

GENETIC DIVERSITY AND CONSERVATION IN TRADITIONAL FARMING SYSTEMS¹

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ABSTRACT.—A few farming systems have carried forth the legacy of Neolithic in the thousands of ancestral crop varieties known as "landraces." Our debt to this heritage is immeasurable, yet the very success of modern agriculture is contributing to the disappearance of landraces. A handful of scientifically bred varieties has replaced thousands of ancestral types in twenty years as part of the worldwide effort to develop agriculture. Although landraces and the farming systems that maintain them are part of long evolutionary processes, rapid change threatens their survival. Given the value of landraces for genetic resources, their replacement has been termed "genetic erosion."

This paper develops a framework for analyzing genetic erosion and discusses the status of genetic resources of crops in two areas of genetic diversity, the Andes and Southeast Asia. Similarities and differences in the pattern of genetic change relating to the adoption of modern crop varieties are observed. The pattern shows a dichotomy between commercial and subsistence farming systems and between micro-regions. By describing conservation and loss of genetic resources we can obtain a more accurate understanding of agricultural change in underdeveloped and marginal areas.

GENETIC EROSION

Genetic erosion refers to the loss of genetic resources because of human activity. It occurs in "natural" ecosystems, for instance with the clearing of tropical forests, as well as anthropogenic systems, for instance when ancient landraces of crops are replaced by modern varieties. Concern for genetic erosion arose with the recognition that biological diversity is being lost at an unprecedented rate because of the rapid demographic, economic and technological changes of the late Twentieth Century (Myers 1981). This paper treats the loss of germplasm from traditional farming systems.

In thinking about genetic erosion, we confront the familiar issue of environmental costs resulting from economic growth. The value of genetic resources, particularly crop germplasm, is undisputed. Crop germplasm is a renewable resource, but agricultural change in areas of genetic diversity may involve replacing one type of germplasm ("landraces") with another ("modern varieties"). This replacement destroys the older type, unless it is collected for storage in germplasm collections of seed banks. Two issues surround this replacement. One is the efficacy of conservation outside of living agroecosystems (Frankel and Soule 1981). The other is the issue of environmental degradation in ancient agricultural systems that existed for millennia without external subsidies. Although increases in productivity can be gained through germplasm substitution, they are usually accompanied by increased management costs and reliance on purchased inputs, especially fertilizer and seed. Genetic diversity in agriculture is also theoretically associated with stability (VanderPlank 1968), and a decrease in diversity thus represents environmental degradation to a less stable system. However, the diversity/stability argument has not been adequately investigated in relation to agriculture, and contrary views are prevalent (e.g. Brown 1983, Altieri, *et al.* 1983).

In the early 1970s, two phenomena coincided to change fundamentally the way we think about the genetic resources for agriculture. First was the recognition that the "Green Revolution" was taking hold in many parts of the world, especially Asia. Predictions of famine that were common in the 1960s were replaced by concerns over the impact of the abundant harvests from the high yielding varieties (HYVs) of rice and wheat (e.g. Wharton 1969). The Green Revolution was succeeding in areas of genetic diversity which are the primary providers of the genetic resources for agriculture everywhere. The success of HYVs showed us that "traditional" cultures were rapidly changing. Second was the spread of the southern Corn Leaf Blight through maize fields of the southeastern United States. This led us to recognize how vulnerable modern agriculture is to exotic pathogens, owing to its reliance on a narrow genetic base [National Academy of Science 1972]. The context for this coincidence included the ideas of a population bomb about to explode, the finite nature of resources, the OPEC oil shock of 1973, and the environmental movement's notion of the "Spaceship Earth" and its celebration of traditional cultures.

This coincidence linked two popular notions: the fragility of modern technology and lack of control over a base of critical resources. The benefits for poor people in underdeveloped countries reaped from the Green Revolution represented a "hidden peril" for agriculture: the loss of genetic resources that serve to protect crops from pests and pathogens [Chedd 1970]. The term "genetic erosion" represents the wedding of these notions, implying a limited resource base being destroyed by peasant farmers as they modernize.

The response to this perceived peril was to increase the collection and conservation of genetic resources. The first half of the 1970s produced landmark studies of the status of genetic resources in agriculture (e.g. Frankel and Bennett 1970; Frankel and Hawkes 1975). National germplasm systems were strengthened, and an international system for monitoring, collecting, conserving, and distributing genetic resources was organized in various ways, including establishing the International Board for Plant Genetic Resources [IBPGR] [Plucknett and Smith 1982]. A systematic program was planned for the world's major food crops, to set priorities for collection and to evaluate the status of germplasm collections.

The growth/conservation debate continues, and it is apparent that information on the nature, status and trend of genetic erosion is much needed [U.S. Strategy Conference 1981]. Research is required for policy and planning, whether to accelerate collection or to develop *in situ* conservation. The use of ethnobiological research tools has great potential for studying the dynamics of genetic resources from ancient farming systems. These resources are cultural as well as biological objects, and selection is a function of social, economic, and cultural factors as well as a function of the germplasm's biological characteristics.

THE ORIGINS OF CROP GENETIC DIVERSITY

Centers of crop origin were first recognized by their high levels of genetic diversity, both at the species and variety level [Vavilov 1951]. Crop germplasm from these centers of diversity forms the foundation of the crop breeding industry that is essential to modern agriculture, and thousands of cultivars have been observed and collected from these centers. Research on the geographic origins of agriculture [Ucko and Dimbleby 1969] indicates a climatic prerequisite of seasonal variability and a well-marked dry season [Hawkes 1983], and it showed that mountainous or hill land areas were especially significant.

