Staff Report: ENVIRONMENTAL DEGRADATION IN MAURITANIA

Board on Science and Technology for International Development

Commission on International Relations

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A Report of Working Discussions held by officials of the Government of the Islamic Republic of Mauritania and the U.S. Agency for International Development, and a panel of scientists convened by the National Research Council, and subsequent activities undertaken by the staff of the Advisory Committee on the Sahel

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CONTENTS

SUMMARY vii

CHAPTER I: AN OVERVIEW OF THE WORKSHOP 2

Background 2
Workshop Organization 2
Workshop Results 8

CHAPTER II: ENVIRONMENTAL REHABILITATION 12

Approaches to Project Identification 12
Recommendations 18

Appendixes
A: List of Participants 48
B: News Clippings 51
C: An Overview of Land Use and Environmental Change in Mauritania 52
D: Seed Distributed by BOSTID for Experimental Planting in Mauritania 84
E: Proposal to Establish Two Agro-silvo-pastoral Centers in Mauritania 87
F: Aerial Seeding 95
G: A Representative Listing of Organizations Collaborating with ACOS Staff 99

LIST OF ILLUSTRATIONS, MAPS, AND TABLES

Mauritania 1

Summary of Environmental Problems and Suggested Solutions 3

Workshop Itinerary 6

Generalized Ecological Provinces 15

Energy Flow Diagram 17

Precipitation Totals and Generalized Crop-Year Subtotals for the Arizona Source Areas of the Dry-Farmed *Zea mays* Seed Distributed in Mauritania and Representative Stations within the Central Oasis Zone 26

Map of the World According to Pomponius Mela, A.D. 43 57

Map of the World According to Ptolemy, A.D. 150 58

The "Bilad al-Sudan" According to Ibn Sa'id, *fl.* 1286 65

Western Africa and the Cape Verde Islands from the *Atlas of Grazioso Benincasa*, 1468 71

Woodcut Map of Africa, Munster, 1540 72

Part of a Map of Africa, from the *Diogo Homen Atlas*, 1558 73

Carte de la Partie Occidentale de l'Afrique, Sr. D'Anville, 1727 74

Map Showing the Progress of Discovery and Improvement in the Geography of North Africa, J. Rennell, 1798 75

West Africa, Society for the Diffusion of Useful Knowledge, Mid-19th Century 77

Diagram of Agroforestry Center 92

SUMMARY

This report describes the background, organization, and initial results of the Mauritania Environmental Workshop. The Workshop objectives were to enhance the sensitivity of Mauritanian officials to the consequences of environmental degradation, and to provide the USAID Mission and government officials with environmental information to use in the formulation of mission projects.

The second part of the report discusses a number of approaches to the environmental rehabilitation of Mauritania, including specific project proposals which are designed to meet not only environmental imperatives but provide socio-economic incentives for their implementation by Mauritanian villagers and traditional social organizations.

The report also includes an historical review of the environmental changes that have taken place in Mauritania. This review was undertaken by BOSTID staff following the workshop, and was necessary because no satisfactory comprehensive overview of the underlying ecological processes was available. An understanding of these processes is essential to determine the causes of environmental degradation and to provide a logical basis for designing and recommending development activities that will encourage ecological and environmental rehabilitation, rather than continue to contribute to degradation. The review had the following objectives:

- To attempt to identify from historical and other sources the species of plants and animals that were found in Mauritania at various periods

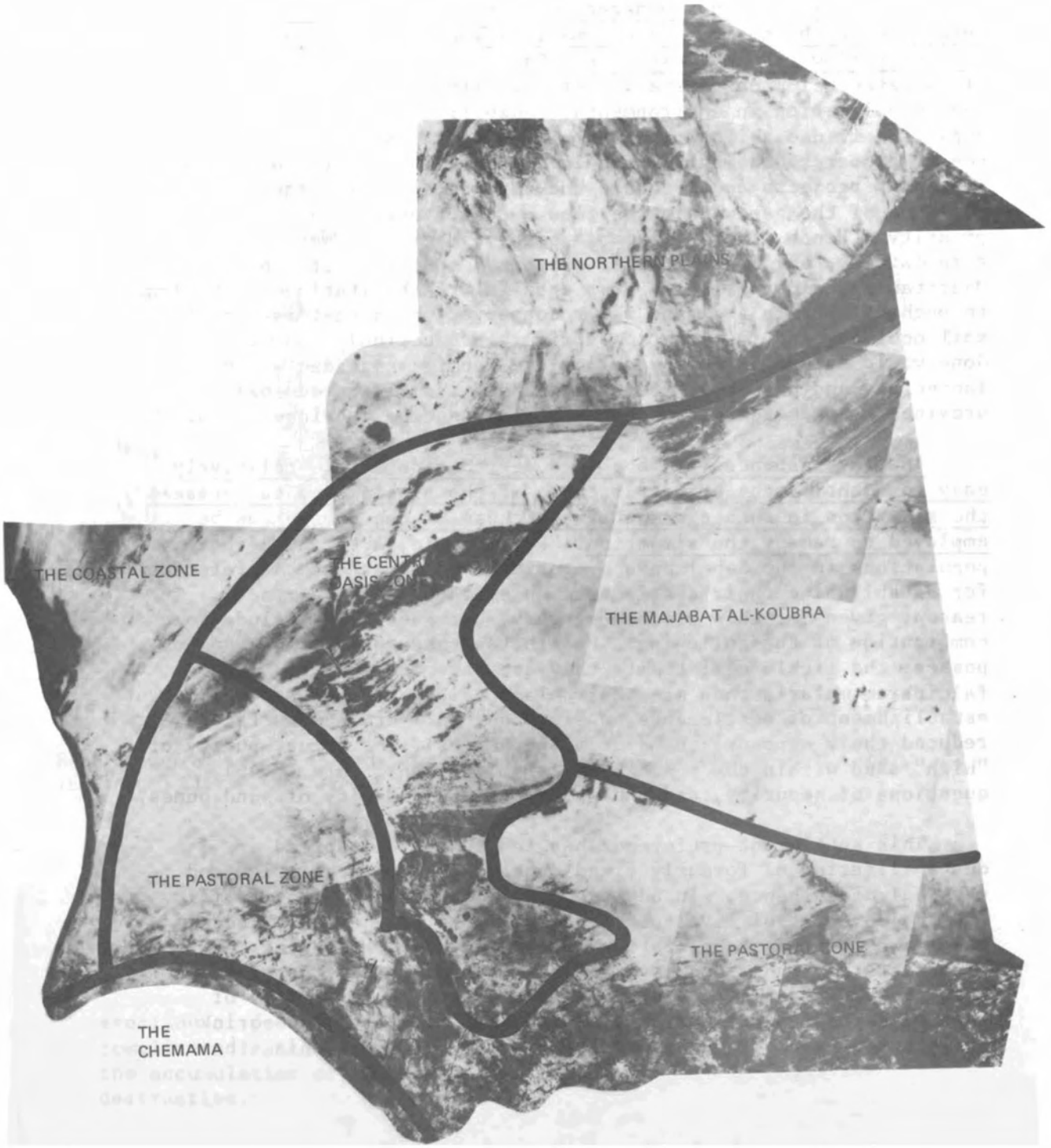
- To relate changes in species composition to climatic and human events and to evaluate their relationship with ecological processes

The base-line information was then compared cartographically with the current status of the region, and the principal agents of environmental change were identified from the literature. The use of various historical charts and maps of the regions permitted a somewhat more satisfactory review of environmental change than could have been achieved through the literature alone, as it both helped target problem areas and allowed the spatial dimensions of progressive degradation to emerge more clearly.

Identification of the agents and processes responsible for degradation is of critical importance to the formulation of a well-focused, effective rehabilitative program. These include charcoal production on the desert margins in association with the caravan trade and, with the expansion of various savannah kingdoms into the region, the introduction of grazing livestock into Sahelian ecosystems and the consequences of each. This knowledge permits developers to deal with problems analytically rather than resorting to supposition or confusing the exacerbating effects of drought with causation. (The native flora and fauna of the region are generally adapted to cope with the range of climatic variation characteristic of the region. Drought, unaccompanied by widespread degradation or poorly adapted livelihood systems, would not result in unusually severe ecological disturbances.)

Because of the structure of environmental systems, the losses of flora and fauna identified in this comparison represent major problem areas in the general dynamics of the Mauritanian environment. At this level of generalization, for example, the comparisons reveal substantial losses of forest, perennial grasses (inferred), and wildlife; indicate significant zonal compression; and permit one to draw additional conclusions based upon generally understood cause-effect relationships (for example, devegetation/breakdown in nutrient cycling/surface sealing and erosion on non-sandy surfaces/depressed ground-water tables/altered soil ecology/declining seed supply and conditions increasingly antagonistic to regeneration/reduced wildlife populations/and so forth). This level of analysis, in and of itself, permits the identification of certain program elements. For example, the problem of zonal compression might be relieved by coordinated efforts above the 150-mm isohyet in ground-water recharge, the aerial seeding of desert legumes along the lines of the Rajasthan experience, and the protection or reintroduction of wild herbivores, such as the mouflon and addax, which were formerly important agents of seed dispersal. (Approaches to ground-water recharge and aerial seeding are discussed in subsequent sections of this report.)

Further refinement permits identification of generalized ecological provinces.



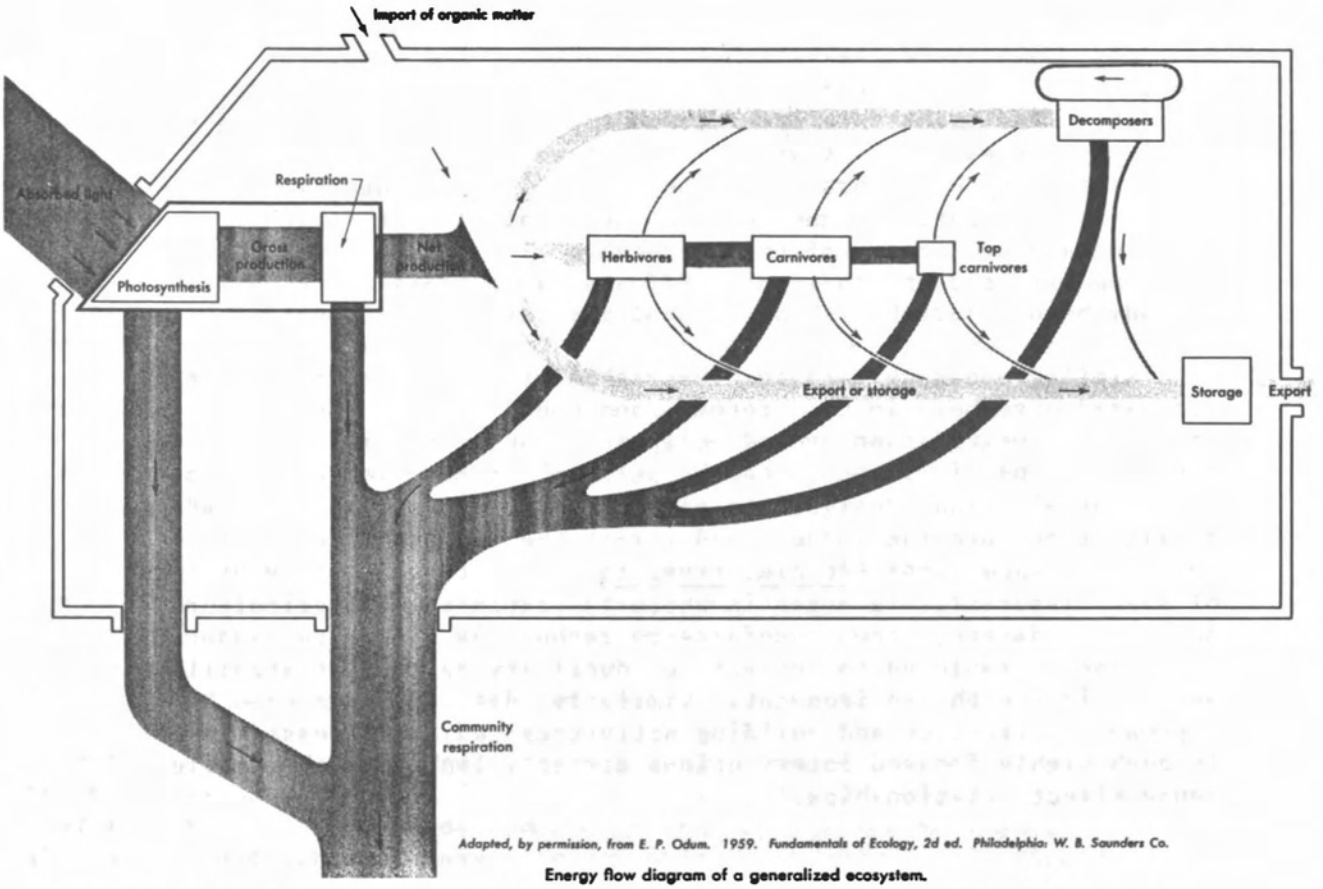
GENERALIZED ECOLOGICAL PROVINCES

The base mosaic was prepared by the Remote Sensing Institute at South Dakota State University under USAID contract AID/afr-C-1619. It has been provided courtesy of the Institute, USAID, and the Mauritanian government.

