Multi–gene-pool Surveys in Areas with Rapid Genetic Erosion: An Example from the Aïr Mountains, Northern Niger

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Abstract: *A survey to sample and document wild and cultivated plants with crop and forage genetic resources was carried out in the Aïr Mountains of northern Niger in 1984, 1985, and 1986. This ecogeographical survey was begun in the 1984 drought after considerable desertification had already occurred. Over the last century in this area, there has been progressive alteration and loss of habitat and populations, with probable genetic erosion. The focus was on wild and weedy species in the following gene pools:* Pennisetum, Sorghum, Olea, Andropogon, Cenchrus, Brachiaria, Eragrostis, Panicum, Setaria, Acacia, Ziziphus, *and* Grewia; *and on crops from irrigated gardens, including pearl millet, sorghum, and barley. Due to the high degree of environmental heterogeneity and the loss of habitat, relativity small numbers of individuals and clumps were identified, a significant portion were probably part of previously contiguous occurrences. In this type of setting, surveys of rapidly diminishing crop and forage genetic resources are especially needed. A basis for identifying strategies for sampling and monitoring as species ecology and successional and cultural factors is outlined.*

Resumen: *En 1984, 1985 y 1986, en las montañas Air del norte de Niger, se llevó a cabo un catastro para muestrear y documentar plantas silvestres y cultivadas con recursos genéticos para cultivos y forraje. Este inventario ecogeográfico fue iniciado durante la sequia de 1984, después de que ocurriera una considerable desertificación. En esta región han habido alteraciones progresivas, con pérdida de habitat y poblaciones, con posible erosión genética, duranta este último siglo. Se enfocó a especies silvestres y a malezas del conjuncto genético de:* Pennisetum, Sorghum, Olea, Andropogon, Cenchrus, Brachiaria, Eragrostis, Panicum, Setaria, Acacia *y* Ziziphus, *y de cultivos de campos irrigados, incluyendo mijo de perla, sorgo, y cebada. Dado al alto grado de heterogeneidad ambiental y a la pérdida de habitat, sólo pudo identificarse un número relativamente bajo de individuos y agrupaciones. Una porción significativa del conjunto genético en referencia, probablemente presentaba ocurrencias contiguas en el pasad. Es para este tipo de escenarios, que se requiere, en forma especial, de inventarios de los recuross genéticos para forraje y cultivos que se encuentran en rápida disminuidos. A continuación, se delínea una base para identificar estrategias para muestrerar y monitorear la ecologia de las especies y los factores susecionales y culturales.*

* *The author would like to dedicate this paper to the remaining people of the Bagzane and the south Tamgak.*
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A survey of some of the wild and cultivated plants with potential crop and forage genetic resources was made of the Aïr Mountains of northern Niger, west-central Africa. Field missions were carried out in the latter parts of 1984, 1985, and 1986 under the auspices of the government of the Republic of Niger.* Technical and financial support was provided by the International Board for Plant Genetic Resources (IBPGR)** and the Food and Agricultural Organization of the United Nations (FAO), with the cooperation of the World Wildlife Fund (WWF) and the International Union for the Conservation of Nature and Natural Resources (IUCN). The field missions were part of an initial survey of some of the plants with potential crop and forage genetic resources in the Sahel (Ingram 1986*a*).

The goals of the Sahel survey were, first, to more systematically sample the germplasm of wild, weedy, and landrace populations as the basis for more extensive *ex situ* conservation, and secondly, to collect ecological and geographical data as the basis for germplasm evaluation. The survey was undertaken because more precise methods were needed to sample and evaluate wild and primitive material from remote areas undergoing rapid genetic erosion. A third goal was to collect data to lay the basis for more comprehensive conservation *in situ* (Jain 1975; Ingram & Williams 1984) for some populations of wild plants with potential genetic resources, as part of a broader effort by the WWF and IUCN to conserve the natural habitats and biological diversity of the Aïr Mountains (Grettenberger & Newby 1986).

Surveys of Plant Genetic Resources

Surveys of genetic diversity (Gregorius 1978) in wild plant populations as a basis for use of genetic material in crop breeding programs have been carried out since the beginning of the Mendelian revolution and the advent of modern genetics. Over the last century, there has been an intensifying discourse on the relationship between environmental factors and the nature and distribution of intraspecific variation within and between populations of the same species (Turesson 1922; Bishop & Cook 1981).

Centers of drop genetic diversity (Vavilov 1926) have been tentatively identified, as have Pleistocene refuges for some types of organisms. But in a few cases there has been much reflection on the implications of these discoveries for sampling and preservation of genetic variation.