Four general factors can be cited in reference to this diversity: (1) the physical diversity of centers of origin, (2) the long history of cultivation, (3) the large number of coevolved

pests, pathogens, and competitors, and (4) cultural practices of selection, maintenance and distribution. These factors have created numerous niches for distinct cultivars, isolating mechanisms, and selection pressure for diversity. Ethnobotanical research shows that all farming cultures classify and select plants according to many criteria: agronomic, culinary, medicinal, ritual. The rich lexical domains associated with traditional agriculture in areas of domestication are indicative of the positive role that farmers have played in selecting and maintaining genetic resources (Brush *et al.* 1981).

Diversity appears to be one of several strategies used to create stable subsistence by farmers practicing low-energy, non-industrial farming. Other strategies include terracing and other slope modification, mulching and other soil amendments, and frequent field rotation with long fallow periods. Diversity is manifested in low-energy farming systems in numerous ways: in the mix of cultivation, gathering, and grazing as productive activities, in nutrition strategies (DeWalt 1983) in polyculture whereby different crops are produced in association with one another (Kass 1978), in the possession and cultivation of numerous small plots (Carter and Mamani 1983), in the agronomic technologies of field preparation and irrigation (Wilken 1972), and in large numbers of cultivars of single species (Brush *et al.* 1981).

Genetic diversity in crops continues in many environments, but its continuity is particularly marked in mountain areas. Genetic diversity continues here for some of the same reasons that made hill lands centers of crop domestication: well-marked environmental change over small distances, marked seasonality, and isolation between small production zones. Equally significant, however, is the relative marginality of mountain regions in world agriculture. This marginality is the result of numerous factors: lower population densities, greater environmental risk, less accessibility to markets, limited arable land, and lower investment in agricultural development.

These environmental and economic factors have retarded the pace of change, including the substitution of improved crop varieties common to lowland areas. Mountain areas are, however, under considerable pressure to change. Population growth, economic development, greater communication, and political reform stimulate change, leading to some alarm over potential environmental degradation in the highlands (Messerli 1983). Well-tuned traditional agricultural practices, such as crop diversity, terracing, small irrigation systems, and long fallow periods, are being replaced by more intensive, and perhaps less stable practices.

While genetic diversity is inherited from ancient agricultural traditions and may be explained as a response to a complex and competitive environment, it is also associated with low productivity. Jennings and Cock (1978) show that crop productivity in centers of origin is appreciably lower than outside these centers. This is true even after economic and cultural differences are taken into consideration. Agricultural development for greater productivity requires increased management and control over the various components of the farming system. Genetic control and improvement has been accomplished by national and international breeding and seed multiplication programs, exemplified by the release of HYVs of rice and wheat. Breeding and multiplication programs have been developed in most underdeveloped regions since World War II, and by the early 1960s the results of these programs were evident. Farmers were beginning to adopt HYVs in large numbers, leading to inquiries about the rate pattern of adoption (Perrin and Winkelman 1976). Concern about whether new technology could or would be adopted on small as well as large farms and concern about negative impacts of adoption lead to an extensive research effort in the social sciences (Feder *et al.* 1982). This effort revealed that adoption cannot be predicted by the scale of the farming enterprise and that negative influences such as decreased labor demand in agriculture do not result. It also revealed that a number of factors in the general agricultural economy influence adoption. These include risk aversion (Roumasset 1976), human capital (Evenson 1973), labor availability

(Norman 1969), credit (Lipton 1976), tenure (Parthasarathy and Prasad 1978), and the availability of complementary components such as fertilizer and water (Clay 1975).

This social science research on the adoption of HYVs also revealed that the pattern and rate of adoption was very uneven across geographic regions. Following the classic analysis of hybrid corn diffusion in the U.S. by Griliches [1957], a sigmoid pattern of adoption of HYVs in the Third World is evident [e.g. Herdt and Capule 1983; Dalrymple 1978]. The rate and ceiling of adoption is variable. Adoption in some places proceeds rapidly toward 100% of farms, while in others it proceeds slowly to a much smaller percentage. The implications of different rates and ceilings of adoption are very significant for our understanding of genetic erosion. They suggest that simple extrapolation from early adoption experience may not be valid to describe the eventual pattern of genetic replacement of traditional varieties of HYVs. In order to elucidate this conclusion, it will be helpful to review two cases of the diffusion of improved varieties. These are the cases of potatoes in the Andes and of rice in Southeast Asia.

SELECTION FOR DIVERSITY: TWO CASE STUDIES

Andean Potato Agriculture.—The potato (*Solanum* spp.) is the staple in the Andes, where it was domesticated. Seven species are cultivated from four ploidy levels (Hawkes 1978). Diversity at the species level distinguishes bitter species (*S. x juzepczukii*, *S. x curtilobum* and *S. ajanhuiri*) from non-bitter species (*S. tuberosum*, *S. x chaucha*, *S. stenotomum* and *S. goniocalyx*). The former are frost resistant and must be processed by freeze drying (into *chuño*) before consumption. Besides species level diversity, the Andes is also a region of tremendous varietal diversity in the potato. The International Potato Center has a collection of some 12,000 named accessions, representing roughly 5,000 distinct clones (A. Huamán, personal communication). Andean farmers employ a systematic folk taxonomy to identify and select varieties (Brush *et al.* 1981). It is common for farmers to be able to identify 40 different varieties, and single fields may be planted in as many varieties. The size of household inventories of potato varieties and amount of field diversity differ greatly between households and regions.