These smaller, more manageable units can then be analyzed with reference to the normal transformations and sequential dependencies of energy flow within ecosystems. Energy flow models such as that illustrated below can serve as particularly useful aids to conceptualization in environmental rehabilitation efforts. In a sense, their use shifts the burden of project identification from the developer to the system itself. "Gaps" in energy flow would represent projects and, because the dependencies are sequential, the position of the gap within the flow sequence determines its priority. Hence, the approach is highly specific. Not surprisingly, according to this approach, most projects in Mauritania would initially focus upon the rehabilitation of the land through efforts in soil and water conservation, a restoration of soil ecology, and revegetation (primary production). How this is done would depend largely upon how the gap is expressed on the landscape, and how it relates to the dynamics of the ecological province. Suggested approaches are discussed by province below.

In many instances of localized degradation, it is relatively easy to identify the principal cause of the problem and to reassess the situation in such a way that the cause of the damage can be employed to remedy the situation. For example, Arab and Berber populations in the Sahel have historically demonstrated a preference for establishing their settlements on elevated sandy surfaces. The reasons given for this preference vary, but generally include some combination of the following: health (as these populations do not possess the sickle-cell trait, they are far more susceptible to falciparum malaria than are their black neighbors, and the establishment of settlements on elevated, well-drained surfaces reduced their exposure to malarial parasites), the ritual purity of "high" sand within the context of Islam (Qur'anic sura IV.46), questions of security, and the water storage capacity of sand dunes.

This settlement preference has led to the widespread destabilization of formerly fixed dunes through devegetation and physical disturbance. In addition to disturbance by foot traffic and the movement of livestock, vehicular traffic has contributed considerably to destabilization in recent years. Changing architectural traditions have further contributed to the problem. Less than 20 years ago, Boutilimit was described as "a city of tents," a description that contrasts sharply with the mud-brick buildings of the city today. In many areas of Mauritania, the



Energy flow diagram of a generalized ecosystem.

Reprinted from Edward J. Kormondy, Concepts of Ecology, Prentice-Hall, Inc. (Englewood Cliffs, New Jersey, 1969), p. 30.

erection of permanent structures in mobile landscapes has greatly complicated matters, as the buildings themselves are responsible for the accumulation of sand which ultimately results in their destruction.

In Mauritania, most settlements with populations large enough to cause destabilization also serve as administrative centers: Shinqit, Tijikja, Nouakchott, Moudjeria, Boutilimit, Magta Lahjar, Boumdeid, Walata, Tamchekket, Mederdra, Kiffa, and Timbedra. Recognition of the problem, coupled with administrative support and available labor, presents numerous possibilities for addressing the problem. For example, it would be relatively easy to establish nurseries in such centers under the care of local Protection of Nature representatives, and to organize local efforts for the planting and protection of trees and shrubs in order to stabilize the community and its environs. Efforts along these lines have already been undertaken through local initiative at Boumdeid.

Similar opportunities to "reverse" destructive processes are discussed elsewhere in this report, and would include the following. Degradation around wellpoints caused by high concentrations of livestock can be partially controlled by protected wellpoint plantings designed to aid precipitation interception and infiltration, provide fodder, and permit the livestock fed on the collected legume pods (Acacia, Prosopis, etc.) to serve as vehicles of seed dispersal. In areas in which the expansion of agriculture has caused damage, known agroforestry techniques and better-adapted crops can be employed to increase productivity as well as stabilize and ameliorate the environment. Similarly, degradation caused by highway construction and building activities can be addressed through highly focused interventions directly linked to observable cause-effect relationships.

RECOMMENDATIONS

The approaches taken have led to a preliminary identification of activities within the various ecological provinces that would contribute to the restoration and maintenance of essential ecological processes, reestablish genetic diversity, and help assure the sustainable utilization of species and ecosystems. Additional project possibilities are suggested in response to special needs or in an effort to take advantage of particular environmental assets within the country. A concerted effort has been made to offer recommendations that are well focused and realistic, that can be pursued within the context of existing social and administrative structures, and that are sensitive to immediate- and long-term economic constraints. The recommendations are roughly ranked within each ecological province in such a way that projects would sequentially restore critical processes.

I. The Northern Plains (extending from the Zemmour to the al-Hank escarpments)

A. Inventory of Biological Resources and Evaluation of Rigaibat Use Patterns and Needs. This province was not visited during the Environmental Workshop or in connection with various BOSTID staff visits to Mauritania. The use history of the province, particularly the exploitation of Acacia raddiana for charcoal production in association with the Saharan trade, and the recorded presence of wildlife species such as ostrich, dorcas and dama gazelles, and the addax suggest that an inventory of the biological resources of the plains would be desirable to determine the extent of the losses and the nature of the remaining assets. The need for such an inventory is described in a Mauritanian proposal, "Etude sur la faune et l'avifaune" submitted to the IUCN subsequent to the Mauritania Environmental Workshop. Further research might be conducted into Rigaibat use patterns and needs in relation to the possible rehabilitation of the province.

B. Evaluation of Pollution Associated with Mining Activities. Disturbance associated with mining activities around Fderik evidently contributes much of the particulate matter that descends upon Nouakchott during the dry-season dust storms. This material, derived from the highly mineralized mobile belt bordering the Afro-Arabian craton, contributes some fertility to the regions affected, as well as annoyance and health hazards to the inhabitants of these regions. Law No. 77-204 of 30 July 1977 includes a provision in the Mining Code concerning "the obligation to repair all damage which the work may occasion to surface property." Should it be determined that the "costs" of the dust outweigh the benefits, and should on-site disturbance and nuisance to the inhabitants of Nouakchott be accommodated by the provision, there exist a number of technical approaches to the stabilization of such areas.

II. The Majabat al-Koubra

Medieval descriptions of the Majabat al-Koubra indicate that the region contained several species of plants and animals: truffles (kam'a), palms, "a little tree of the kind that grows in the sand," insects such as flies and lice, snakes (hayya); and herds of addax (al-baqar al-washshiyya). The Masufa, ancestors of the modern Namadi, also lived in the region with their hunting dogs.

The continued presence of substantial numbers of addax in the Majabat al-Koubra was recorded in recent years by M. R. Chudeau in 1920, by G. Bouet in 1934, by Bigourdan and Prunier in 1937, by

Lieutenant Sévenet in 1943, by M. Lenormand in 1950-1952, by V. Monteil in 1951, by G. Roure in 1952, and by C. Timothée in 1955. Théodore Monod, traveling between Arawan and Aratan in 1960, recorded a density of addax on the order of 17 per 100 sq. km. Monod has also recorded a considerable diversity of plants and other forms of wildlife in the Majabat al-Koubra, including several species of birds, the fennec fox, and jackals. The feeding habits of the various animals recorded futher implies the presence of other species. For example, the addax and fennec obtain water from the rhizomes of Philipaea lutea and the addax subsist largely upon Aristida pungens.

While various travelers, petroleum prospectors, and others observed occasional addax in the Majabat al-Koubra during the 1960s and 1970s, verified sightings have declined abruptly in recent years. This decline can be largely attributed to increased hunting pressure. For example, in 1974 a Mauritanian forestry agent confiscated a shipment of approximately 700 kilograms (kg) of tishtar near Tishit. Given the weight loss in the drying process, this would represent between 30 and 35 antelopes. Similar examples are numerous.

The addax of the Majabat al-Koubra supported the Namadi hunters of the region. As the addax populations of the region have declined, so too has the culture and livelihood of the Namadi.

A. The Creation of a Wildlife Reserve in the Borderlands of the Majabat al-Koubra. The principal, and most urgent, recommendation for the Majabat al-Koubra province is the creation of an extensive wildlife reserve extending from Walata westward through the southern extent of the Majabat al-Koubra and adjacent areas of the Awkar and Tagant regions, and northward into the Mauritanian Adrar.

The historical record does not suggest that the support capacity of the region for the principal wildlife species of the proposed reserve (addax, oryx, mouflon, and ostrich) has declined appreciably in recent years. Hence, extensive efforts in environmental rehabilitation would not be a prerequisite to other reserve functions and activities.

The creation of the reserve would serve various social, economic, and environmental objectives. It would permit the protection or reintroduction of various species of wildlife that have long served as important sources of food, that have in the past attracted numerous tourists and hunters to the region, and that play critical roles in the stimulation of vegetation and seed dispersal.

The importance of wildlife as a dependable source of high-quality food has been consistently underestimated by Sahelian governments and development agencies. The high social value assigned to bush meat in Mauritania is well attested. It should also be noted that the potential standing biomass of wildlife populations is much greater than livestock populations living under similar conditions. For example, studies undertaken in East Africa indicate that acacia savannah carrying 19.6 to 28.0 kg per hectare (ha) of cattle can carry from 65.5 to 157.6 kg/ha of wild ungulates. In contrast to domesticated livestock, wild animals occupy distinct and usually complementary ecological niches; food preferences are largely complementary; wildlife utilize foraging resources that are often too coarse for most livestock; and wild animals use water more efficiently and are more tolerant of stress and disease. Hence, the wildlife of the reserve could serve as an important source of food during periods of want.

In accordance with emerging multiple-use emphasis in reserve management, regulated hunting could also be conducted in the reserve and could serve as an important source of revenue for the government. The creation of the reserve could also be useful in providing employment for the Namadi, a group whose knowledge of the animals of the region is unsurpassed, and could generally stimulate economic activity in the oases bordering the Majabat al-Koubra.

Within the more general framework of environmental rehabilitation, progressive efforts in habitat improvement could be better justified in economic terms with the establishment of a reserve, and the efforts would help relieve pressure on the increasingly compressed Sahel zone to the south by enhancing the genetic diversity of the reserve area and restoring essential processes. The reserve could also serve as a much-needed West African dryland biological laboratory for the study of minimum critical habitat for desert species, stress-avoidance mechanisms in desert organisms, and other similarly neglected areas of research.

Various approaches to the creation and maintenance of such a reserve were discussed at the Central and West African Conference on Protected Areas held in Ouagadougou in February 1980. It is suggested that the Mauritanian government and interested donors pursue this matter in cooperation with the Commission on National Parks and Protected Areas of the International Union for Conservation of Nature and Natural Resources.

III. The Central Oasis Zone

It was pointed out during the Environmental Workshop that rapidly falling ground-water levels are a particularly serious problem in the oasis zone. While the impact of this problem upon agricultural production is well understood, the relationship of depressed ground-water tables to environmental degradation is often less well understood. As noted above, falling water tables directly result in the elimination of those plant species physiologically incapable of retrieving water from lower levels. Further losses follow as dependency and affinity relationships are disturbed within plant communities. The reduction of plant cover leads to surface sealing, which further depresses the ground-water table, and to erosion which reduces the capacity of the land to support revegetation.

Falling ground-water levels also contribute to the destabilization of formerly immobile sand dunes. In addition to supporting vegetative cover on dunes, the ground water drawn into the base of a dune through capillarity itself contributes to adhesion and introduces cementing agents in solution (such as Fe_2O_3 and SiO_2 in the Adrar) which further stabilize the dune. Depressed water tables sharply reduce the contributions of capillary water to surface stabilization.

