Jr., Andrew Laahty, and the Zuni Community. 1994. Gifts from the Creator: intellectual property rights and folk crop varieties. Pages 21–40 in T. Greaves, ed. *Intellectual Property Rights for Indigenous Peoples: A Sourcebook*. Society for Applied Anthropology, Oklahoma City, OK.
Soleri, D., and S. E. Smith. 1994. Morphological and phenological comparisons of Hopi maize varieties conserved in situ and ex situ. Paper presented at the 35th Annual Meeting of the Society for Economic Botany, Mexico City, Mexico, 20–26 June 1994.
Srivastava, J. P., and S. Jaffee. 1993. *Best Practices for Moving Seed Technology: New Approaches to Doing Business*. World Bank Technical Paper Number 213. The World Bank, Washington, DC.
Thurston, H. D. 1992. *Sustainable Practices for Plant Disease Management in Traditional Farming Systems*. Westview Press, Boulder, CO.
Timothy, D. H., P. H. Harvey, and C. R. Dowswell. 1988. *Development and Spread of Improved Maize Varieties and Hybrids in Developing Countries*. Bureau for Science and Technology, Agency for International Development, Washington, DC.
United Nations Conference on Environment and Development (UNCED). 1993. *Agenda 21: Programme of Action for Sustainable Development*. United Nations Department of Public Information, New York.
Vaughan, D. A., and T.-T. Chang. 1992. In situ conservation of rice genetic resources. *Econ. Bot.* 46: 368–383.
Weltzien, E., and G. Fishbeck. 1990. Performance and variability of local barley landraces in Near-Eastern environments. *Plant Breeding* 104: 58–67.
Williams, J. T. 1991. Plant genetic resources: some new directions. *Adv. Agron.* 45: 61–91.
Worede, M. 1992. Ethiopia: A genebank working with farmers. Pages 78–94 in in D. Cooper, R. Vellvé, and H. Hobbelink, eds. *Growing Diversity: Genetic Resources and Local Food Security*. Intermediate Technology Publications, London, UK.
Zimmerer, K. S. 1991. Managing diversity in potato and maize fields of the Peruvian Andes. *J. Ethnobiol.* 11: 23–49.

LINKED CITATIONS

Do Folk Crop Varieties Have a Role in Sustainable Agriculture?

David A. Cleveland; Daniela Soleri; Steven E. Smith

BioScience, Vol. 44, No. 11. (Dec., 1994), pp. 740-751.

Stable URL:

http://links.jstor.org/sici?sici=0006-3568%28199412%2944%3A11%3C740%3ADFCVHA%3E2.0.CO%3B2-B

References cited

Rethinking Crop Genetic Resource Conservation: A View From the South

Miguel A. Altieri

Conservation Biology, Vol. 3, No. 1. (Mar., 1989), pp. 77-79.

Stable URL:

http://links.jstor.org/sici?sici=0888-8892%28198903%293%3A1%3C77%3ARCGRCA%3E2.0.CO%3B2-1

Coevolution of Agroecosystems and Weed Management

C. M. Ghersa; M. L. Roush; S. R. Radosevich; S. M. Cordray

BioScience, Vol. 44, No. 2. (Feb., 1994), pp. 85-94.

Stable URL:

http://links.jstor.org/sici?sici=0006-3568%28199402%2944%3A2%3C85%3ACOAAWM%3E2.0.CO%3B2-P

Conservation of Traditional Agroecosystems

Margery L. Oldfield; Janis B. Alcorn

BioScience, Vol. 37, No. 3, Whence Seeds for the Future? Biologists Address Global Agricultural Issues. (Mar., 1987), pp. 199-208.

Stable URL:

http://links.jstor.org/sici?sici=0006-3568%28198703%2937%3A3%3C199%3ACOTA%3E2.0.CO%3B2-2

LINKED CITATIONS

Conserving Biological Diversity in Agricultural/Forestry Systems

David Pimentel; Ulrich Stachow; David A. Takacs; Hans W. Brubaker; Amy R. Dumas; John J. Meaney; John A. S. O'Neil; Douglas E. Onsi; David B. Corzilius

BioScience, Vol. 42, No. 5. (May, 1992), pp. 354-362.

Stable URL:

http://links.jstor.org/sici?sici=0006-3568%28199205%2942%3A5%3C354%3ACBDIAS%3E2.0.CO%3B2-%23

International Agricultural Research for the Next Century

Donald L. Plucknett

BioScience, Vol. 43, No. 7, International Agricultural Research. (Jul. - Aug., 1993), pp. 432-440.

Stable URL:

http://links.jstor.org/sici?sici=0006-3568%28199307%2F08%2943%3A7%3C432%3AIARFTN%3E2.0.CO%3B2-K