As intra-specific variation has been more systematically recognized and confirmed, the interplay of ecological factors and species and genetic diversity has had increasing relevance to plant breeding and introduction. But only a minute portion of any gene pool will ever be of use. Parallel approaches to identification and procurement of promising subsets of intraspecific variation have emerged. Adapted complexes of alleles and discrete genotypes can sometimes be associated with particular configurations of selection factors. Secondly, certain heterogenous environments support higher levels of species and allelic variation.

As the demand for and potential uses of germplasm in crop improvement and introduction programs have increased, approaches to exploration and survey design have diversified. Unfortunately, out of the muddle of short- and long-term priorities (Brush 1989) and conflicting scientific positions, few principles have emerged. Most problematic has been differentiating approaches to wild, weedy, and cultivated portions of gene pools.

In recent decades, three discussions have laid the basis for development of a pool of methods for sampling, documentation (Thompson 1975), and subsequent *ex situ* evaluation: Bunting and Kuckuck (1970), Qualset (1975), and Simpson (1984). All three approaches assume that (1) sampling strategies (Marshall & Brown 1975) invariably reflect projected priorities for utilization of material in breeding programs; (2) decisions on sampling and evaluation should be based on knowledge of the variation of geographical and ecological factors over a distribution of a species; and (3) different sampling strategies can sometimes produce strikingly different results in capturing genetic diversity within a local gene pool, in determining perspectives on the nature of such diversity, and in its subsequent utilization in breeding programs.

There is a problem, however, with the circular nature of planning ecogeographical surveys: decisions on sampling and documentation determine what variation is captured and, in part, how it is evaluated. This then suggests the nature of the genetic variation and more appropriate sampling strategies. But a high proportion of potentially useful alleles within a gene pool are to be conserved, a number of phases in surveying are necessary. In both planning and the field decisions need to be made systematically and linked for subsequent utilization.

Surveys of one species are complicated, and surveys of a number of species are difficult. Although multi–gene-pool surveys are often more onerous, they are increasingly necessary to efficiently study and salvage populations in areas of rapid habitat alteration and conversion and subsequent genetic erosion. Unfortuantely,

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*** Designated repositories of the genetic material included Danida Seed Centre, Denmark; Forêts et de la Faune, Niamey, Niger; International Livestock Centre of Africa, Addis Ababa, Ethiopia; ORSTOM Bondy, France; ORSTOM Niamey; and U.S. Department of Agriculture. All of the samples sent outside of Niger were to remain the property of the Republic of Niger.*

the techniques for monitoring such loss of genetic diversity are still inadequate, and there are difficulties in working inductive data, on habitat loss, for example, into projections of genetic erosion and into the subsequent establishment of priorities for sampling and monitoring.

How can we set priorities, recognize the inevitable gaps in sampling, and provide the basis for ongoing monitoring in areas of rapid change? And how can we best use multi–gene-pool surveys of geographically and ecologically related variation to develop integrated strategies of both *ex situ* and *in situ* conservation of plant genetic resources? The following example of such a scientific enterprise illustrates some of the opportunities, limitations and dilemmas for integration of ecological data with suspected patterns of genetic variation and subsequent conservation initiatives.

The Aïr Mountains

The Sahel region of Africa is rich in grass and woody species. It has been losing significant portions of this diversity, however, due to the expansion and intensification of grazing and farming, the drying of the climate, and subsequent desertification. In the Aïr, this process of alteration and loss of habitat, with drastic shifts in populations and species compositions, has been occurring for over a century, as comparisons between present conditions and historical descriptions indicate (Barth 1857; Stebbing 1937). Indeed, the climate of the Sahel has been highly unstable since the late Quaternary, with fluctuating periods of drying and increasing rainfall.

The Aïr Mountains extend from roughly 17°N to 21°N and 7°E and 10°E (see Fig. 1). There are four extensive areas above 1,500 meters: around Mt. Greboun; the north Tamgak Plateau; the south Tamgak Plateau; and the Bagzane Plateau. The highest and most extensive area is the Bagzane Plateau, which comprises nearly 5,000 square kilometers. Surrounding these elevated areas is rugged country with smaller massifs, peaks, and canyons with alluvial flatlands (*wadi*), which extend down to just above 500 meters.

The Aïr Mountains, particularly the southern areas, are on the cusp of the Sahara and the Sahel. The area contains Pleistocene relicts such as a *Rhus* sp. and *Grewia* spp., which are more characteristic of temperate mountain floras of the southern Mediterranean directly to the north. More humid phases of recent millennia have brought *afrotropical* (Udvardy 1978) species from the south, and the recent desertification has brought *paleoarctic* (Udvardy 1978, 1984) species such as *Pennisetum divisum* from the north.