A. Efforts in Water Conservation and Ground-Water Recharge. During the Kiffa discussions, Protection of Nature agent Eyih Banda recommended that the problem of falling ground-water tables be addressed initially through the imposition of severe restrictions upon the use of motor pumps in drawing water. A complementary measure would be the initiation of systematic efforts in water conservation and ground-water recharge. While the elements of such a program would necessarily be determined by site-specific circumstances, they might include such proven approaches as revegetation supported by various water-harvesting techniques and the use of sand-filled storage dams to capture and hold runoff water that would otherwise be lost. Many of these approaches are discussed in a 1974 National Academy of Sciences publication, More Water for Arid Lands: Promising Technologies and Research Opportunities.

Several of the approaches that would be appropriate for the oasis zone could simultaneously serve other objectives. For example, water held in sand-filled reservoirs could support crops sown on the reservoir surface. The water drawn off through drainage pipes could be used to maintain livestock or wildlife.

Water-harvesting techniques can also be used to support the establishment of multipurpose shelterbelts in areas where conventional approaches would be frustrated by inadequate precipitation.

B. Sand Dune Stabilization and Utilization (Approaches and Demonstration Workshop). Many of the oases of this zone suffer from problems of encroaching sand. As indicated above, in those instances in which surface disturbance and use pressure are directly associated with population centers, approaches to stabilization that take advantage of the available labor and social structure of such centers to solve the problem should be encouraged. Elements of the solution might include minimal training in nursery and dune stabilization techniques for key individuals (perhaps the Protection of Nature representative and individuals identified for active roles in stabilization efforts by traditional leaders), the establishment of a community nursery, and project implementation with external technical backup.

The training might be provided by a BOSTID demonstration workshop held in a place that is frequently visited and regarded as being of significance to the peoples of the oasis zone. Even though other cities are more threatened by dunal encroachment, Nouakchott would perhaps be the most logical choice.

In anticipation of the workshop, the government would select the dune to be stabilized during the workshop and would be responsible for providing seedlings and procuring millet stalks or other materials to be used for mechanical stabilization in the demonstration effort. This could be done in cooperation with development agencies already involved in stabilization efforts in Mauritania.

BOSTID would be responsible for identifying experts in dune stabilization who have proven themselves under conditions similar to those encountered in the oasis zone. Possibilities would include R. N. Kaul, Director of Forestry Research at the Indian Forest Research Institute at Dehra Dun, and Fred R. Weber of the International Resources Development and Conservation Services. Other BOSTID responsibilities would include providing information regarding the species of seedlings to be grown in advance of the workshop (and possibly the provision of seed), the workshop schedule, as well as details regarding the filming of the workshop and production of the training manual.

The participants would emerge from the activity with training in nursery techniques, with practical experience in dune stabilization, with a concise illustrated manual on stabilization, and with access through the government and various donors to the continuing support necessary to assure project success.

With regard to questions of species selection, mechanical stabilization might be attempted with Euphorbia balsamifera, Agave spp., or palm fronds as well as with millet stalks or other appropriate crop residues. Plantings within the checkerboards for further stability and the contribution of organic matter might include species such as Acacia senegal, A. raddiana, Cercidium floridum, and Prosopis juliflora. Each has been successfully planted in analogous situations elsewhere.

In addition to the attention directed toward the hazards of dunal encroachment, it would be well to remember that dunes also possess a variety of valuable characteristics that might be better exploited. For example, dunes efficiently intercept and store rainwater. Further, many dry-land plants of economic value are typically associated with sand dunes, including such locally important species as Acacia senegal (gum arabic) and promising exotic species such as Simmondsia chinensis (jojoba). Sand can also serve as a moisture-conserving mulch on agricultural lands.

In many instances, the potential benefits are relatively obvious and could be cited to further justify stabilization in economic terms and to encourage local participation in stabilization projects. It is clear, for example, that the destabilization of dunes around Boutilimit and Mederdra is, in large measure, the result of the disappearance of formerly important gum forests. Hence, the restabilization of the dunes might appropriately be undertaken by restoring the forests. It could be convincingly argued that this would actually constitute an effort to increase gum arabic production and that dune stabilization would merely be a by-product of the effort. Such an argument would undoubtedly be more appealing to the local population than the more intimidating proposition that they are being charged with the task of holding back the desert.

C. The Application of Agroforestry Techniques to Oasis Agriculture. The stability and productivity of oasis agricultural systems could in many instances be increased by the application of agroforestry techniques. These might include increased use of field trees and living fences, more diverse and better-adapted crops, planting browse reserves on marginal lands, and establishing multipurpose shelterbelts.

FIELD TREES. The appropriateness of the more commonly known field trees (Acacia albida, A. senegal, etc.) would naturally be determined by local considerations. Although field plantings of A. albida would normally be discouraged to the north of the 300 mm isohyet, such plantings might be attempted with some success within the oasis zone based upon the historical presence of the species in the area and the greater relative availability of ground water in many oases. The establishment of field trees is to be encouraged for many reasons: micro-climatic amelioration, nutrient cycling, nitrogen fixation, improved soil ecology, better precipitation interception and infiltration, and erosion control. The reverse foliation of A. albida is particularly attractive as it comes into leaf following the rainy season and remains green during the hot, dry season. Hence, it does not deny sunlight to crops during the most critical period of their growth and provides livestock with shade (which reduces their water requirements) and forage following the harvest. The manure deposited by the livestock around the trees during the dry season further enriches the field for the next cropping cycle.

LIVING FENCES. Many useful tree and shrub species serve well as living fences. For example, Prosopis juliflora fences produce palatable leaves, pods that are eaten by livestock or can be ground into flour for human consumption, flowers that produce nectar of good quality for honey, and wood for fuel. Further, the trees coppice, accommodate nitrogen-fixing bacteria, and serve several of the other functions noted with regard to field trees. The bee populations that the fences help support are of critical importance in pollination and seed production. It might be added that some care should be taken in the placement of Prosopis trees, as there is concern that they might harbor nematodes. Acacia senegal, with its contributions of gum arabic, tannin, browse, and fuelwood, can also be used in living fences, as can A. albida, A. ataxacantha, A. macrostachya, Commiphora africana, Dichrostachys glomerata, Dodonaea viscosa, Euphorbia balsamifera, Parkinsonia aculeata, and a variety of other species.

BETTER-ADAPTED CROPS. Planting crops that require less water could both help conserve ground water and reduce the risk of crop failure on marginal lands. A number of food crops and crops of enonomic interest could actually be dry-farmed in most of the central oasis zone (see table p. 26): Amaranthus spp. (grain amaranth), Cucurbita mixta (Cushaw squash), Echinochloa turnerana (channel millet), Phaseolus acutifolius (tepary beans), P. coccineus (Tarahumara runner beans), P. lunatus (Hopi mottled lima beans), P. vulgaris (Tarahumara pink beans), Sesamum indicum (sesame), Zea mays (Pima-Papago 60-day maize); Cyamopsis tetragonoloba (guar), Simmondsia chinensis (jojoba), and others. There is also a native

Precipitation Totals (in mm) and Generalized Crop-Year Subtotals for the Arizona Source Areas of the Dry-Farmed Zea mays Seed Distributed in Mauritania, and Representative Stations within the Central Oasis Zone.

Stations	Crop Year										Sub-Total			Annual
	J	F	M	A	M	J	J	A	S	O		N	D	
Casa Grande (Arizona)	18.2	19.5	15.2	5.0	1.5	4.3	28.1	27.6	19.3	7.8	82.8	16.7	24.1	187.3
Tuba City (Arizona)	13.9	14.4	9.9	12.9	6.6	7.8	21.5	20.3	19.3	16.7	77.8	12.9	14.2	170.4
Atar	2.1	1.4	1.5	0.3	1.3	2.4	5.9	31.9	37.8	7.5	83.1	7.5	4.3	103.6
Kiffa	0.6	0.8	0.8	0.9	3.7	24.6	91.3	121.1	85.9	16.6	314.9	2.4	2.0	350.7

Sources: Smith, H.V. The Climate of Arizona. Bulletin 197. Agricultural Experiment Station, University of Arizona, 1945

Toupet, Charles. La sédentarisation des nomades en Mauritanie centrale sahélienne. Thèse présentée devant l'Université de Paris VII le 10 Avril 1975.

Peruvian strain of cotton that might be considered. It is unusually resistant to insect infestation and disease, "virtually grows in the desert," is grown without the use of insecticides or fertilizers, contains natural pigmentation (the fibers produced are white, tan, brown, chocolate brown, or purplish-gray), and is higher yielding than commercially harvested cotton in Peru. Seeds for some of these species have been provided by BOSTID for experimental plantings in Mauritania, and the seeds of several other species of possible interest have been requested.

In addition to the possibility of introducing crops previously unknown in the oasis zone, it might be well to consider the reintroduction of crops once commonly grown in the zone or in climatically analogous regions elsewhere within Saharan Africa. Although the following list is drawn from several sources, it is based largely upon the 19th-century observations of Gustav Nachtigal. In addition to mention of northern grains such as Triticum (wheat) and Hordeum (barley), southern cereals such as Sorghum (dhurra) and Pennisetum (dukhn) were grown. Some mention is

made of Zea mays as well. With reference to vegetables, Vicia faba (broadbean), Lablab purpureus (lubia), and Pisum sativum (peas) were grown, as were: Daucus carota (carrots), Corchorus olitorius (jute), Abelmoschus esculentus (okra), Brassica rapa (turnips), B. oleracea (swedes and cabbage), Cucumis sativus (cucumbers), various kind of melons (batteikh and dulla), Cucurbita pepo (pumpkins, squashes), Portulaca oleracea (purslane), Solanum melongena (eggplant), Lycopersicom esculentum (tomatoes), Raphanus sativus (radishes), Beta vulgaris (beets), Allium cepa (onions), A. sativum (garlic), and Capsicum annuum (chili peppers). Other cultivated food crops included Malva parviflora (little mallow), Cuminum cyminum (cumin), Coriandrum sativum (coriander), and Capsicum conicum var. orient. (Sudan chillies or shetta). Capsicum spp. are often listed as items traded by the oasis dwellers for the products of Europe and the lands of the Mediterranean. As domesticated capsicum peppers are generally considered to be New World species, it is of some interest that they are evidently listed as trade items of African origin in Portuguese commercial documents predating Columbus's voyage in 1492.

In addition to the date palm, Ficus carica (fig trees), Citrus limon (lemon trees), and C. aurantium (Seville orange trees) were reported in many oases. Grapes were grown in medieval Awdaghast as well as in many other oases, and raisins have long been an important trade item. Apple and quince trees were found growing in Murzuq by Nachtigal. Almonds, peaches, and apricots have done well in various oases. Pomegranates did well and were widely distributed. Olive trees were also found in many oases.

Economic crops include Gossypium herbaceum (cotton) and Indigofera argentea (indigo). Alfalfa and clover (safsafa or fossa) were grown as fodder, and Nicotiana rustica (Aztec tobacco) was grown for local use. Some flax is reported as well; bottle-gourds were grown; and henna has long been a popular crop in the Saharan oases. A particularly versatile species that has been neglected in recent years is Stipa tenacissima (esparto grass). Esparto fiber was long used for the manufacture of paper in England and Italy; for weaving such items as sandals, hats, and carpets; for rope, fuel, stock feed; and for other uses. Wax, extracted from the grass by mechanical cleaning, approaches carnauba in quality.

In determining the species content of shelterbelts and other plantings, it would also be well to remember the historical significance of various wild food sources to oasis dwellers: for example, colocynth, Zizyphus spina-christi, Z. lotus, Hyphaene thebaica, truffles, Nitraria tridentata, and the seeds of the Aristida pungens so important also in maintaining addax populations.

It is easy to be struck by the poverty of oasis agriculture in modern Mauritania, both in contrast with accounts from medieval Mauritania and accounts from oases elsewhere. Some of the slippage can be attributed to factors of social change; some to environmental degradation. This survey nevertheless indicates that the potential for substantially increased crop diversity exists and provides some guidance for species selection in oasis agriculture programs in Mauritania.