Andean potato agriculture is diverse in many ways besides the number of species and varieties under cultivation. The management of potato farmland is frequently under simultaneous control by households and communities. Households are responsible for selecting varieties, for most of the labor employed in potato cultivation, and for post-harvest processing, storage and marketing. The community controls sectoral fallowing which determines where the household will grow its crop; it regulates the agricultural calendar; and, in some cases, community-based irrigation is used for potatoes. As in all potato agriculture, the maintenance of viable seed is crucial. This depends on the regular rotation of seed tubers between ecological (altitudinal) zones. This system may be managed at the household level by the ownership and use of different fields at various altitudes or by communities and market systems that move large quantities of seed across wide regions. Traditional potato agriculture is also associated with a highly fragmented land-holding system. Carter and Mamani (1983), for instance, describe a farming community in Bolivia in which the average household owns 21 different plots in the potato zones. Tillage techniques (Tapia 1983) and post harvest technology (Werge 1979) are similarly varied.

The same forces that contribute to agricultural change elsewhere are felt in the Andes. Population has grown at over 2.5%/year for three decades, popular pressure for development and increased living standards are evident, reform has been undertaken to stimulate agricultural change, and an agricultural research and development infrastructure has been created to promote change. Urban demand has grown in the highlands stimulating the growth of market systems (Appleby 1976).

Highland potato agriculture in Peru has been the object of development efforts for over three decades. Improved varieties from native germplasm were first released in the early 1950s, and since then over 30 varieties have been released. These are now ubiquitous throughout Peru. Besides the release of improved varieties, the Peruvian National Potato Program has promoted the diffusion of selected native clones and encouraged the adoption of modern techniques such as the application of chemical fertilizers and pesticides. The availability of credit for these agrochemical inputs has been tied to the adoption of improved varieties. Three decades of these development efforts have had a clear impact in the Andes; the use of agrochemicals is common, improved varieties have been adopted to some extent almost everywhere, and the infrastructure to promote these changes [markets, roads, extension services, seed production systems] has been expanded.

The extent of these changes has led to predictions of serious genetic erosion in the Andes (Ochoa 1975), and some of the limited data available from the region indicates that these predictions are valid. Research in the Mantaro Valley, for instance, indicates that roughly 65% of the potato land is planted in improved varieties (Horton 1984). This valley, however, is not typical of most of the highlands, being one of the most commercial and intensively cultivated anywhere in highland Peru. The poor performance of Andean agriculture (Caballero 1981; Gonzales 1984) suggests that the overall adoption of new technology, including improved varieties, is low. My impression supports this conclusion, but systematic data on the use of improved and traditional varieties are insufficient to calculate regional or national rates of the use of different types of potato. Horton (1984) reports high adoption rates for well developed and important commercial production areas, but these rates should not be extrapolated over the general Andean region. Bidegaray and Schmidt (1985) report a low 25% adoption rates in the Cuzco area.

Changes, including genetic erosion, are evident everywhere in highland potato growing regions of Peru, but their distribution is very uneven. In some areas diverse native collections have been entirely replaced by improved varieties, while in others native types continue to dominate. The distribution of this change follows socioeconomic and environmental contours. The greatest loss has occurred in lower potato growing zones and those within major valley systems with urban centers and markets. The least genetic erosion occurs in higher zones more distant from urban centers and markets. Research conducted by the International Potato Center (CIP) and by Brush, Mayer and Fonseca, indicates that the adoption of improved potato varieties is only one of several possible options open to small farmers, and it may not be the first option taken to increase production.

CIP studied three agroclimatic zones, based on altitude, in the Mantaro Valley of central Peru. The lowest zone (3000-3450 m) is adjacent to the major urban and market centers of the valley. Although small farms are most typical, this zone has more medium and large scale farms than the other zones, and these types produce potatoes for commercial distribution. The mid-altitude (3450-3950 m) and high latitude zones (3950-4200 m) have fewer commercially oriented potato farms, and potatoes are generally more important as a crop. Farms in all three zones share a number of characteristics: use of agrochemicals, marketing of a portion of the crop, and reliance on off-farm employment to supplement farm income. One of the most striking differences between these agroclimatic zones is in the adoption of improved varieties. Franco *et al.* (1979) report that 87% of fields of all farms in the low zone were planted in these varieties. This reliance drops sharply as one crosses into higher zones. In the intermediate zone roughly half of the fields were planted in improved varieties, while in the highest zone, the rate drops to 12%. Other research indicates that farmers in the high zone interplant improved and native varieties and frequently reserve one or more fields for mixed native varieties alone [Brush *et al.* 1981].

The distribution of innovations in potato agriculture that is found in the Mantaro Valley appears to be typical of most of the Peruvian highlands. Current research being conducted by Brush, Mayer, and Fonseca along the eastern slopes of the Andes corroborates this. In the Tulumayo Valley, east of CIP's Mantaro study area, improved varieties and selected native varieties are grown for commercial purposes in both high and mid-altitude zones. Mixed fields of native varieties are retained under traditional tillage practices, although they are grown in only the highest fields. The total area devoted to native varieties is smaller, and these are grown under greater environmental stress than previously. In the Paucartambo Valley, east of Cuzco, improved potato varieties have made less impact, but much land once grown in native potato varieties has been converted to barley as a cash crop in the regional beer industry.