Until the last century, virtually the entire Aïr Mountains area was Sahelian with extensive grassland and mountain woodlands. Virtually all of the Aïr is in White's (1983) category of Semidesert grassland and shrubland, with White's categories of Saharan, *regs, hamadas,* and *wadis* expanding into the eastern and northern portions of the area.

In recent decades, dramatic desertification (Niger 1980) has led to rapid loss of habitat and species in many areas. However, certain pockets in the mountains sometimes receive more rainfall and are grazed less intensively, and here some semi-arid forage species have persisted. A number of such valuable species are currently vulnerable to destruction. In addition, as the water table falls, some irrigated gardens become impossible to maintain, which could end cultivation of certain crops and thereby narrow local gene pools in certain areas.

The four massifs with the highest elevations represent a progression of desertification. The most northerly, Mt. Greboun, has been reduced to virtually a Saharan flora, with more Sahelian elements persisting in southerly localities. Because of lack of water, there is little regular human presence or land use in the Greboun area.

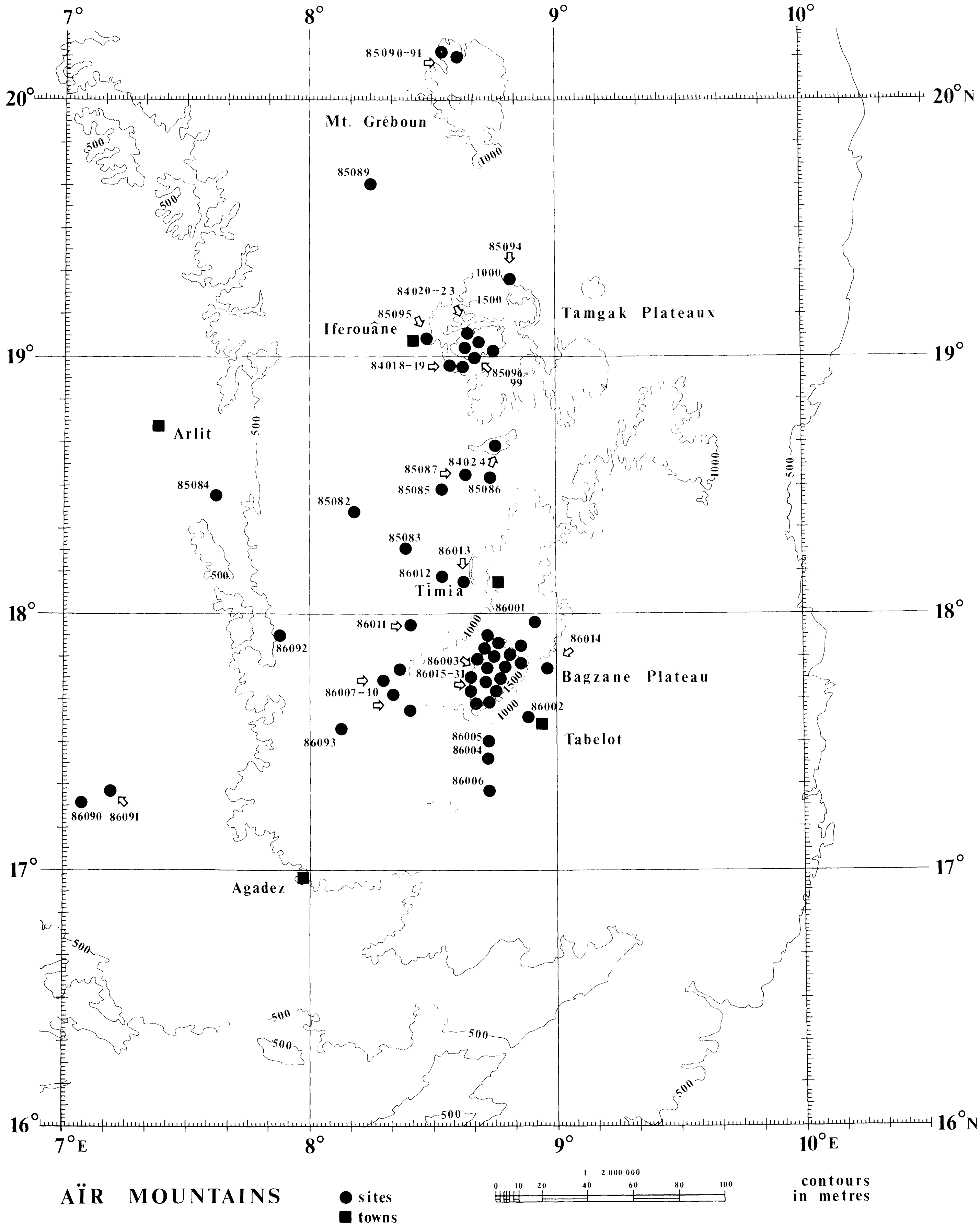
The Tamgak plateaus have a more extensive flora as well as vestigial woodland dominated by *Acacia* spp. and larger stands of *Olea* sp. The Tamgak supports a few families with ties to the village of Iferouâne. The south Tamgak is a rare example of desertification under relatively low human and livestock pressures.