BROWSE RESERVES. The presence of browse trees and shrubs on marginal lands serves as a conservation measure, as a seasonal source of forage for livestock and as an emergency source of food for human populations (many browse species bear fruit, leaves, gum, or other edible substances), and as a source of income through the sale of gum arabic and other collected products. Such plantings further contribute to local environmental amelioration, intercept precipitation and promote infiltration, and serve other environmental objectives.

SHELTERBELTS. Although the use emphasis shifts from the needs of livestock to the requirements of human populations in shelterbelt design, shelterbelts offer a range of benefits in many ways similar to those described in connection with living fences and browse reserves. (The physical exclusion of livestock from shelterbelts is proposed to avoid the removal of the understory and the selective elimination of many legumes and other plants that contribute to human diets during periods of scarcity.)

It is proposed that extensive (perhaps 80-200 hectares), fenced shelterbelts be established to the northeast of villages and well sites experiencing serious degradation. The shelterbelts should be designed to protect villages, fields, and wells from the effective dry season northeasterlies. By performing this function, they would also intercept drift sand, exploit the northeasterlies to scatter seed over degraded sites, and otherwise ameliorate the local environment by intercepting precipitation and promoting ground-water recharge, lowering soil temperatures, recycling nutrients, permitting the reestablishment of soil microorganisms, supporting wildlife, and other functions. Through thoughtful species selection and careful management, the shelterbelts could also provide desirable forest products including vegetable gums, tannin, fruit, honey, construction materials, medicinal substances, bush meat, and fuelwood.

By increasing the uses and economic value of the shelterbelts, they becomes less subject to neglect and predation. This has been well demonstrated at the village of Vidau Thingoly in northern Senegal; where the villagers (sedentary herders) freely enter the

nearby enclosed forestry plantations, which they use to satisfy a diversity of needs; particularly to cut and deliver fodder to their livestock when other sources of feed are not available. These plantations are well protected by the local population. It is clearly important that those affected by similar projects participate in the design of the project, particularly in species selection, and it should be made clear immediately that they are to be the principal beneficiaries of their efforts and not simply laborers in some poorly understood forestry program. It would be useful to arrange discussions involving the elders of Vidau Thingoly, Mbiddi, or other Senegalese villages with fenced forestry plantations and their Mauritanian counterparts during the design phase of the Mauritanian projects.

In establishing shelterbelts, it is important not to neglect lower-story species, as the turbulence of lower free-flowing layers of wind is often increased by belts composed only of taller trees and damage can actually be increased by their exclusive use. Special note should also be made of the potential of gathering and feeding the pods of large-seeded legumes, such as Acacia spp. and Prosopis spp., to livestock. The livestock, which digest the pods but not the unbroken seeds, transport and deposit the seeds in their wanderings, thus acting as agents of dispersal and contributing further to regional revegetation. As noted elsewhere in this report, wild ungulates were formerly responsible for the widespread distribution of many African tree and shrub legumes.

The shelterbelts described in this report are proposed in part as alternatives to village woodlots. Although family plantations should be encouraged and compound plantings will undoubtedly continue to contribute marginally to fuel needs, interviews with men and women in rural areas of Mauritania and Senegal have revealed less concern regarding fuelwood supplies than anticipated but considerable anxiety concerning the growing scarcity of wild fruits, browse shrubs, medicinal herbs, building materials, and other forest products that were available locally in the past. This is a result of high-grading through selective use pressure. As the composition of local vegetative communities changes, useful species are progressively replaced by less useful species. These less useful species often serve adequately as fuel, but fail to satisfy the broader requirements of local populations. Hence, the establishment of village woodlots represents only a partial solution to the perceived problems of these populations. Local indifference to village woodlots is often aggravated further by unimaginative species selection, and the projects commonly succumb to the usual difficulties encountered in managing the commons. The continuing emphasis placed upon fuelwood by donors tends to obscure the complexity of local problems and could prolong their resolution.

The collective environmental impact of a systematic program in agroforestry within the central oasis zone could be quite substantial. Many of the abuses of earlier agricultural activities could be rectified, essential ecological processes could be locally reestablished, wildlife habitat would be expanded considerably, and the increased biological diversity of the oases would help buffer the adverse impacts of natural hazards such as drought.

D. Protection for Remanent Mouflon Populations. Please see Section II. A above.

IV. The Pastoral Zone

A. Efforts in Water Conservation and Ground-Water Recharge. Please see Section III. A above.

B. The Restoration of Acacia senegal Forests. The destructive impact of the gum arabic trade upon the Acacia senegal forests of the Trarza region is discussed in some detail earlier in this report. Because A. senegal is a relatively short-lived tree (generally 25-30 years) and because it occurs in age-graded stands, gum forests are particularly susceptible to excessive use pressure. Further, the normal processes of regeneration have been frustrated in Mauritania by herd increases and resultant seedling losses to foraging livestock.

The importance of the gum forests to the Mauritanian economy is well established. Few trees can boast a greater range of uses than the Acacia senegal. As noted above, the tree can be incorporated into living fences. In addition to producing gum, it provides browse, supports honey production, and is a source of tannin, wood, and charcoal. The hard wood is often used in the manufacture of such items as tool handles and weavers' shuttles, and a strong fiber can be obtained from the tree's long, flexible surface roots. Within the Sahel, the gum enjoys a range of uses extending from the preparation of ink for use in Qur'anic schools to use, in solution, in stabilizing the interior walls of mud-brick structures. Exported gum is used in the manufacture of medicine, chewing gum, confectionery, soft drinks, and a variety of foods. It is also used for printing in the textile industry.

The reestablishment of the recently destroyed gum forests of the Boutilimit and Mederdra regions should be assigned a particularly high priority. As noted in the course of the Environmental Workshop, the presence of large numbers of fallen Acacia senegal trees in the Mederdra area, as well as in the Brakna region, introduces an excellent opportunity to enlist the cooperation of

pastoralists and local villagers in a program of extensive rehabilitation. (Some Sahelian pastoralists practice vegeculture, the cultivation of certain wild plants, and are willingly enlisted in efforts to plant A. senegal along their migratory routes.) Untreated seed could be planted by dibble directly under the protective debris of the fallen trees. The seedlings emerging through the branches of these trees (1) would be protected from livestock, as attested by the relative abundance of grass under the fallen trees; (2) could utilize the vacated root channels of the dead trees, permitting rapid taproot penetration and thereby better assuring the seedling's chances for survival during the dry season; and (3) would profit from the nitrogen released by the decay of the dead acacias. In addition, by planting directly under the fallen trees, chances are better that the Rhizobium strains normally associated with A. senegal, and which are responsible for nitrogen fixation, would already be in place.

In other instances, such as in the northern Trarza, the regions formerly occupied by gum forests are often only sparsely inhabited (0.1 to 0.99 inhabitants per square kilometer). In such cases, it might be well to resort to more experimental approaches to reseeding. Of these, aerial seeding would seem to be particularly promising (for further information, see Appendix F). Other possibilities would include the application of various rangeland rehabilitation techniques employed in the American West.

Although it is suggested that improved seed be acquired for this effort from the forestry research station at Mbiddi, Senegal, it would undoubtedly be necessary to obtain additional quantities of seed at local markets or through organized collection campaigns in rural areas (generally during December and January). Such collection campaigns were conducted successfully in Chad during the mid-1970s in support of an effort to establish gum plantations and reestablish natural gum forests in that country, and have been proposed for Mauritania by BOSTID.

In Mauritania, it is particularly important that efforts to reestablish the gum forests be accompanied by a program of instruction in less destructive tapping methods. Further information regarding the development of such a program might be sought by contacting A. G. Seif el-Din, a gum-arabic specialist associated with the Nairobi office of the International Development Research Centre.

Understandably, the well-being of the gum trees is also linked directly to the maintenance of a dependable system for the commercialization of gum arabic. If the gum cannot be conveniently sold, interest in the trees will shift from gum production to

browse, fuel, and other uses that are intrinsically damaging to the trees. Hence, efforts in the reestablishment of gum forests should be explicitly related to the commercialization of the gum. This would require that elements of commercialization such as collection, purchase, grading, storage, transportation, and marketing be considered. Finally, in recent years, some concern has been expressed regarding the long-term stability of the natural gum market. All assessments reviewed suggest that the market is both strong and expanding. Should more specific information be required, it might be obtained from D. M. W. Anderson, Department of Chemistry, University of Edinburgh.

C. The Establishment of Multipurpose Shelterbelts. Please see Section III. C above.

D. Sand Dune Stabilization and Utilization. Please see Section III. B above. In addition to stabilization efforts in association with threatened communities and areas of agricultural production, or to stabilization as a by-product of the other interventions listed in this section, further attention should be directed toward problems of dunal encroachment along the Nouakchott-Nema highway.

V. The Coastal Zone

A. Efforts in Water Conservation and Ground-Water Recharge. Please see Section III. A above.

B. Sand Dune Stabilization and Utilization. Please see Section III. B above.

Within the coastal zone, initial attention might be directed toward the Nouakchott area proper and the areas of encroachment along the Nouakchott-Rosso highway. These efforts in stabilization could draw upon the diverse resources of Nouakchott, would be highly visible and, given the resources of the city, could have an active research component. It is preferable not to undertake experimental programs in areas with limited resources as it is sometimes difficult to resurrect such programs should failure occur.

With regard to species selection, particular attention might be directed toward the local species of the coastal desert. Many of these species, such as Euphorbia balsamifera and Tamarix senegalensis, can be irrigated with brackish water, and would serve well as the principal species for mechanical stabilization. Athel tamarisk or Acacia senegal could be planted within the checkerboards, depending upon site conditions. Both species are of

economic value, although the value of A. senegal exceeds that of the tamarisk. On the other hand, the low palatability of the tamarisk affords some protection from foraging livestock. Other species that might be considered include Acacia cyanophylla, A. cyclops, A. raddiana, Agropyrum jumceum, Ammophila arenaria, Artemisia monosperma, Calligonum comosum, Lotus creticus, Mesembryanthemum spp., Parkinsonia aculeata, Pennisetum dichotomum, Polygonum equisetiforme, Retama roetam, Saccharum biflorum var. aegyptiaceum, Salvadora persica, and Vernonia spp. Additional information regarding appropriate species for dune stabilization efforts in the Mauritanian coastal zone can be provided by BOSTID.

Most of the preceding species can be sown directly; others, including Acacia cyanophylla, Artemisia monosperma, Pennisetum dichotomum, Calligonum comosum, and Saccharum biflorum perform more satisfactorily if transplanted. For projects around Nouakchott, the plantings could perhaps be composted with city garbage. The use of chemical mulches might be considered in certain critical areas, but is not to be generally recommended. Such mulches include bituminous emulsions, Curasol, Huls 801, Unisol 91, Coharex, Rohagit, polymeric emulsion of Askar, and crude oil.

In planning stabilization efforts in the littoral zone, it might be well to remember that according to the forestry decree of 4 July 1935, all littoral dunes are classified as perimeters of reafforestation. Hence, all activities are prohibited until the dunes are sufficiently revegetated that they can be reclassified as multiple-use classified forests. An awareness of the legal status of any proposed project area is critical in determining the extent to which access to the area can be limited, at least technically, until the vegetation is established.

C. The Nouakchott Greenbelt. Despite its apparent shortcomings, the Nouakchott greenbelt has already had a stabilizing impact upon the Noukchott region, both through the physical presence of the Prosopis chilensis seedlings and the microclimatic modifications that have permitted some regeneration of local species. Nevertheless, the objectives of the greenbelt could be better realized through improved nursery techniques, greatly expanded species trials, and better plantation management.

BOSTID panelists have suggested several measures that would improve the performance and survival of the seedlings produced in the greenbelt nursery. These include the use of deeper seedling containers, the inoculation of leguminous seedlings with their appropriate strains of Rhizobium (or in some cases, Rhizobium in combination with endomycorrhizae), and the imposition of greater

stress before seedlings are transplanted. It should also be noted that for many dry-land species, direct seeding in the greenbelt itself might be preferable to starting the trees in a nursery.