As adoption occurs, farmers tend to subdivide their farming system into commercial and subsistence sectors. The former are located on the best land, often with irrigation, and receive higher capital inputs. Although the subsistence sector is also important, it is relegated to poorer land and receives fewer inputs. It is possible that families experiencing land and/or labor shortage might eventually abandon the subsistence sector altogether. This relates to the frequency of off-farm employment and to greater reliance on purchased food.

Andean farmers have many reasons for preferring native over improved varieties, but culinary and agronomic ones stand out. Improved varieties are considered "watery", a negative attribute compared to the preferred "floury" quality of native varieties. The almost universal consensus among farmers interviewed about variety choice was that the new varieties were inferior eating potatoes, suited for soups, frying, or undiscriminating urban consumers. For subsistence farmers, whose diets remain predominately reliant on potatoes, keeping traditional varieties is a culinary necessity. No nutritional differences, other than water content, are noted between traditional and improved varieties. Improved varieties also do not remain viable as seed potatoes for more than a few seasons. Farmers observe that they degenerate and ultimately fail as seed. This can be overcome by purchasing new seed, but this is a costly requirement for subsistence farmers. Native seed potatoes are kept viable indefinitely by rotating seed between altitudinal zones, but the seed rotation system used for native seed are generally not applied to improved varieties.

Although farmers have reasons for maintaining traditional varieties, they have other reasons for adopting modern ones: their greater productivity and their resistance to the two greatest risks, frost and late blight (*Phytophthora infestans*). Traditional varieties are generally recognized to be more susceptible to these risks than improved varieties. This challenges the notion that older types are more "adapted" than new ones.

Genetic erosion is undoubtedly occurring because farmers are changing their farming system. What is not known is the rate of genetic erosion relative to this change. Potato agriculture in commercially developed valleys such as the Mantaro and Cajamarca valleys has rates of replacement above 60%, but away from these areas the rate appears much lower, perhaps below 25%. There seem to be no areas in the higher altitudes, away from market centers or where subsistence production continues, where farmers completely abandon native varieties for improved ones or for other crops.

Genetic change is as inevitable and essential to subsistence agriculture as it is as to commercial agriculture. Subsistence farmers consciously select among clones, eliminating unwanted ones and emphasizing others. This selection is evidenced by the distribution of varieties within fields, by the cosmopolitan distribution of certain varieties over very large regions, by the use of certain types for gifts and exchange, by their cultivation for seed, and by the commercial status of a few native varieties. The contemporary pattern of genetic change continues patterns that predate improved varieties

and development programs, but with these new elements, the rate of change has accelerated, justifying the concept of erosion.

Besides the introduction of new varieties and other innovations for potato agriculture over the last thirty years, another major change is the rise of commercial potato production on the coast. Coastal production involves larger farms than are typical in the highlands, relies on purchased inputs, is commercially oriented, and employs improved seed produced under certification. The average yield on the coast is 17.85 metric tons per hectare while in the highlands it is only 5.86 metric tons (Peru 1975:2). Coastal potatoes are grown largely for the Lima market, only a short distance from the major center of coastal production in the Cañete Valley.

The successful development of potato agriculture on the coast is a potentially limiting factor in the rate of agricultural change in the highlands. Farmers in the central highlands compete in some of the same markets as coastal farmers, and the economies of scale, more optimal agroclimatic conditions, and proximity to markets of coastal producers give them great advantages over the highlands. This increases the risk to highland farmers of investing in new agricultural technology.

Besides competition with coastal producers, small farmers in the highlands face two opportunity costs in adopting improved potato varieties. First is the cost of diverting resources to change potato agriculture. Capital to purchase new seed can be invested in other crops, in livestock, or in other household production such as artisan activities. The Andean household economy is extremely diversified and variable, and given the uncompetitiveness of potato agriculture at higher altitudes, it is likely that available capital would not be diverted there. Second is the cost in time needed to make the adoption decision, learn about new varieties, locate and purchase seed. A significant portion of household income in all sectors of the Andes comes from off-farm employment, and these activities make more difficult an already complex agricultural calendar for farmers involved in a vertical economy. The time involved in the adoption decision may be an additional cost too great to bear. The result of these two opportunity costs is the decision to keep growing traditional varieties.

Although the data is insufficient to predict future trends of potato germplasm conservation and loss, we can identify factors that both promote and constrain genetic change. It is promoted by continued high population growth, increasing demand from urban markets, improvement in transportation and communication, changing consumption patterns, and active and well organized national and international crop improvement programs. It is constrained by population loss from some areas, consumer preferences, and the marginality of certain areas because of high risk, land fragmentation, and isolation from markets. The balance of these factors has resulted in the uneven pattern of change described above.

It is reasonable to assume that the balance will not be altered rapidly, for instance by technological breakthroughs that make remote highland regions more active in commercial potato markets or by a return to native varieties. It is possible that development programs could overcome these constraints to adoption and accelerate genetic erosion of potatoes in the highlands. The likelihood of this is diminished, however, by several features of the agricultural development policy of Peru. These include a serious financial crisis in the government, an emphasis on development in the tropical lowlands of eastern Peru rather than in the highlands, and a steady migration away from the highlands, especially from the small farm sector. These features are compounded by political pressures for cheap urban food from the coast as well as from abroad (Ferroni 1980), by ethnic differences between regions, and by failure of reforms to improve productivity in the highlands (Caballero 1981). These features indicate that the distribution of agricultural change and the adoption of improved potato varieties will not change in the near future.