Due to its higher elevation, the Bagzane Plateau in the south of the Aïr receives the most precipitation. Because of its isolation, the Bagzane supports some of the most traditional communities of Tuareg pastoralists and farmers. Unfortunately, high densities of forage animals and expanding gardens have severely altered upland riparian and *wadi* habitats. In recent decades, many *wadi* areas throughout the Aïr have been converted to intensively farmed irrigated gardens.

The role of the Aïr in west African crop domestication is unclear. The Aïr are one of three mountain centers of environmental heterogeneity in the Sahel. Jebbel Marra of Sudan is the best documented (Wickens 1976) and probably the most diverse. The Tibesti Mountains of northern Chad have been the most vulnerable to recent desertification and to the ravages of war.

There are also three areas of extensive riparian habitat in the western Sahel: the headwaters of the Niger Basin, the inland delta of the Niger River, and Lake Chad. All three of these lowland areas have played significant roles in west African crop evolution, including the do-

Figure 1. Ecogeographical survey of some crop and forage genetic Aïr Mountains, Republic of Niger 1984–86—List of site. The numbers indicate the site report numbers which are preceded in the list of sites and NER and the year of the visit and sampling of germplasm.



Mt. Gréboun
Tamgak Plateaux
Iferouâne
Arlit
Tîmia
Bagzane Plateau
Tabelot
Agadez
85090-91
85089
85094
84020-23
85095
84018-19
85096-99
84024
85087
85085
85086
85084
85082
85083
86013
86012
86001
86011
86092
86014
86003
86015-31
86007-10
86002
86093
86005
86004
86006
86090
86091
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1000
1500
7°
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10°
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19°
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17°
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7°E
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1 2 000 000
0 10 20 40 60 80 100
AÏR MOUNTAINS
● sites
■ towns
contours in metres

Table 1. Ecogeographical survey of some crop and forage genetic resources Aïr Mountains, Republic of Niger, 1984–86; list of site reports and samples.

Gene pool	Taxonomic label	Wild	Weedy	Landrace	Major crop genetic resource	Minor food or medicinal genetic resource	Forage genetic resource
			Cereals				
Pearl millet	pearl millet landraces			NER86002-C003[a] NER86006-C018 NER86013-C034 NER86014-C037 NER86014-C038 NER86015-C042 NER86016-C046 NER86017-C053 NER86017-C054	X		X
	Pennisetum sieberianum syn. *Pennisetum americanum* subsp. *stenostachyum*		NER85082-C121 NER85086-C126 NER85086-C128 NER85086-C129 NER85087-C130 NER85095-C141 NER86066-C019 NER86016-C047		X		X
	Pennisetum violaceum syn. *P. mollisimum*	NER84018-C023* NER84021-C036* NER84024-C041* NER85082-C120 NER85083-C122 NER85084-C123 NER85085-C124 NER85087-C130 NER85101-C149 NER85102-C151 NER86090-C190 NER86092-C192			X		X
Possibly in tertiary	*Pennisteum pedicellatum*	NER85097-C143 NER85099-C147 NER86020-C031					X
gene pool of pearl millet	*Pennisetum divisum*	NER85091-C137 NER85094-C140 NER86001-C001 NER86011-C030 NER86030-C108					X
Sorghum	sorghum landraces			NER85086-C127 NER86002-C007(b) NER86006-C020 NER86006-C021 NER86015-C043 NER86016-C048 NER86016-C049 NER86016-C050	X		X
	Sorghum bicolor X *S. arundinaceum*		NER86018-C059		X		X
	Sorghum aethiopicum	NER85090-C136 (Newby 1986)			X		X
Barley	barley landrace			NER86017-C051 NER86017-C052	X		
Lesser-known cereal	*Brachiaria laeta*	NER86028-C104				X	X

* *Possibly all three samples are* Pennisetum pedicellatum.

Table 2.