Much of the seed distributed in Mauritania by BOSTID was intended to be used in diversifying the species content of the greenbelt. This would include the seed of such species as Acacia berlandieri, A. senegal, Cercidium floridum, Larrea tridentata, Leucaena retusa, Olneya tesota, Parkinsonia aculeata, Prosopis glandulosa var. torreyana, P. juliflora, P. velutina, and Purshia glandulosa. The BOSTID staff has subsequently identified something in excess of 200 native and exotic plant species that would likely be suitable for greenbelt conditions.

Most comments regarding plantation management have dealt with possibilities for better utilizing the limited water available to maintain the plantation. These include (1) various methods of reducing the evaporation of water from the plantation reservior through the use of chemical sealants, or the use of blocks, rafts, or beads that would float on the reservior surface thus reducing the area where vaporization can occur; (2) exploration of the use of trickle irrigation; (3) use of various water-harvesting techniques that could increase the quantity of water available to the trees and increase ground-water recharge; and (4) institution of a schedule of watering better suited to the species and conditions of the greenbelt plantation. With regard to the fertilization of the plantation, it might be well to consider utilizing the presently discarded coastal fisheries by-catch as a dressing to aid seedling establishment. The by-catch is presently lost because it has no perceived value and because the boats used by the coastal fishermen are too small to accommodate both the by-catch and the more marketable fish. A possible solution would be to anchor lighters in the principal fishing grounds and purchase the by-catch directly from the fisherman at sea. The lighters could then be towed to the coast and the by-catch distributed.

D. Coastal-Zone Revegetation. With regard to species selection, BOSTID research has largely focused on species appropriate for Tamarix senegalensis-dominated saline environments such as the Aftout as-Sahali. Many of the species identified provide food for human consumption, and virtually all are valuable forage plants. Many can be irrigated with sea water, including Atriplex barclayana, A. canescans, A. glauca, A. lentiformis, A. linearis, A. polycarpa, A. rependa, Batis maritima, Prosopis tamarugo, and Salicornia europaea. With the exception of Prosopis tamarugo, all have undergone open-field trials in the Sonoran Desert utilizing hypersaline (40 ppt salt) sea water for irrigation. Seed for many of the Atriplex species was provided by Cyrus McKell of

Utah State University, and was distributed in Mauritania by the BOSTID staff during the Environmental Workshop. Additional species, such as Cassia sturtii, are being identified through a systematic inventory of the plant resources of climatically analogous (BWh and BSh) coastal deserts in the Americas, elsewhere in Africa, Asia, and Australia.

To the north and east of Nouakchott, species selection has been keyed largely to the dominants within vegetative communities as recorded earlier in the century. These dominants include Acacia senegal, Commiphora africana, Stipagrostis pungens, and Acacia raddiana. In some cases, inferences regarding appropriate species have been drawn from the literature of palynology or from other sources. It was on the basis of such inference, for example, that the BOSTID staff provided Argania spinosa seed to Eyih Banda during the Workshop for trial plantings in the coastal zone and in the Adrar. Argan forests existed in the western Sahara during the Middle Ages and the tree is often associated with species known through palynological studies of the Mauritanian sebkha of Chemchane.

In reestablishing the vegetation of the northern coastal zone, particular attention might be directed toward the wadi courses. Small-scale plantings could be undertaken along the upper courses of the wadis, allowing the periodic flow of the wadis to amplify project impact by distributing the seed downstream. Aerial seeding might also be considered for revegetation efforts within the coastal zone, particularly in the Stipagrostis- and Acacia-dominated areas. The surface of such areas is characteristically less compacted and the strike is therefore somewhat better. As noted in Appendix F, Prosopis juliflora has been successfully established through aerial seeding in analogous areas of India.

E. Coastal Process. For over 500 years, the maritime literatures of the Portuguese, Spanish, Dutch, French, and British has been unanimous in designating the Mauritanian coastline one of the most active and treacherous in the world. Shipwrecks have long been frequent along the coast, and authors from Herodotus (The Histories 4.196) to James Riley have described inhabitants of the coast whose livelihood was derived primarily from the salvage of wrecked ships and silent barter. It was partially to avoid these dangers that trade was carried overland between Mauritania and the Mediteranean rather than by sea.

Apart from problems of navigation, littoral drift is causing severe undercutting at Nouadhibou and will seriously affect the port developments near Nouakchott. Many of these problems could be mitigated through the construction of groins or the use of by-pass techniques. Because of the serious economic implications of these

problems, it is suggested that a special study be undertaken to explore this matter further. Various NAS committees have dealt with coastal process in recent years, and could perhaps be contacted for additional information.

F. The Establishment of an Environmental Reserve around Nouakchott. In June 1979, the Mauritanian Military Committee for National Salvation (CMSN) announced the initiation of a national reafforestation plan. As an element of this plan, the CMSN has discussed the possibility of designating a 30-km wide zone around Nouakchott as an environmentally protected area. As attested by the natural regeneration of Acacia senegal within the Nouakchott greenbelt, the area could be expected to respond well to such protection.

While the desirability of such an undertaking is evident, one might anticipate some problems in managing such an extensive reserve in such a densely populated area. To a certain extent, these problems can be avoided by increasing the perceived value of the reserve by managing it on a multiple-use basis. Hence, use would be controlled but not totally restricted. The potential contributions and uses of such an area are many. For example, improved precipitation interception and infiltration in such an area would render the Nouakchott water supply somewhat less precarious; considerable wildlife habitat would be restored and the government could enjoy some revenue from controlled hunting; the area could serve as a browse reserve for livestock during periods of severe drought; the zone could serve as a research area for the study of arid-zone processes; it could accommodate a much expanded Nouakchott zoological garden; and the zone could serve an an area in which strategies for environmental rehabilitation could be developed, tested, compared, and implemented.

G. The Activation of the Rural Development Extension Center near Nouakchott. As noted in BOSTID's April 1979 "Assessment of Agro-Forestry Potential within the Environmental Framework of Mauritania," only "minor capital expenditure is required to connect the station to water and electrical supplies and to secure and improve the access road. The Government of Mauritania has funds for staff and recurrent expenditures."

It is suggested that this center be activated and that its functions be increased. While the center was designed primarily as a research facility for livestock development, it could also serve as an experimental station for dryland agriculture. The Nouakchott area would be ideal for experimentation (1) in short-cycle desert food crops such as tepary beans and Pima-Papago 60-day maize; (2) the further development of salt-tolerant crops such as the date

palm, pomegranate, fig, olive, grape, muskmelon, citrus, apricot, and others (all of which, incidentally, formerly existed within the region during the Mauritanian Middle Ages); (3) the evaluation of dryland economic crops such as jojoba and guar; and (4) trials in the use of sea water for irrigation.

Also as indicated in BOSTID's April 1979 report, "some of the pressure on the peri-urban vegetation imposed by browsing livestock might be relieved by the local production of Spirulina, a filamentous blue-green alga which is elswhere utilized as livestock feed. It is also used as a protein-rich additive to human diets in Chad, Algeria, Mexico, and other countries." The Nouakchott area would be ideal for Spirulina production, and sufficient research has already been conducted that a Spirulina project could be established as a turnkey operation. The production of Chlorella and Azolla might similarly be explored.

This center could also be called upon to determine the comparative efficiency of various forms of livestock and their compatibility with dryland ecosystems. It could similarly be used to evaluate the comparative advantages of domesticated livestock vis-à-vis selected, wild ungulates such as the addax and oryx. As much of this activity would take place in or near the proposed Nouakchott Environmental Reserve, the functions of the center could perhaps be expanded even further to include experimental efforts in game ranching or the establishment of sustained-yield game production systems. Movement toward more efficient, more environmentally compatible herd animals would contribute greatly to the rehabilitation of natural systems in Mauritania.

H. Consolidation of the Arguin-Region Park and Reserves. This region contains two important nature reserves and a major national park. The reserves--the Baie du Levrier Wildlife Reserve and the Mauritanian Islands Nature Reserve--were established in April 1962; the Arguin Bank National Park was established in March 1977. The region boasts a remarkable diversity of marine life and birds, as well as additional forms of wildlife and interesting geological formations. Waterbirds perhaps constitute the principal attraction in the area, and include the long-tailed cormorant, gull-billed terns, royal terns, bridled terns, slender-billed and grey-headed gulls, the spoonbill, grey herons, reef-herons, flamingoes, and many others.

While it is essential that existing restrictions relating to these sites be maintained or even strengthened, it is believed that the park and reserves could be consolidated, that the functions of the consolidated unit could be increased, and that the unit could be more flexibly managed on a multiple-use basis.

With reference to a possible expansion of functions, it is suggested that the important historical sites of the Arguin region and the assets of the Arguin Bank be better evaluated in relation to tourism. It might be supposed, for example, that the many shipwrecks of the Arguin Bank would be of interest to skin divers and underwater archaeologists. Some of these shipwrecks are the most famous wrecks in history, for example, the tragic wreck of the French frigate Méduse, so vividly described in Savigny and Correard's Naufrage de la Frégate la Méduse faisant partie de l'expédition du Sénégal en 1816 and Charlotte Dard's La Chaumière Africaine, caused enormous repercussions in French society and government. Incidentally, lost along with the Méduse were three barrels containing 90,000 francs in gold belonging to the king. The wreck of the American brig Commerce near Cap Blanc had a similarly great, if somewhat more indirect, impact upon American society. It was the narrative of the enslavement of the brig's officers and crew, published in 1817, that first aroused abolitionist sentiments in young Abraham Lincoln. Additional shipwrecks are described in the 15th-century journal of Alvise Ca' da Mosto, and in other sources dealing with the Arguin region.

The drawing power of marine parks has proven to be considerable. The Buck Island Reef National Monument near St. Croix in the Virgin Islands, for example, attracted 600 visitors in its first year of operation; three years later it attracted 15,500. The Arguin region is readily accessible through the international airport at Nouadhibou, which is served by several major airlines, including UTA, Aeroflot, and Iberia, as well as by Air Mauritanie.

VI. The Chemama

A. Erosion Control. Many formerly forested areas along the Senegal River between Boghé and Rosso have been totally denuded of trees and shrubs. Such an area is illustrated in Figure 1 of BOSTID's 1979 report, "An Assessment of Agro-Forestry Potential within the Environmental Framework of Mauritania." In the year since the assessment was made, erosional activity, particularly gullying, has increased measurably. The rate of increase and its far-reaching implications add a note of urgency to the following suggestion.

Initially keying upon the areas most damaged by erosion, it is suggested that barbed-wire exclosures be established to protect parcels of perhaps 100 hectares. The effort should first address erosion control. If land preparation, either manual or mechanical, is envisioned for reafforestation projects, many of the necessary erosion control measures could be undertaken in the course of such

preparation (for example, filling gullies and establishing diguettes or microcatchments to interrupt surface flow). Several variations of the fenced reafforestation parcels might be considered depending upon the range of needs to be served. These might include the provision of forest products; use as browse reserves; control of access to areas susceptible to erosion; study of natural regeneration; training and experimentation in method of revegetation; dune stabilization or interception; and the reestablishment and maintenance of wildlife populations. The range of needs, combined with site characteristics, would naturally influence design, surface treatment, species selection, and other considerations. Certainly, to the extent possible, these projects should conform to the so-called Forestry for Local Community Development (FLCD) approach. Needs should be largely defined by local populations, and it should be made clear that these populations are to be the direct beneficiaries of the projects. Projects elsewhere have failed because this either has not been made clear or because local experience has demonstrated that indeed they are not the beneficiaries of their efforts.

It is suggested that a broad range of native and exotic species be considered for these projects. Although it might be worthwhile to consider Acacia scorpioides var. adstringens among the natives, it is doubtful that A. scorpioides var. nilotica, the gonakier previously dominant in the area, could be successfully reestablished. Research conducted in the Sudan in the 1950s indicated that the latter is sustained by the exceptional floods also responsible for the dispersal of its seed. This dependency is partially reflected in the age classes of existing gonakier stands. Such floods will, of course, be eliminated with the completion of the Manantali Dam. As many of the species envisioned can be established by direct seeding, the project could be initiated without nursery support.