Southeast Asian Rice Agriculture.—Rice (*Oryza sativa*) cultivation in Southeast Asia is a useful comparison to potato cultivation in the Andes. Unlike the Andes, where virtually all of the research on genetic diversity has been done in one country (Peru), Southeast Asia has similar research in several countries. Case study material from Thailand, Indonesia, and the Philippines demonstrates their similarity to Peru in terms of agricultural, economic and cultural diversity. Although the true center of domestication for rice is in northern India and southern China, the area of rice diversity extends into Southeast Asia (Chang 1976). Rice has been the object of intensive breeding and development programs for several decades, and modern varieties have diffused widely throughout the region. These include HYVs from the International Rice Research Institute (IRRI) and earlier releases of national breeding programs. Rice agriculture and the diffusion of new varieties have been examined in detail (Grist 1965; Hanks 1975; Barker 1978; Herdt and Capule 1983). Southeast Asia is characterized by different agroclimatic zones associated with hill and mountain environments. As in the Andes, the diffusion of improved varieties of rice corresponds to this zonation.

Reliable aggregate data on improved variety diffusion is more readily available for Asia than for the Andes. Economic and agronomic research on rice provides a good overall picture of the presence or absence of modern rice varieties (Herdt and Capule 1983), but little research has been done on the retention of diverse stocks that might accompany some adoption. Most research on adoption has concentrated in areas with relatively high acceptance of new varieties. These areas tend to be optimal for rice production and not "traditional" by virtue of their cultural diversity, ecological diversity or agroecological marginality (Huke and Duncan 1969). An exception to this pattern of research is work done in the Chang Mai Valley of northern Thailand (Rerkasem and Rerkasem 1984).

While lacking the varietal distinctiveness of a sexually propagated potato clone, rice is self-pollinating and thus typified by distinctive varietal populations (Grist 1965). Asian rice is subdivided into three major subspecies (*indica*, *japonica* or *sinica*, and *javanica*) which are geographically distinct and differ according to their grain. Each of these species is subdivided into numerous varieties whose grand total may be as high as 120,000 (Swaminathan 1984). In Indonesia, an estimated 8,000 varieties, primarily *javanica*, are found (Bernsten *et al.* 1982), while in the Philippines and Thailand, 1,500 and 3,000 varieties respectively are found with *indica* varieties predominating (IRRI 1978).

As in Andean agriculture, the genetic diversity of rice is recognized culturally in Asia. This recognition occurs at both the general level in the distinction between the major subspecies over large regions and at the specific local level. This specific cultural recognition is evident in naming and folk taxonomic systems, in planting patterns, in culinary aspects and in rituals. Among the Ifugao, H. Conklin (personal communication) has elicited a folk classification of five levels for rice. In 1973, this system was applied to the classification of 78 varieties grown by the Ifugao. Among the Iban of Sarawak, Sutlive (1978), found that each family maintained a variety of strains which were named according to such criteria as place or origin, bouquet, and culinary property. Sutlive describes the Iban practices of planting varieties in separate portions of the field and locating a special ritual segment in the middle of a field where a special variety is planted. At harvest time, the Iban gather each variety separately. Long and short grain rices are stored separately, and varieties that have not produced well that year are gathered and stored separately (V. Sutlive, personal communication). In Thailand, Rerkasem and Rerkasem (1984) note that farmers have a good appreciation for the concepts of "variety" and "selection". Farmers in Chang Mai identified 42 varieties from 55 grain samples according to color, shape and size of the grain and panicle branching and size (Rerkasem and Rerkasem 1984:304-305). All of this indicates the high level of cultural awareness and care for the genetic diversity of rice that is generalized across a wide area.

Rice cultivation in insular Southeast Asia is customarily divided into two major subsystems: upland (dry) rice and lowland (irrigated) rice. Variations exist (Padoch 1983), and irrigated areas may add a dry season rice crop which is not irrigated (Grist 1965). Upland rice is directly seeded and intentionally grown under aerobic conditions (McIntosh *et al.* 1984). Upland rice covered the majority of rice acreage in Asia, accounting for 61%, while irrigated rice covers 33% and deep water rice 6% (Huke 1982). In Southeast Asia, however, upland rice accounts for only a small percentage of the total area—in Indonesia 11% and in the Philippines 14% in 1977 (IRRI 1984). Upland rice is associated with lower inputs (labor, capital) and also with lower productivity, averaging less than 1ton/ha compared to 4ton/ha for irrigated rice (IRRI 1984; Barker 1978). Sedentary agriculture accounts for most upland rice, although it is also found in swidden agriculture. In each it is primarily associated with subsistence production in which rice is supplemented by other crops (IRRI 1984).

Upland and lowland rice varieties belong to the same species but are distinguished along a continuum of morphoecological groups. Lowland rice exceeds upland in the number of varieties and genetic diversity. This would appear to contradict the image of a homogeneous agroecosystem for irrigated rice. Upland rice is distinguished by diversity relating to drought tolerance (IRRI 1984). It is associated with cropping systems that are generally more diverse and "traditional" than lowland ones. Chang (1976) suggests that the smaller diversity among upland types indicates that they are not ancestral to lowland types.