		Forage grasses					
Gene pool	*Taxonomic label*	*Wild*	*Weedy*	*Landrace*	*Major crop genetic resource*	*Minor food or medicinal genetic resource*	*Forage genetic resource*
Eragrostis	*Eragrostis pilosa*	NER86028-C105					X
Andropogon	*Andropogon gayanus*	NER86008-C023 NER86012-C031					X
	Andropogon tectorum	NER86026-C093					X
Cenchrus	*Cenchrus ciliaris*	NER86004-C015 NER86005-C016 NER86008-C025 NER86015-C040 NER86019-C062 NER86020-C069 NER86022-C075 NER86026-C092 NER86027-C101 NER86091-C191 NER86093-C193					X
	Cenchrus prieurri	NER86008-C024					X
Lasiurus	*Lasiurus hirsutus*	NER85088-C133 NER85089-C134 NER86020-C064					X
Stipa	cf. *Stipa* sp.	NER86020-C067					X
Cynodon	*Cynodon dactylon*	NER86015-C041					X
Setaria	*Setaria verticillata*	NER86002-C002 NER86013-C032 NER86014-C036 NER86018-C057 NER86019-C061 NER86026-C091 NER86027-C099					X
Panicum	*Panicum turgidum*	NER85085-C125 NER85087-C131 NER85089-C135 NER85094-C139 NER85101-C150 NER86003-C008 NER86004-C012 NER86011-C029 NER86030-C107				X	X
	Panicum laetum	NER86020-C070 NER86026-C095					X
	Panicum anabaptistum	NER85067-C099					X
Stipagrostis	*Stipagrostis ciliata*	NER85093-C138					X

mestication of the two most important cereals in the Aïr, pearl millet and sorghum. The significance of upland areas to the intra-specific variation of particular crop gene pools is debatable due to these areas' highly unstable nature. It is very desirable, however, that areas such as the Air be explored for complexes of alleles associated with adaptations to marginal environments.

Mountains involve complex mosaics of biophysical gradients. As one moves north and east in the Aïr, precipitation decreases (Morel, n.d.), temperatures become more extreme, and Saharan elements of flora and fauna become more dominant. But within valleys and escarpments, there are highly variable patterns of precipitation (Niger 1980), geology, geomorphology, soil (Unesco & FAO 1983), and soil water retention. Similarly, the impacts of desertification, with loss of groundwater and

Table 3.

		Trees					
Gene pool	*Taxonomic label*	*Wild*	*Weedy*	*Landrace*	*Major crop genetic resource*	*Minor food or medicinal genetic resource*	*Forage genetic resource*
Olive	*Olea laperrinei*	NER84019, NER84021 NER85092, NER85097 NER86026			X		X
Acacia	*Acacia raddiana*	NER84020-C028 NER85097-C142 NER86002-C004 NER86003-C009 NER86003-C010 NER86003-C011 NER86005-C017 NER86013-C035 NER86014-C039 NER86016-C045 NER86017-C055 NER86020-C071 NER86024-C082 NER86025-C085 NER86026-C090 NER86027-C097 NER86031-C110					X
	Acacia albida	NER86024-C083					X
	Acacia laeta	NER86004-C013 NER86008-C026 NER86010-C028 NER86019-C060 NER86021-C072 NER86022-C073 NER86026-C089 NER86027-C096 NER86030-C109					X
	Acacia seyal	NER86024-C084					
	Acacia ehrenbergiana	NER84020-032 NER84019-C025 NER86009-C027					X
	Acacia nilotica	NER84022-C038 NER86013-C033					X
	cf. *Acacia senegal*	NER84018-C022 NER84018-C024 NER84021-C035 NER84022-037					X
	cf. *Acacia polyacantha*	NER84020-C030					X
Dichrostachys	*Dichrostachys cinerea*	NER86025-C088					X
Ziziphus	*Ziziphus mauritiana*	NER85097-C141D NER85098-C145 NER86021-C034 NER86002-C006 NER86004-C014 NER86018-C056 NER86019-C063 NER86023-C078 NER86025-C086					X
	Ziziphus spina-christi	NER86002-C005					X
Ficus	*Ficus* cf. *salicolia*	NER84020-C027				X	

Table 4.

Other herbaceous species and shrubs							
Gene pool	*Taxonomic label*	*Wild*	*Weedy*	*Landrace*	*Major crop genetic resource*	*Minor food or medicinal genetic resource*	*Forage genetic resource*
Okra	okra landrace			NER86002-C007 NER86007-C022	X		
Cowpea	cowpea landrace			NER86015-C044 NER86031-C111	X		X
Local vegetables	*Grewia flavescens*	NER86022-C074 NER86023-C077 NER86027-C103				X	
	Grewia tenax	NER86023-C079 NER86026-C094				X	
	Grewia villosa	NER86023-C080				X	
Mollugo	*Mollugo nudicaulis*	NER84023-C039				X	X
Rhus	*Rhus tripartita*	NER86018-C059 NER86022-C076 NER86025-C087				X	X
Bauhinia	*Bauhinia rufescens*	NER84023-C040 NER85098-C144 NER86027-C098				X	X
Undetermined	Rubiaceae sp.	NER86029-C106				X	
Ocimum (basil)	*Ocimum canum*	NER85096-C141B NER85097-C141C NER86018-C058 NER86020-C066				X	X
	Ocimum sp.	NER86020-C068 NER86023-C081 NER86027-C100				X	X
Lavender	*Lavandula* cf. *antineae*	NER86027-C102				X	X
Undetermined	*Cucumis* sp.	NER85098-C146				X	X
Cassia	*Cassia senna*	NER85100-C148				X	X