B. The Restoration of Selected Classified and Protected Forests. A second high-priority activity might be the restoration of selected classified and protected forests. The degree of classification or level of protection should be sufficiently restrictive that the forests could serve as living herbaria or reservoirs of genetic diversity as per the biosphere reserve program which emerged from Man and the Biosphere (MAB) Project 8.

Determinations regarding appropriate species for such efforts might be guided by historical descriptions, analysis of relic or analogue florae in comparable areas of Africa, existing forestry records, and the observations of local populations. Lower-story vegetation, such as grasses, forbs, and shrubs, should be considered as well as trees. Information regarding the former composition of

these remanent forests might be obtained from Taleb Diack or Eyih Banda of the Mauritanian Service for the Protection of Nature. It should perhaps be emphasized that particular attention would be directed toward restoration rather than toward "upgrading" or "enrichment." Hence, exotic species such as the neem (Azadirachta indica) should not be considered in connection with this particular effort.

Unlike the suggested urban plantation project (below), initial efforts could, and perhaps should, be limited to more stringently enforced protection. A scheduled active phase, possibly employing techniques such as tissue culture to accelerate multiplication, particularly of endangered species, could follow as soon as resources and interest permit. Should the forest of Silbe be selected for restoration, reference should be made to Decree No. 10.028 of 17 February 1961 to determine how the altered status of the forest might affect program objectives.

C. Gonakier Replacement. It is suggested that a supervised program be established to directly replace trees felled above the 2.50-m retention level of the Diama Reservoir in connection with charcoal production. This program would provide for the establishment of a nursery at Rosso to provide seedlings. Responsibility for the planting and protection of the replacement seedlings would reside explicitly with the permit holders who profit from the production of charcoal. The method of protection could be as simple and inexpensive as the single-tree exclosures used locally in village plantings or the erection of thorn fences utilizing the smaller branches of the trees felled. Enforcement could be regulated under the terms of Decree No. 65.080 of 29 April 1965, which fixes fees for the exploitation of forest products. In this case, payment in kind could perhaps be viewed as being more appropriate than cash payment given the obvious limitations of the resource exploited and given the documented irregularities of the present system.

In addition to the maintenance of these stands through direct replacement, further efforts might be devoted to the enlargement of existing riverine forests through various techniques currently employed elsewhere in large-scale land reclamation. As indicated in Appendix F, aerial seeding should be included among the techniques considered.

D. The Establishment of an Irrigated Urban Plantation to Serve the Needs of Nouakchott and Rosso. Although compensation for the loss of gonakier (Acacia scorpioides var. nilotica) through charcoal production and OMVS (Organisation pour la Mise en Valeur du Fleuve Sénégal) program activities is of critical importance, it may be

unrealistic to address the problem largely through direct replacement. Hence, it is suggested that consideration be given to the establishment of an irrigated urban plantation to provide charcoal and poles for Nouakchott and Rosso. It is further suggested that the plantation be located between Rosso and Keur Massene. Such an effort could be organized with little delay by the Mauritanian Government and interested donors. It will be much less difficult to accurately assess the real forestry needs of the Chemama once the pressures imposed by Nouakchott and Russo are removed from the "natural" system, the OMVS impact is better understood, natural regeneration is reassessed and there is some movement toward a new equilibrium. Establishment of the plantation west of Rosso would guarantee labor availability, facilitate irrigation, permit direct access to Nouakchott over an all-weather highway, and allow the plantation to serve as auxiliary habitat for the Keur Massene reserve and the neighboring Djoudj National Park in Senegal.

With reference to species composition, it might be well to initially concentrate upon familiar, rapidly growing species such as Eucalyptus camaldulensis and Salvador-type Leucaena leucocephala. Both species are widely used elsewhere for poles and charcoal (the heating value of the less well-known leucaena charcoal is around 7,000-7,250 calories per kilogram). In addition to its rapid growth, leucaena is of value as a companion species because its roots house Rhizobium bacteria that fix atmospheric nitrogen. This nitrogen contribution would be of some value in accelerating the growth of the eucalypts and would partially compensate for the depletion of soil nutrients in the plantation. The forage value of leucaena would further permit the plantation to serve as a browse reserve for domesticated livestock and wild ungulates following a period of initial protection sufficient for the establishment of the trees.

While initial efforts might concentrate upon familiar species with known performance, concomitant research might be undertaken at the plantation to evaluate other species perhaps better adapted to the conditions of the project area. The extent of the plantation would be determined by species composition, site conditions, management systems, and demand.

There appears to be little difficulty in justifying such a plantation in economic terms. For the country as a whole, demand is currently estimated to be 1,100,400 tons of wood per year. The value of wood as construction material is increasing rapidly, and the value of charcoal currently stands at approximately 6000 ouguiyas per ton. In addition to the value of the wood and fodder provided

by the plantation, the project would create new employment opportunities and would contribute both directly and indirectly to environmental rehabilitation.

The preceding items have dealt largely with interventions related to primary production within the Chemama region. As indicated in the course of the Workshop, further attention should be directed toward problems of wildlife and fisheries.

Many of these problems have been described in detail in the Gannett Fleming Corddry and Carpenter (GFCC) assessment of environment effects of proposed developments in the Senegal River Basin. The GFCC assessment includes three reports of particular interest: a "Partial Report for Mammalogy and Herpetology" by Douglas Reagan, a "Partial Report for Ornithology" by Douglas James, and a "Partial Report for Fisheries" by Donald Dorfman.

While these reports clearly indicate that severe environmental problems will be precipitated by OMVS activities in the Chemama, a more detailed discussion of the problems would exceed the scope of this report. Hence, the reader is referred to the GFCC reports for further information. It is unfortunate that within the broader context of the OMVS effort, no apparent attempt has been made to compare the aggregate value of the sustainable resources that will be lost with the relatively transitory benefits of the capital-intensive development activities that will replace them. For example, rather sustantial declines in productivity might be anticipated in recessional agriculture, coastal fisheries, and tourism dependent upon wildlife and a diverse avifauna.

It should be noted in closing, however, that the BOSTID staff did suggest four possible projects during the Workshop that are not explored in detail in the GFCC reports and that would contribute further to income generation within the Chemama. These projects are outlined below:

E. The Creation of an International Wildlife Reserve in the Delta Region. It is doubtful that further agricultural development would represent a wise use of the Delta region. For example, R. J. Harrison Church of the London School of Economics summarized the problems of the current Delta irrigation scheme in his volume, West Africa, as follows: "...the area is infertile so that heavy applications of artificial fertilisers are necessary, while the soils have a high salinity.... There are problems of preventing sheet erosion by wind during the dry season, and of prodigious losses at harvest time from quelea birds and, to a lesser extent, from ducks and grasshoppers. Wild rice is another nuisance.

Although originally about 6000 ha were to be irrigated, no extensions are being made. Capital costs have been written off, and current costs are heavily subsidised. The scheme has made only a modest and very costly contribution to Senegal's rice needs."

Hence, it was proposed at the workshop that an international park or reserve be formed by joining Djoudj National Park in Senegal with the Keur Massene hunting reserve in Mauritania. It has been indicated that the Senegalese authorities responsible for Djoudj National Park are willing to substantially increase the size of the park, extending it to the Mauritanian border.

Economic analyses by the Senegalese government have determined that the Djoudj National Park generates more income (around 100,000,000 CFA per annum with a benefit per cost ratio of 1.81) than would known alternative land-use options. The creation of a larger park would increase critical habitat and thereby permit the park to accommodate a greater diversity of wildlife. Increased diversity, in turn, would tend to attract more visitors to the park.

If managed on a multiple-use basis, controlled hunting could still be permitted within the reserve complex. Indeed, the hunting of certain game species, such as the wart-hog, might be encouraged in areas of the park that adjoin agricultural lands. Such hunting could both reduce crop damage and increase employment opportunities in the region.

With regard to the current species content of the Delta region, there exists a considerable diversity of birds, mammals, amphibians, reptiles, and fish.

More than 230 species of birds are associated with the region, prominently including water birds such as the teal (Anas crecca), garganey (A. querquedula), wigeon (A. penelope), pintail (A. acuta), shoveler (A. clypeata), pochard (Aythya ferina), ferruginous duck (A. nyroca), fulvous whistling duck (Dendrocygna bicolor), white-faced whistling duck (D. viduata), Egyptian goose (Alopochen aegyptiaca), spur-winged goose (Plectropterus gambensis), comb duck (Sarkidiornis melanotos), African pygmy goose (Nettapus auritus), white pelican (Pelecanus onocrotalus), pink-backed pelican (P. rutescens), white stork (Ciconia ciconia), black stork (C. nigra), glossy ibis (Plegadis falcinellus), spoonbill (Platalea leucorodia), greater flamingo (Phoenicopterus ruber), crowned crane (Balearica pavonina), black-tailed godwit (Limosa limosa), ruff (Philomachus pugnax), and the avocet (Recurvirostra avosetta). According to a well-known expert on the birds of the Delta region, Francis Roux of the Museum of Natural History in Paris, the number of species in the region has declined markedly in recent years because of habitat

deterioration. This decline has naturally been accompanied by a corresponding decline in the contributions of such bird populations to seed dispersal, insect control, and tourism.

The animals of the Delta region would include the white-bellied hedgehog (Atelerix albiventris), shrews (Crocidura spp.), straw-colored fruit bat (Eidolon helvum), Gambian epaulet bat (Epamophorus gambianus), Egyptian tom bat (Taphozous perforatus), common African leaf-nosed bat (Hipposideros cafer), slit-faced bats (Nycteris spp.), Abyssian horseshoe bat (Rhinolophus fumigatus), Gambian free-tailed bat (Tadarida gambiana), Schreber's brown bat (Scotophilus nigrita), Ruppell's pipistrelle (Pipistrellus rueppelli), the African hare (Lepus capenis), Gambian sun squirrel (Helioscirus gambianus), striped ground squirrel (Euxerus erythropus), giant rat (Cricetomys gambianus), Felovia vae, crested porcupine (Hystrix cristata), Graphiuris huetti, Rattus rattus, Arvicanthis niloticus, Mastomys spp., Mus spp., Acomys spp., Tetera spp., Taterillus spp., Desmodilliscus spp., lesser galago (Galago senegalensis), patas monkey (Erythrocebus patas), vervet monkey (Cercopithecus aethiops), common jackal (Canis aureus), pallid fox (Vulpes pallide), zorilla (Ictonyx striatus), ratel (Mellivora capensis), Cape clawless otter (Aonyx capensis), African civet (Viverra civetta), common genet (Genetta genetta), white-tailed mongoose (Ichneumia albicauda), marsh mongoose (Atilax paludinosus), Egyptian mongoose (Herpestes icheumon), slender mongoose (H. sanguinineus, banded mongoose (Mungo mungo), striped hyaena (Hyaena hyaena), African wildcat (Felis libyca), serval (Felis serval), caracal (Felis caracal), the endangered African manatee (Trichechus senegalensis), wart-hog (Phacochoerus aethiopicus), bushbuck (Tragelaphus scriptus), Bohor reedbuck (Redunca redunca), dorcas gazelle (Gazella dorcas), dama gazelle (G. dama), and the red-fronted gazelle (G. rufifrons).

With habitat disturbance, there has been a progressive decline in the number of mammal species within the region. As is generally the case, such decline has been accompanied by explosive increases in the populations of many species that are adaptable and that multiply rapidly. Many of these species, including many rodents, are unfortunately destructive both to the environment and to crops. Hence, in order to reintroduce environmental checks, reduce crop damage in areas adjoining the reserve, and increase the attractiveness of the region to tourism, it would be well to relate efforts in habitat restoration to a systematic program in species reintroduction.

In addition to the birds and mammals noted, the Delta region supports many species of amphibians and reptiles. Some of the species are endangered, many are of interest scientifically, and several would contribute further to the appeal of the region to

tourism. For example, there are several species of frogs and toads in the region, including the large ranid frog (Dicroglossus occipitalis) and toads of the genus Bufo that possess interesting adaptations to prevent water loss. The reptiles of the region include the emydid turtle (Clemmys caspica) and the large land tortoise, Geochelone sulcata. Although turtles are legally protected in the Senegalese section of the Delta, there is no apparent enforcement and their numbers are declining rapidly.