Lowland rice in Asia is famous for intensity and productivity. Geertz (1963) describes this as a product of "involution," an evolutionary process whereby increased labor is absorbed by fine-tuning the complex paddy system to achieve increased productivity. Although involution may be disputed (Collier 1981), the evolution of irrigated rice in the Philippines and Indonesia has resulted in high population densities, land fragmentation, and much higher yields than found in the upland systems. Densities associated with upland swidden systems generally fall below 50 persons per square kilometer while irrigated systems support 500 or more (Geertz 1963; Gourou 1966). On Java, which is dominated by wet rice, 63% of the land under cultivation is in farms of less than 0.5 hectares, and the average farm size is 0.64 ha (Birowo and Hansen 1981:5). On the Outer Islands of Indonesia, where irrigated rice is secondary to upland systems, the figures are the opposite, with 70% of the farms larger than 0.5 ha. On Kalimantan, where swidden is common, the average farm size is 2.71 ha.

For dry rice production in Indonesia, Gourou (1966) reports production of 812 kg. per hectare, while the Philippines wet rice employing traditional methods yields an average 2427 kg/ha (Conklin 1980). The disparity is even greater when modern varieties and other subsidies are applied to wet rice, and yields of over 4000 kg/ha are achieved (Barker 1978). Another distinctive characteristic of irrigated rice is the dominance of rice as a cultigen and subsistence item. Although rice is culturally significant among the Hanunoo, it accounts for less than 20% of their diet. Irrigated rice, on the other hand, is associated with monocropping and with heavy reliance on rice as the staple (Gourou 1966). Although the relative hegemony of rice decreased in Java during the Colonial period, it has continued in other parts of Southeast Asia (Geertz 1963).

A final distinction between the two systems is that irrigated rice is associated with an elaborate and stratified land tenure system in contrast to the simple and egalitarian system of tenure of swidden. The tenure system of paddy reflects the density of the population and the complexities of the water control system. Differential access is determined by ownership and a variety of rental and share tenancy arrangements (Utami and Ihalauw 1978; Conklin 1980). These create disparities between different sized farms and between landowners and the landless. Although the distribution of paddy is relatively egalitarian

among those who own land in Java, over 40 percent of the population is landless or near landless (Birowo and Hansen 1981).

The rate of change is greatest in lowland systems, that is in those that originally had the greatest diversity. As expected from this difference, the rate of genetic erosion in lowland rice greatly exceeds that of upland rice. Special agronomic characteristics, such as deep water or pathogens limit adoption, and cultural characteristics, such as preference for glutinous rice, may also be limiting. Considerable research has been devoted to the question of farm size as a limiting condition, concluding that it is not a significant factor (Herdt and Capule 1983).

Lowland rice systems have proved to be among the most dynamic small farm economies in the world, measured by the adoption rate of HYVs and other inputs. Herdt and Capule (1983:5) report that between 1966 and 1981, the overall percentage of Asian rice area planted in modern varieties rose from 1.4% to 39.5%. In countries where lowland rice predominates this rate is much higher. In the Philippines, for instance, by 1981 77.4% of the total rice area was planted in modern varieties. Although the Philippines represents an unusually high national average, numerous areas within other countries have achieved similar rates (Herdt and Capule 1983; Bernstein *et al.* 1982; Chang 1984).

The extent of genetic erosion in lowland rice in the Philippines is unusual in Asia, although the potential for replacement exists elsewhere. Indonesia, for instance, had 60% of all its rice land in modern varieties by 1981 (Herdt and Capule 1983). There is, however, some reason to speculate that HYV replacement may be limited in some lowland or irrigated rice systems. Prabowo and Sajogyo (1981) compare two villages on Java with widely differing adoption rates. In the East Java village, virtually complete adoption was reported, while in the West Java village, adoption rose and then sharply declined to 17% following an outbreak of gall midge. Poor water control and lack of fertilizer have limited adoption elsewhere (Herdt and Capule 1983).

Thailand is a striking contrast to the rapid diffusion of HYVs in the Philippines and Indonesia. By 1980, less than 10% of the Thai rice area was planted in HYVs, even though lowland rice predominates (Herdt and Capule 1983). Several reasons have been suggested for this low rate. Thailand is famous for high quality and glutinous rices, especially for export, and HYVs are not regarded as competitive in quality. Glutinous rice is preferred as a staple, and although glutinous modern varieties are available, they are inferior to native varieties (Rerkasem and Rerkasem 1984). Fukui (1975) notes that native varieties performed as well as HYVs, given limited fertilizer use and underdeveloped water control. He observed that Thai farmers adopted HYVs not as a replacement to indigenous varieties but as a second crop because of their short growing period and non-photosensitivity. Rerkasem and Rerkasem (1984) describe the ethnobiological basis of non-adoption in the Chang Mai Valley. Their case study reveals that HYVs are grown on 5% of the land in the valley. Traditional varieties are grown on 20%, and two selected local varieties cover 55% of the land. These authors note that numerous criteria are used to evaluate rice varieties and that the farming system has many specific agroclimatic niches for which specific varieties are selected. It is unlikely that any single variety can meet all of these criteria or perform well across all niches.