[a] NER refers to the Republic of Niger field missions. 84, 85, and 86 refer to the year the site was first documented, and the three integers that follow refer to the number of the site. The numbers preceded by the C refer to the IBPGR Sahel Survey sample number. Where a site number is not followed by a number with a C, no sample was available.
Unless otherwise noted, taxonomic labels are those used by Hutchinson and Dalziel (1954, 1972).

soil (FAO et al. 1980), are variable over short distances. Site-specific factors may be the most significant and are the most difficult to distinguish in the early stages of surveys of geography- and ecology-related intraspecific diversity (Babbel & Selander 1974; Hamrick 1983).

The most important site factors include: soil depth, surface water, shelter from winds from the north, shade from *Acacia* spp. trees and canyon walls, and the extent of accessibility for grazing by livestock.

Areas of environmental heterogeneity sometimes support distinctive forms of plant evoluation (Briggs & Walters 1984) at the species and intraspecific levels. Elevational and climatic barriers can foster disjunct distributions (Stott 1981). Genotypes can sometimes be correlated to ecology-related selection factors (Endler 1977). Densely packed vegetation zonation can sometimes foster species richness, a diversity of selection factors, and occasional hybridization. But such evolutionary forces require a modicum of stability. And with desertification the nature of the loss and persistence of these assemblages of elements becomes less predictable and more site-specific and random.

The presence of the Tuareg (Bernus 1981) has further fragmented the noncultivated landscapes of the Aïr. This culture links both cosmopolitan and insular communities associated with trans-Saharan trade, pastoralism, and an ancient but erratic history of irrigated agriculture (Thomson 1983). In recent decades, a new wave of Tuareg farming has occurred in response to the destruction of the semi-arid ranges.

Most of the Tuareg use of plants in the Aïr involves wild populations. But the ethnobotany of the Aïr has been barely explored. The southerly dialect of the Tamacheq language (Peyre de Fabreques 1982) was the only guide to local plant names. In the past, both the Tamgak and the Bagzane massifs supported more sedentary communities with origins stretching back to Neolithic cultures; these were displaced in recent centuries as the older, Sahelian agro-ecosystems disintegrated with the desiccation. But there have been many twists to the evolution of land use in recent millennia. This highly variable, isolated, and site-specific pattern of human pressure and domestication in an unstable environment has been characteristic of plant domestication in the Sahel (Munson 1976; Clark 1976; Williams 1984).

Methods of Sampling and Documentation

Multi–gene-pool surveys of intraspecific diversity are needed to efficiently study and sample genetic material over wide areas. There were three central concerns in these IBPGR/WWF-supported field studies: to collect genetic material from a range of natural and agricultural settings; to visit the full range of habitats and environmental gradients in the Aïr region to capture material from less common and diminishing species, especially those severely effected by desertification; and to lay the basis for ongoing procurement of germplasm and *in situ* conservation, where feasible.

The region's biophysical and cultural parameters were reviewed. Areas with steep elevation gradients, and therefore possibly high degrees of diversity of selection factors and genotypic variation, were identified. To sample the full range of genotypes in this region, it was assumed that it was necessary to visit remote and relatively undisturbed areas as well as more accessible agricultural landscapes. It was also necessary to visit the same areas over a number of years with varying annual rainfall. Given the nature of the terrain and environmental gradients, the 1984–86 field work was only a beginning.

In 1984, two weeks in late October and November were spent as part of a reconnaissance of Niger (Ingram 1985). There had been a severe drought and little forage and seed was available (Ingram 1986*a*, pp. 48–49). The Agades-Inferouâne area and the south Tamgak plateau were visited by vehicle and on foot. In 1985, the same areas as in 1984 were visited in late November and early December, by foot and vehicle (Ingram 1986*b*). The northern Aïr, particularly around Mount Greboun, were also visited. In 1986, one month was spent in the southern Aïr focused on the Bagzane plateau (Ingram 1986*c*; Ingram et al. 1987). Travel was by foot and, when they consented, by camel.