Many species of lizards and snakes are present in the region, including several geckos, the rainbow lizard (Agama agama), the Nile monitor (Varanus niloticus), the colubrid snake (Psammophis sibilans), the spitting cobra (Naja nigricollis), and the puff adder (Bitis arietans)--the latter two species are among the few dangerous snakes found in the Delta. Finally, while the endangered Nile crocodile (Crocodylus niloticus) is found in the region, its range is decreasing and its numbers are declining rapidly.

F. Protection of the Endangered African Manatee. Because the African manatee (Trichechus senegalensis) is currently an endangered species, special efforts should be made to preserve the existing manatee population of the Chemama. This would necessarily include a determination of current status, an understanding of the probable impact of OMVS activities upon the manatee, and explicit provisions for the conservation of the species.

With regard to existing efforts in irrigated agriculture, as well as to proposed OMVS activities, it should be noted that manatees are extremely efficient in controlling the aquatic weeds that are so frequently a problem in tropical irrigation schemes. They are voracious, remarkably nonselective feeders, which often consume as much as 20 kilograms of wet vegetation per day. The animals are also extremely docile, easily managed, and seem to move freely between fresh- and salt-water environments. The maintenance of manatees in the canals of irrigation projects could serve both economic objectives and as an element of a strategy for the conservation of the species.

Further information regarding the manatee can be found in a 1976 Academy report entitled Making Aquatic Weeds Useful: Some Perspectives for Developing Countries.

G. The Conservation and Economic Exploitation of Crocodiles. The Nile crocodile (Crocodylus niloticus) is currently an endangered species in the Chemama. Thus far, most discussions concerning crocodiles in the region have focused upon the problems of poaching and the resultant decline of the species. Little apparent effort has been made to reconcile the objectives of the hunters with those of the conservationists.

Such an effort has been made in Papua New Guinea, however, where the approach to crocodile management is economically attractive to rural populations and promotes environmental stability. With this approach, a regulated number of young crocodiles are captured in the wild and raised in captivity for their hides. Because the International Union for Conservation of Nature and Natural Resources (IUCN) and other conservation groups have endorsed the approach, the hides can then enter restricted markets. This both assures relatively substantial levels of income and serves as a powerful incentive to preserve the habitat necessary to maintain breeding populations in the wild.

The Papua New Guinea approach has been received favorably by participating governments in developing countries because it generates higher levels of economic activity at lower levels of risk than existing alternatives such as irrigated agriculture. The approach also has a beneficial impact upon inland fisheries yields, as the crocodiles feed largely upon coarse fish which, without their predation, would increase at the expense of favored genera such as Tilapia.

Further information regarding this approach to crocodile management can be obtained through BOSTID.

In addition to the crocodile populations of the Chemama, some attention should be directed toward the conservation of the relic crocodile populations of the Sahelian mares. During the Workshop visit to Tamchekett, for example, it was noted that pygmy crocodiles had long been established in the nearby mare. Similar populations are known historically from other areas of the Sahel and the Sahara. Unfortunately, these scientifically important populations have largely disappeared in recent years. Their disappearance has been attributed largely to sport hunting and poaching.

During the course of the Tamchekett visit, we were told that perhaps the last of the local crocodiles had been recently killed by Senegalese hunters. Other villagers maintained that tracks had been observed shortly before our visit and that some crocodiles may still survive in the mare. In scientific terms, it is of critical importance that the Mauritanian mares be surveyed in order to determine if they still support pygmy crocodiles or other forms of relic fauna. If it is found that they do, every effort should be made to inform the people of the area of the importance of the fauna and to assure the conservation of the species involved. When the populations are restored to appropriate levels, the inhabitants of the region could profit from the sale of excess animals to zoological gardens, universities, or other research institutions.

H. The Water Buffalo. During the course of the environmental workshop, it was suggested that the Asiatic water buffalo (Bubalus bubalis) possesses characteristics that would permit it to make both economic and environmental contributions to the Chemama.

At the time of the workshop, sterilized milk sold for approximately US$1.50 per liter in Nouakchott. Most of the milk was imported from Europe, and in many areas was seasonally unavailable. The establishment of sedentary buffalo herds near such towns as Rosso, Boghé, and Kaédi in the Chemama would permit the development of a stable dairy industry in the region. In addition to the production of milk and cheese, buffalo produce beef of excellent quality, and can provide traction as well. Significantly, the buffalo could provide these benefits and maintain its health while subsisting on coarse forage inadequate for the support of cattle. They also feed on aquatic vegetation and could be used to control the growth of weeds such as the water hyacinth in irrigation projects.

In environmental terms, the water buffalo would appear to be well adapted to the Chemama. Given current trends in the sedentarization of pastoral peoples in Mauritania, it is quite possible that buffalo could partially replace cattle in the livestock systems of the country, much as they have in several areas of the Middle East. This would permit some relaxation of use pressure in the pastoral zone and could thereby contribute to the rehabilitation of the zone. It is assumed that a shift to water buffalo would be unacceptable to traditional pastoralists such as the Peul, but might well be acceptable to the many groups in Mauritania that have only recently introduced cattle into their livestock systems.

Further information regarding the possible contributions of the water buffalo to the Sahel can be obtained from BOSTID.

APPENDIX A

List of Workshop Participants

Haida Ba	Service for the Protection of Nature, Rosso, Mauritania
Mamadou el-Khasoun Ba	Service for the Protection of Nature, Nema, Mauritania
Eyih Banda	Service for the Protection of Nature, Atar, Mauritania
Mohamed Bathily	Agricultural Service, Kiffa, Mauritania
Allassane Correra	Service for the Protection of Nature, Kiffa, Mauritania
Charles Fluegel	Lutheran World Relief, New York, New York, USA
Vernita Fort	U.S. Agency for International Development, Abidjan, Ivory Coast
James Hughes	U.S. Agency for International Development, Nouakchott, Mauritania
J. Rowland Illick	U.S. Agency for International Development, Nouakchott, Mauritania
Hadya Kane	Agricultural Service, Nouakchott, Mauritania
Cheikh ould Hamma Lamine	Service for the Protection of Nature, Nouakchott, Mauritania

Ould Hadj Liman	Animal Husbandry Service, Nouakchott, Mauritania
Ibrahima Ly	Animal Husbandry Service, Nouakchott, Mauritania
François Mergen (Chairman)	Yale University, New Haven, Connecticut, USA
Paul Meyers	U.S. Agency for International Development, Nouakchott, Mauritania
Liberty Mhlanga	Environment Training Programme (ENDA), Dakar, Senegal
Tanya M'Bodge	Youth and Sports Agency, Nouakchott, Mauritania
Mohamed ould Nah	Radio Mauritania, Nouakchott, Mauritania
Amadou Ibra Niang	National Center for Forestry Research (CNRF), Dakar-Hann, Senegal
Cheikh Moussa Niasse	Renewable Resources Project, Nouakchott, Mauritania
Carol Olsen	U.S. Agency for International Development, Noukchott, Mauritania
Abdoul Oumar Sarr	Service for the Protection of Nature (on leave in Mali)
Moustapha Sidatt	National Health Center, Nouakchott, Mauritania
Louis Siegel	U.S. Agency for International Development, Nouakchott, Mauritania
Stanley Staniski	U.S. Agency for International Development, Washington, D.C., USA
Adama Sy	National Agricultural School, Kaedi, Mauritania
Fadel Touré	U.S. Agency for International Development, Nouakchott, Mauritania
Gerrit ten Velde	Lutheran World Federation, Nouakchott, Mauritania

Mamadou Wade	National Center for Agronomic Research, Kaédi, Mauritania
Fred Weber	International Resources Development and Conservation Service, Boise, Idaho, USA
Jeffrey Gritzner	Staff Officer, Board on Science and Technology for International Development, Commission on International Relations, National Research Council, Washington, D.C., USA
Augustus Nasmith	Staff Officer, Board on Science and Technology for International Development, Commission on International Relations, National Research Council, Washington, D.C., USA

APPENDIX B

ORGANISE PAR LA COMMISSION SCIENTIFIQUE DES EXPERTS DE L'ACADEMIE DES SCIENCES DES USA

LE SEMINAIRE DESIGNERA AUJOURD'HUI UN COMITE TECHNIQUE MIXTE

Le seminaire organisé par la commission scientifique des experts de l'academie nationale des sciences des USA procédera ce matin à la désignation d'un comité technique mixte constitué de representants du ministère du développement rural et ceux de l'academie.

Les séminaristes ont aussi designé hier matin la commission de synthèse chargée de l'elaboration du document final. Ils ont visité la ceinture verte de Nouakchott et la pepiniaire où ils ont entendu des explications détaillées concernant ces réalisations.

La mission s'est déjà rendue dans les régions du Trarza, du Brakna, de l'Assaba et du Hodh.

Au cours de ce périple la mission a visité les zones présentant un intérêt écologique.

Chaab, Monday, September 24, 1979

SEMINAIRE NATIONAL SUR L'ENVIRONNEMENT

DES PROPOSITIONS CONCRETES VONT ETRE FAITES POUR PREVENIR LA DEGRADATION DE L'ENVIRONNEMENT

La mission du ministère du développement rural comprenant plusieurs directeurs de services et experts scientifique americains a regagné la capitale la semaine derniere apres avoir visité quelques regions et localites du pays.

De ce fait nous avons rencontré M. Cheikh Lamine O. Hamma, directeur de l'environnement qui nous a tiré les conclusions de cette importante mission.

Il a ainsi declaré que des experts americains ont eu au mois d'Avril dernier à sillonner le pays en vue de savoir les origines essentielles de la degradation de l'environnement. C'est ainsi a-t-il dit, qu'ils ont constaté que si nous n'intervenons pas rapidement et efficacement le phénomène de dégradation de l'environnement risquerait de devenir irréversible.

De ce fait, a-t-il indiqué, nous avons décidé la tenue d'un seminaire sur l'environnement, seminaire auquel viennent de prendre part 17 cadres nationaux et 14 experts américains dont le but est de voir sur le terrain les lieux ou se manifestent les formes de degradation et éventuellement les moyens de lutte contre ce phénomène.

La mission a ajouté le directeur de l'environnement, a visité plusieurs regions et localites du pays avant de tenir une conférence à Kiffa qui a été l'occasion pour nous d'évoquer d'une manière générale les problèmes de l'environnement.

Plusieurs exposés suivis de débats ont également, marqué cette conférence qui a désigné une commission technique comprenant des experts américains et des cadres du développement rural chargée de rediger le document final, a-t-il souligné.

Ce document, a-t-il conclu, qui contiendra des propositions concrètes paraitra à la fin de cette année ou au début de l'année prochaine.

A noter enfin que cette mission tiendra vers la fin de la semaine une table ronde qui évoquera entre autres questions, les résultats de sa visite à l'intérieur du pays.

Chaab, Wednesday, September 26, 1979

APPENDIX C

An Overview of Land Use and Environmental Change in Mauritania

To place the problems of environmental degradation in Mauritania in better perspective, a BOSTID staff member has undertaken a comprehensive survey of the country's human occupation and environmental change. This survey is drawn principally from the literature of Pleistocene ecology, geography, botany, prehistory, history, and ethnology.

THE PREHISTORIC PERIOD

The complex movement of peoples and technologies over the so-called "Mauritanian road" of prehistory undoubtedly influenced the content and character of the region's environmental systems. While the antiquity of this movement remains conjectural, a sequence of tangible reference points emerges in the form of Acheulean lithic implements dating from around 600,000 B.P. (years ago) in the Adrar, Zemmour, Tiris, and Mekteir regions; in the form of Mousteriod industries dating from the Middle Palaeolithic; and as Aterian occupation sites in the Atlantic coastal zone and in the north-central uplands dating from approximately 20,000 B.P. to around 9000 B.P. Interestingly, and contrary to the earlier assumptions of most prehistorians, revised Pleistocene chronologies indicate that Aterian bands migrated from northwestern Africa to Mauritania during the Ogolian oscillation, a climatic phase far drier than any experienced in historical times. Aterian occupation, as archaeologically defined, ended during the more humid Chadian climatic oscillation.