Data from other lowland rice growing areas in the Asian center of diversity is insufficient to judge whether we should regard Thailand as typical of resistance to the diffusion of HYVs on the Asian mainland. Farmer (1979) notes that the new varieties have limited use during the wet season in India, Sri Lanka and Bangladesh, although they are widely used during the dry season, because of their non-sensitivity to photoperiod and their short duration. Regional wet season problems, such as deep water are important in limiting diffusion, as are problem soils in some areas (Farmer 1979). On Indonesia's outer islands, the percentage under improved varieties declines in higher elevations and areas under tidal influence and with toxic soils (Bernstein *et al.* 1982).

In South Kalimantan, for instance, modern varieties account for only 30% of the area in wet seasons and 20% in dry seasons (Bernsten *et al* 1982:21).

Besides these agronomic issues that limit diffusion of HYV rice, economic issues can also be identified. The first economic issue to be studied in relation to adoption was scale of farming, and this proved to be a non-issue. Small farmers were repeatedly found to be adopters, and in some areas, they actually exceeded larger farmers in adopting HYVs (Herdt and Capule 1983). In lowland rice, more marginal zones (as measured by degree of water control, access to major markets, etc.) are less likely to adopt than more optimal areas. This difference would appear to explain the relatively low adoption of modern varieties in Orissa (25%) compared to other Indian States, Andhra Pradesh (63%), West Bengal (41%) (Herdt and Capule 1983).

The most significant economic issue dividing high and low adoption is the difference between lowland and upland rice. Unlike lowland rice, the upland version is characterized by continued use of traditional varieties. Nepal with 75% of its rice in upland systems only achieved a 25% adoption by 1980 (IRRI 1984; Herdt and Capule 1983). In India, states with the highest proportion of upland rice show generally lower adoption of modern varieties. In Madhya Pradesh, with 40% of the rice area in upland, less than 2% is planted to modern varieties (IRRI 1984; Herdt and Capule 1983). Two limiting factors for adoption of improved rice varieties in upland farming systems have been observed: the dependence of improved varieties on water and the requirement for technical knowledge of and heavy investments in fertilizers (Kunstader *et al.* 1978). These two characteristics make the new varieties inherently unacceptable to poor upland farmers.

Besides the inappropriate nature of HYVs for upland systems, the particular characteristics of those systems must be understood in relation to technological adoption. As noted above, these systems have always been less intensive than lowland ones. They are associated with subsistence rather than market product, marginal agroecological zones, and culturally distinct groups. Upland agriculture is often located in mountainous regions where slopes, soils and, socioeconomic conditions impede the construction of irrigation and terrace systems for paddy rice. Moreover, upland rice is usually only one component, often secondary, in diverse farming systems. The investment to learn about and acquire new varieties thus represents an opportunity cost to the other components.

DISCUSSION

Similarities and differences in the pattern of adoption of improved crop varieties are evident in comparing these two centers of genetic diversity. In both the Andes and Southeast Asia, the pattern of adoption is associated with a dichotomy between farming systems and with an upland/lowland dichotomy. In both, the genetic diversity of the major crop is retained in more marginal agroecological zones where farming systems are highly mixed and oriented toward subsistence. In the Andes, these zones are associated with higher altitudes where the environmental limits to the crop are more proximate. In Asia, these zones are also associated with hill agriculture and higher altitudes. In each area, advantages of the improved varieties are more apparent in the more intensive lowland system, where they are adopted. These systems are characterized by commercial production, greater control over the various inputs of agriculture, and better access to markets. The size of a particular farm does not seem to deter adoption in these areas. In some Asian rice systems, as in Andean potato systems, the adoption of new varieties is accomplished because they can fill special niches, such as in dry season rice farming.

In upland farming systems in both regions the advantages of improved varieties are outweighed or made irrelevant by other features of the system. In the Andes, high altitude potato farmers adopt new technology, but they do not replace older varieties with

improved types. The costs of seed, poor market access and culinary preference are the major limiting factors. In Asia, improved varieties of rice are not suited for specific lowland environments, such as deep water farming, and they are generally not acceptable to upland farmers who lack water control and other intensive management techniques. In each area, the availability of other critical inputs, such as fertilizers, influence the adoption of crop varieties.

The similarities between potatoes and rice in respect to genetic erosion may be summarized by reference to the importance of agroclimatic zone, cultural preference, and farming system differences regarding control over inputs, markets access, farm diversity, and subsistence orientation. Genetic change in each is more rapid in areas where intensive and commercial agriculture existed prior to improved varieties. In marginal areas, adoption is slower and is often accomplished by fitting improved varieties into a diverse farming system, rather than by simple replacement of the older seed stock.

While potato and rice farming systems share several attributes that indicate a general pattern of genetic erosion, it is also important to note that they seem to differ in the extent of change. Although it is impossible to generalize across all of Asia or the Andean region, rice in some Asian countries has experienced far greater change than potatoes anywhere in the Andes. This may be because new potato varieties do not outperform older ones to the same extent as new rice varieties. No Andean country in the original hearth of potato domestication has seen a majority potato fields planted in improved varieties, while several Asian countries have passed this mark in rice. These differences show clearly in a comparison between Peru and the Philippines. Unfortunately, regional and national data on potato agriculture in Peru is not comparable to information about Philippine rice, but the limited data available suggests that genetic erosion there is perhaps less than half the Philippine adoption rate of 77%. Although a majority of Peruvian farms in regions close to urban areas have converted to modern varieties, this rate drops sharply with distance from cities. With the exception of the upland/lowland rice dichotomy, the Philippine case shows a high overall adoption rate, regardless of location in relation to urban markets.