Local knowledge was used extensively (Ingram 1985, 1986*b*, 1986*c*; Ingram et al. 1987), but its quantity and quality varied greatly among communities. The guides and local informants played key roles in choice of areas to explore. Samples were often available through their requests to the local gardeners.

On the Bagzane Massif, the irrigated gardens seem to be largely a male affair, whereas knowledge of wild plants was a matrilineal trait. Due to the greater desertification to the north, both taxonomic and ecological knowledge for the other massifs is far less extensive.

The sampling was as random as possible along informal transects within the obvious boundaries of populations. Most populations were relatively small, in some cases just a few individuals. All of the perceived microhabitat and successional variation was represented where possible. Where distinct microhabitat-phenotype correlates were suspected, segregated samples were taken. With small populations, however, particularly where seed availability was severely limited, samples often consisted of nearly all of what was present or could be harvested.

For the germplasm of highly diverse wild populations to be of use in breeding programs, information on morphological, phenotypic, environmental, and ecological factors is necessary. While this data can only provide clues to the adaptations in the population and to the genotypes they represent, if taken systematically they can constitute a framework for isoenzyme and biochemical analysis that can help isolate coadapted complexes of genes and even single alleles for further study.

Such data can also help determine which populations are adequately represented in *ex situ* collection and in protected populations *in situ*. Gaps in germplasm collections and networks of protected areas can be subsequently identified. The wild species in such gene pools can also provide one of a number of foci for environmental monitoring in highly unstable settings such as the Sahel—monitoring that could also influence locally oriented land mangement policies.

Priority Gene Pools

Species recognized to be in the gene pools of the IBPGR crop and forage priorities were the preoccupation (IBPGR 1981, 1985; Williams 1988). Several other species were also included, however, to further the long-term interests of plant germplasm (Bates 1985) and to avoid the rapid disappearance of lesser-known gene pools. A number of other economic plants exist in the region (Dalziel 1948; Burkill 1985; Zeven & de Wet 1982), and in this difficult environment, any species that survives and is regularly eaten by livestock can be considered a potential forage genetic resource for semi-arid regions.

The highest priorities for collecting were the wild species in the gene pools of crops. Due to drought resistance, the species in the primary and secondary gene pools of pearl millet, *Pennisetum glaucum* (Clayton 1986), were given special attention; these included the wild, *Pennisetum violaceum* syn. *P. mollisimum*, and the weedy, *chibra*, *P. sieberianum* (Clayton 1986) syn. *Pennisetum americanum* subsp. *stenostachyum* (Brunken 1977; Brunken et al. 1977; Grouzis 1979; Hanna & Dujardin 1982; Pernes 1984) (Table 1). There are various wild and weedy types of sorghum, including *Sorghum aethiopicum* (Newby 1986) (Table 2). One of the closest wild relatives of olive, *Olea laperrinei* (Quézel 1965), occurs in the area, though germplasm sampling was not possible when they were visited (Table 3). Other priorities were landraces of pearl millet (Clement 1985), sorghum (Doggett 1976; de Wet et al. 1976), barley (Table 1), okra, and other local fruits and vegetables (Table 4). The "winter" wheat was not available for sampling during my visits and the barley samples came from prized personal stashes.

The noncrop priorities included forage grasses and woody species (IBPGR/Royal Botanic Garden, Kew 1984) in the following genera: *Andropogon; Cenchrus;* other species of *Pennisetum* not in the primary gene pool of pearl millet; *Stylosanthes; Panicum* (Naegeler 1977; Williams & Farias 1972) (Table 2); and *Acacia* (Celles & Manière 1980; Hutchinson & Dalziel 1954; von Maydell 1983) (Table 3). Other species that hold promise as semi-arid forage were also included. The last priority was wild, weedy and cultivated populations in the gene pools of the lesser-known Sahel cereals (Porteres 1976), such as species of *Eleusine, Digitaria, Paspalum* (Hutchinson & Dalziel 1972), and *Brachiaria* (only a single sample of *Brachiaria laeta* was found) (Table 1).

Significance of the Samples and Priorities for Further Field Studies

The majority of the species sampled are on the northern, most arid margins of their distributions. None of these species are endemic to the Aïr or to Niger (IUCN Threatened Plants Unit 1984). Given the general pattern of high levels of endemism in tropical mountains, the lack of such populations in the Aïr suggests that such species may have already disappeared with the advent of pastoralism and desertification.

The populations probably represent some of the genotypes that are better adapted to arid conditions. There has not been sufficient time, however, for much evolutionary response, especially for perennials. In this disintegrating ecosystem, factors more random and entropic predominate over those related to natural selection and speciation.

Implications for Sampling and Monitoring Programs in Areas of Rapid Genetic Erosion

As the list of samples suggests, this survey is characterized by a small number of samples of a relatively large number of species. This is problematic for the capture of representative variation. Except for some of the *Pennisetum* spp. samples, most quantities were relatively small.

Ecogeographical surveys should involve strategies for covering an almost infinite array of intraspecific variability and selection factors. But without detailed knowledge of species biology and genetic architecture (Brown 1978), which is years away for all but the best-known crops, we are reduced to extended explorations that second-guess a range of possibilities.

Perhaps the crisis mentality invoked by work in areas with rapid environmental deterioration and supposed genetic erosion obscures issues pertaining to acceptable levels of genetic conservation and documentation and recognition of the limitations of sampling. Namkoong (1983) speaks of "desired diversity" and notes that additional social and scientific choices must be made if we are to conserve intraspecific variation rather than simply avert species extinctions.

In surveying, we must visit as many populations as possible within a brief season and sample them as randomly and extensively as possible. But in the Aïr we walked for days at a time to find tiny quantities of seed from a small number of surviving individuals.

The sampled material may be considered "representative," but "representativeness" is relative to the extent and conditions of particular populations. And a set of samples may be more representative of the declining status of the species within an area than of its historical levels of diversity or fitness.

Landscape Types

Due to limitations related to accessibility and the location of remaining soil and vegetation, most sites and samples were in alluvial areas. Attempts were made to collect from below and along the steep canyon walls, but few samples could be obtained in such areas.

Locations of plants were determined by a number of environmental variables and related cultural factors. The proximity to surface and subsurface water and annual duration of water were the primary determinant of occurrences. Soil type and percentage of stones was a second key set of variables. A third set was slope and aspect. There were two main elevational zones: above and below 1,500 meters. Higher elevations received more rainfall and some night temperatures below freezing.

Human-related disturbance was most pronounced in the bottoms of *wadis* and diminished in drier and less accessible terrain. Virtually all of the large (>1 hectare), flat, alluvial areas with water near the surface are in use for irrigated gardens or livestock grazing.

The categories "wild," "weedy," and "landrace" refer not only to the nature of the genetic material but also to markedly different categories of ecological factors. All of the landraces require irrigated gardens, which receive well water and tilling. All of the weedy material was in adjacent lowland areas with disturbed soil and seasonal livestock grazing. The difference between weedy and wild populations is that weedy species require human-induced disturbance while wild species do not.

Since much of the material was from the alluvial valley bottoms, the ecological gradients stretching from gardens to more "wild" areas were quite narrow. Few gardens were more than 100 meters from uncultivated canyon walls.

Implications for *In Situ* Conservation

It is worthwhile to conserve virtually all of the surviving populations of these wild plants with genetic resources, *in situ,* but the painful fact is that some grazing and human use are inevitable, as are more losses of populations even if the climate were to stabilize. The recently established Aïr and Ténéré Nature Reserve (Grettenberger & Newby 1986) could employ a more extended survey approach with some of these species as the basis for ongoing monitoring in the northern part of the Aïr.

The irrigated agriculture situation is far too unstable for *in situ* conservation of the landraces to be possible. This is not to suggest that the types of *in situ* conservation in agricultural landscapes proposed by Altieri & Merrick (1987) is not workable for some settings in the world. But the history of agriculture in the Aïr Mountains suggests that gardens have been neither stable enough nor sustained long enough to permit easy and secure preservation of the full range of genetic variation of crops.

The cosmopolitan nature of Tuareg society, lying as it does at the southern end of the old trans-Sahara trade routes, has encouraged enthusiastic experimentation with introduced material rather than preservation of old varieties, especially now with the influence of Islam intensifying. Some local farmers, however, expressed the hope of adapting longstanding varieties for new conditions in the expanding irrigated gardens.

As for wild populations, a diversity of categories of culturally relevant protected areas and management zones are necessary. The national park option is presently unavailable for the management of the Bagzane, where higher human densities require more severe compromises.

In the northern parts of the Aïr, where depopulation has been severe, a more classically preservationist position may be preferable especially for management of the influx of affluent European tourists with all-terrain vehicles (who come down from the north). The goals of *in situ* conservation for an array of populations, species and communities will need to be clarified.

The remaining plant genetic resources of the Aïr are products of a long evolution with a rapid entropy. Maintenance of the selection factors associated with the former ecosystems in order to conserve the area's genetic variation is a contradiction in terms. But the erroneous assumption that some sacks of seeds from a few seasons can represent more than a small portion of local plant genetic resources will ultimately be an obstacle to germplasm utilization and conservation. Authentic conservation of the genetic resources will ultimately require a plan for monitoring and ongoing procurement of germplasm that is integrated with land management and the aspirations of the local Tuareg for their chosen forms of sustainable development.

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