Several differences between the two crops and farming systems may be cited in relation to the more dynamic performance of rice in the Philippines. A primary one has to do with the national markets of each crop. Entering the 1960s, the Philippines experienced a serious deficit in rice production for its national consumption, and demand for rice has remained high. Peru, on the other hand, has only faced potato shortages in time of severe crop failure, and it has imported potatoes only in emergencies. The urban population of Peru consumes fewer potatoes than the rural one, and this keeps the potato market relatively weak. The strong national market in the Philippines seems to have reduced the disadvantages experienced by more isolated farms that are important in Peru. Transportation costs are relatively less for rice than for potatoes, and there is no comparable need to market the crop as a fresh vegetable.

Besides these market differences, two other factors may be cited to account for the lower rate of genetic erosion in Peru: a) different emphasis given to crop development in the two countries and b) fundamental agronomic differences between the crops. The high overall adoption of improved varieties in the Philippines followed large scale promotion campaigns which made credit, fertilizers, information, and improved varieties available. Faced with a serious deficit in rice production in the late 1960s, the Philippines undertook a successful agricultural extension program, the Masagana 99 program. This has been heralded as responsible for the dramatic changes in Philippine rice agriculture (Merrick 1981), typified by the adoption of HYVs. The success in improving Philippine rice production to self sufficiency through technological innovation is closely correlated with institution building in national research and extension programs.

Peru, on the other hand, has a generally poor record in improving agricultural productivity and a mixed record in institution building and extension. For the last 40 years, Peru has conducted national agricultural research programs aimed at improving potato production, and these programs have turned out over 30 improved varieties since 1950. Yet from 1954 to 1972, potato yields actually fell by 25% (Eastman and Grieshop 1986). No single campaign comparable to the rice programs in the Philippines was ever mounted in Peru. Peru has always been self sufficient in potato production (Eastman and Grieshop 1985) and urban food habits emphasize rice and bread rather than potatoes (Ferroni 1981). Agricultural research and extension suffered major setbacks in the 1968 military revolution, that attacked rural underdevelopment through agrarian reform rather than technological change. The National Potato Program ceased to function in the early 1970s, and the national agricultural extension service was abolished shortly after the military revolution. The National Potato Program was reorganized with CIP's help in the early 1980s, and the national agricultural extension service has been refashioned.

The adoption rates of new crop varieties in Peru and the Philippines are also affected by differences between the two crops. Perhaps the most important difference relative to genetic erosion is the ability of new rice varieties to outperform older varieties. In contrast, the newer potato varieties have some advantages, such as precocity or disease resistance, but their overall performance is not as clearly advantageous as rice HYVs. As an asexually reproduced and vegetatively propagated crop, the potato is disadvantaged by very slow seed multiplication. The time that it takes to produce a sufficient amount of new seed material in tuber crops is roughly ten times what sexually reproduced cereal crops require. The promotion of improved varieties in rice is enhanced by the ease of seed duplication, and by less cumbersome seed production and distribution systems. An important result of these differences is the availability and acceptability of greater amounts of improved rice seed to all types of farmers.

Another difference between the two crops is the complexity of seed maintenance in potatoes. As discussed above, native Andean agriculture employs a system of seed rotation between ecological zones. New varieties can be incorporated into this system, but farmers who adopt usually depend on regular purchase of new seed because of the degeneration of new varieties. This is a major limiting factor on the rate of adoption. In rice, on the other hand, no such cumbersome seed rotation system is required, and improved varieties have been easily incorporated into the pre-existing seed system. A third difference between potatoes and rice concerns storage. Potatoes, of course, are a fresh vegetable with a very high water content. In storage, they lose weight at water evaporates. Weight loss may be controlled by refrigeration, but this is not an option available to small farmers. As noted above, small potato farmers in Peru are in direct competition with larger farmers in the highlands or on the coast. Larger farmers who can afford refrigerated storage can play the market to their advantage by waiting until the price is advantageous. Small farmers without this storage capacity cannot afford to delay selling their crop. The result is that traditional varieties are kept for consumption and household income is sought from other sources.

The patterns of adoption and diffusion of new varieties of rice and potatoes described above are derived from the agroecology of the different farming systems producing each crop, by the socio-economic characteristics of these systems, and by the nature of the particular crop. Although retention of diverse, native germplasm in each crop is still evident, the ongoing evolution of these farming systems may later this picture. Systemic pressures for the adoption of improved varieties are present in both regions. These include rapid population increase, changing expectations and consumption patterns, and the generation of new technology more appropriate to marginal farm areas. This paper suggests that it is now advantageous for the farmers in these mixed agroecosystems to retain their ancestral landraces. Genetic change in these marginal areas will take renewed

and increased research and promotion and will require change in the overall agricultural system to make other technological inputs available. Competition with the more optimal farm regions already changed by the green revolution will retard this.

The conclusion is that genetic erosion does not occur evenly and will probably not proceed as rapidly as once expected. Agricultural development in marginal areas is but one of many alternatives for developing countries, and there are few institutional or political pressures to invest heavily in this. On the other hand, the people in these areas are as eager as any to improve living standards. As the world looks to ways to protect its genetic resource base, the continued cultivation of traditional varieties in marginal areas may be seen as a positive rather than a negative feature. The challenge for development planners is to devise ways to improve living standards of poor farmers and to encourage continued cultivation of traditional varieties. Conservation cannot and should not be pursued at the expense of the well-being of farmers who today manage the Neolithic legacy.

NOTE

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