Palynological studies of the sebkha of Chemchane northeast of Atar, of the Boghé region, and elsewhere indicate that the biota of the Mauritanian Palaeolithic was substantially more diverse during both more humid and more arid climatic oscillations, than it is at

the present time. Unfortunately, the probable impact of Palaeolithic man upon the environment is difficult to determine. Not surprisingly, the lithic artifacts associated with the Mauritanian Palaeolithic are largely identified with hunting and game preparation. Hence, it can be assumed that selective hunting pressures have affected Mauritanian ecosystems for many thousands of years. Because "hunting" populations characteristically subsist largely upon botanical resources rather than upon game animals, it can be further assumed that selective gathering similarly affected Mauritanian ecosystems. What is not known, of course, are the various implications of nonrecoverable perishable materials and subsistence strategies in relation to environmental impact. If fire had been employed in hunting, for example, the environmental impact of relatively modest populations could have been substantial. In instances where populations were largely dependent upon a limited range of species, such as the near total dependence of the historical Namadi upon the addax, the impact could have been relatively modest.

The Mauritanian Neolithic is better documented and better understood in contextual terms than the Palaeolithic. The Ogolian oscillation had evidently been triggered by the Older Dryas glacial advance of the Würm. Not only were substantial quantities of water "locked up" in the glaciers, but glacially-induced, depressed sea levels altered land-sea relationships and, in turn, climatic patterns. Following the Younger Dryas advance (11,000-10,000 B.P.), glacial melt-water replenished the ocean basins. This resulted in a relatively humid climatic phase in Mauritania, the so-called Chadian oscillation. During this phase, rising sea levels produced marine transgressions, and increased precipitation supported the formation of lakes in the Adrar, Tagant, and Dahr Tishit-Walata-Nema depressions.

The vegetation of the Chadian and early Nouakchottian periods, approximately 10,000 B.P. to 5000 B.P., roughly corresponds with that found historically in the savannah zone of West Africa. For example, the presence of Celtis integrifolia in the Zemmour region suggests that the region roughly marked the 450 millimeter (mm) isohyet. Similar palynological evidence would place the 800 mm isohyet at approximately the latitude of the Senegal River. The flora of the Boghe region, for example, prominently included Elaeis guineensis and Bombax spp. During the same period, the fauna of the Adrar and Tishit regions was composed largely of savannah species such as elephant, hippopotamus, rhinoceros, giraffe, gazelles, wart hogs, zebras, wild asses, and various carnivores. Also present were several species of birds (including ostriches, bustards, guinea fowls, and water birds), reptiles (particularly the tortoise,

Trionyx triunguis, and the Nile crocodile), various fish (including the Nile perch, Lates niloticus, and several siluriforms), and mollusks, as well as a considerable array of rodents and insects.

It is within this environmental context that, around 8000 B.P., the Neolithic savannah civilizations of Mauritania were established by negroid peoples from the south, and by North African peoples with Capsian affinities. Many of the villages of the period were clustered along the northern shoreline of Lake Awkar beneath the Dahr Tishit and Dahr Walata escarpments. The inhabitants of these villages were supported by fishing, hunting, and gathering. Although it has been widely assumed that domesticated livestock were maintained by these populations, this hypothesis seems to have been weakened by recent discoveries. Similarly, the proposition that agriculture was practiced by these Neolithic villagers requires further examination. This proposition is based largely on the belief that the querns recovered from the village sites were used for grinding domesticated grains. It is perhaps more probable that they were used to grind grass seed, other vegetable materials, and jerked meat.

From 5500 to 1700 B.P., a two-meter rise in sea level resulted in an extensive marine transgression that created the Gulf of Nouakchott, an embayment extending well inland through the interdunal troughs of the Akchar, Taffoli, and Amoukrouz regions. During this transgression, from approximately 3300 to 1950 B.P., the climatic and ecological conditions of Mauritania deteriorated significantly. The larger species of savannah wildlife virtually disappeared from the Adrar and Tishit regions, and declining precipitation progressively diminished the lakes formed earlier in the interior of the country. It is not clear whether this disappearance was simply a function of environmental change in relation to the requirements of the species involved or was a result of a combination of habitat change and increased hunting pressure. If animal husbandry and agriculture were not practiced during the Mauritanian Neolithic, it may be assumed that climatic and ecological deterioration would be accompanied by increased pressure upon those plant and animal resources that remained. The water requirements of many of the savannah mammals would have resulted in their concentration around a decreasing number of watering places, thus increasing their vulnerability. Such situations frequently result in overkill, and occasionally in species extinction. A crude parallel might be drawn between this episode and the wholesale eradication of large mammals in Mauritania during the 20th century. Although this latter period also witnessed severe environmental degradation, it was increased hunting pressure rather than habitat

modification that was most directly responsible for the wildlife losses suffered. (This is discussed further elsewhere in this report.)

According to some scholars, growing conflict within the Awkar region encouraged lakeside dwellers to reestablish themselves in fortified villages of 2,500-3,000 inhabitants on the nearby plateaus. According to others, environmental deterioration simply provided an incentive for these populations to relocate near the many springs that issued from the escarpment to the north and east of Lake Awkar. It is assumed that the population of the Lake Awkar villages was heterogeneous, and that livelihood specialization generally occurred along ethnic lines. Hence, it is probable that the diverse ethnic components of the villages were attracted to areas better able to support their particular specialization. It is therefore of some interest that hunting and gathering (and possibly agriculture) were stressed in the newly established villages of the plateaus, and that oral tradition identified these villagers as the Gangara (or Wangara) ancestors of the Sahelian Soninke. Similarly, the fishermen of the lakeside villages might well have been the legendary proto-Berber Bafur, the alleged ancestors of the coastal Imraguen fishermen of the present day.

The villages of the plateaus, well known for their diversity of art forms, pottery manufacturing, and metal working, were increasingly subject to attack during the 3rd and 4th centuries A.D. as camel-mounted Berber groups migrated southward into Mauritania in order to escape the anarchy and warfare of the late Roman period in North Africa. Many of those who elected to remain in the oases of the Awkar region were subjugated by the immigrant Berbers, and many who had fled southward were later returned to the upland oases in bondage. Additional groups of camel-mounted Berbers arrived in Mauritania during the 7th and 8th centuries. Many of these were Sanhaja affiliates which professed neither Christianity nor Judaism and were therefore regarded as infidels by the ascendant Muslims of the Maghrib, and as such were subject to slavery. It was apparently the desire to avoid subjugation that initially drew them southward to Mauritania.

Because the current literature of desertification often associates the present environmental crisis in Mauritania with long-term use pressure by pastoralists, it should be noted that medieval Arabic sources dealing with Mauritania indicate that these North African immigrants were almost wholly supported by the milk and flesh of their camels. Cattle, goats, sheep, and other forms of livestock were not associated with Berber pastoralism in Mauritania at this time.

From these numerous and diverse ethnic groups emerged the historically-documented pre-Islamic populations of Mauritania.

THE HISTORICAL PERIOD

Somewhat ironically, there is relatively little reliable bio-climatic data for the historical period in Mauritania. Although Hanno (ca. 425 B.C.) provides us with a brief account of the Mauritanian coastal zone and the Chemama, and Herodotus (The Histories 2. 32) alludes to a Nasamonian expedition which may have passed through the Hawd, the principal sources for such data are medieval authors such as al-Ya'qubi (d. 891), the geographer Ibn Hawqal (fl. 988), al-Muhallabi (d. 990), the Andalusian geographer al-Bakri (d. 1094), the geographer al-Idrisi (1100-1166), ad-Dimishqi (d. 1327), and Ca' da Mosto (fl. 1455), a Venetian serving the Portuguese. Additional information is available in the reports of modern travelers such as de Chambonneau (fl. 1677) and Monteil (fl. 1879). The collection of systematic scientific data for Mauritania dates largely from the conclusion of the French "pacification" in the 1930s.

Medieval Mauritania

Various scholars have suggested that some of the fires in the interior of Africa reported by Hanno might well have been bush fires intentionally set by local inhabitants. Hence, the descriptions of vegetation contained in the medieval accounts of Mauritania possibly refer to the species of an already degraded fire sub-climax. Comparisons of plant communities reconstructed from medieval sources with the species listed in the palynological literature for periods that were comparable climatically do in fact indicate that by the dawn of the Middle Ages the vegetation of Mauritania was already a cultural artifact. The following references to Awdaghast and environs chronicle a continuing deterioration.

Awdaghast: A Brief Case Study of Environmental Degradation during the Mauritanian Middle Ages

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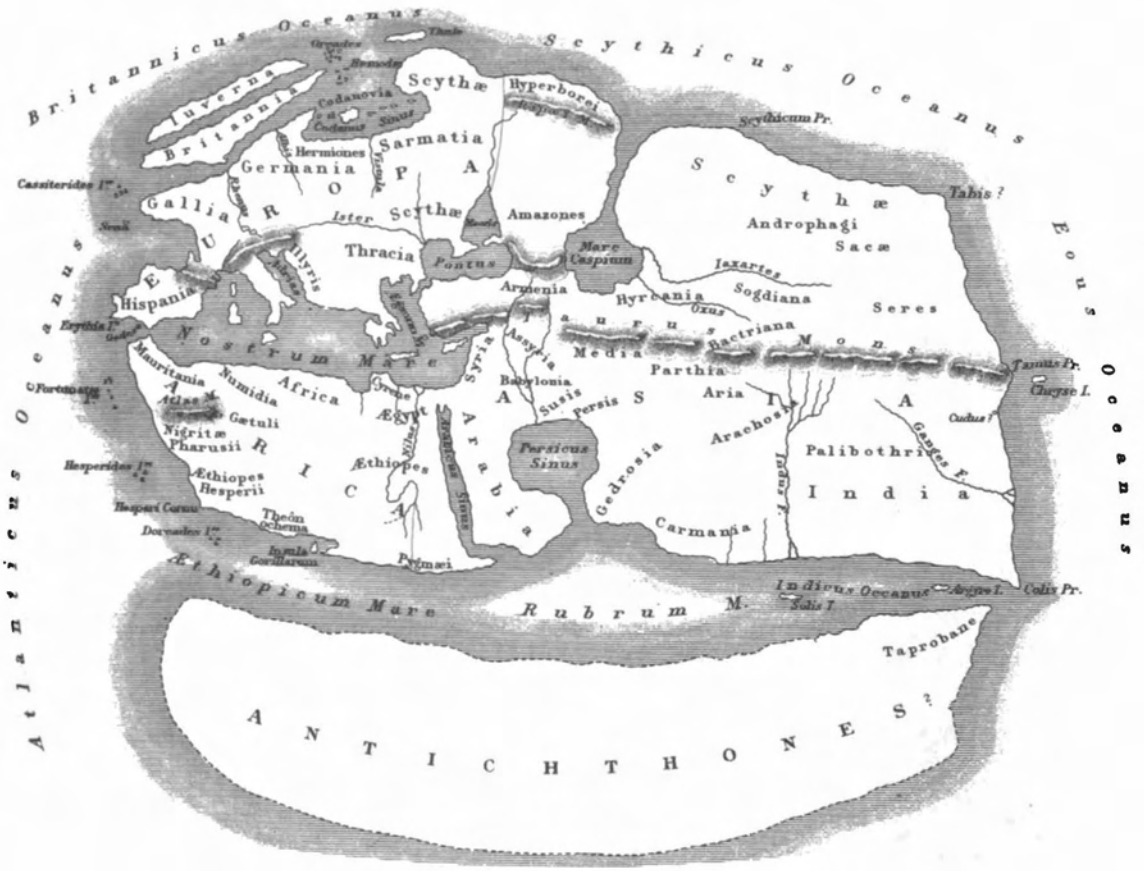
Awdaghast (Tegdaost) is believed to have been founded during the 6th century A.D., possibly by Negro cultivators. The oasis subsequently grew in importance as a caravan center, evidently controlled by Zanata Berbers. The Sanhaja Berber

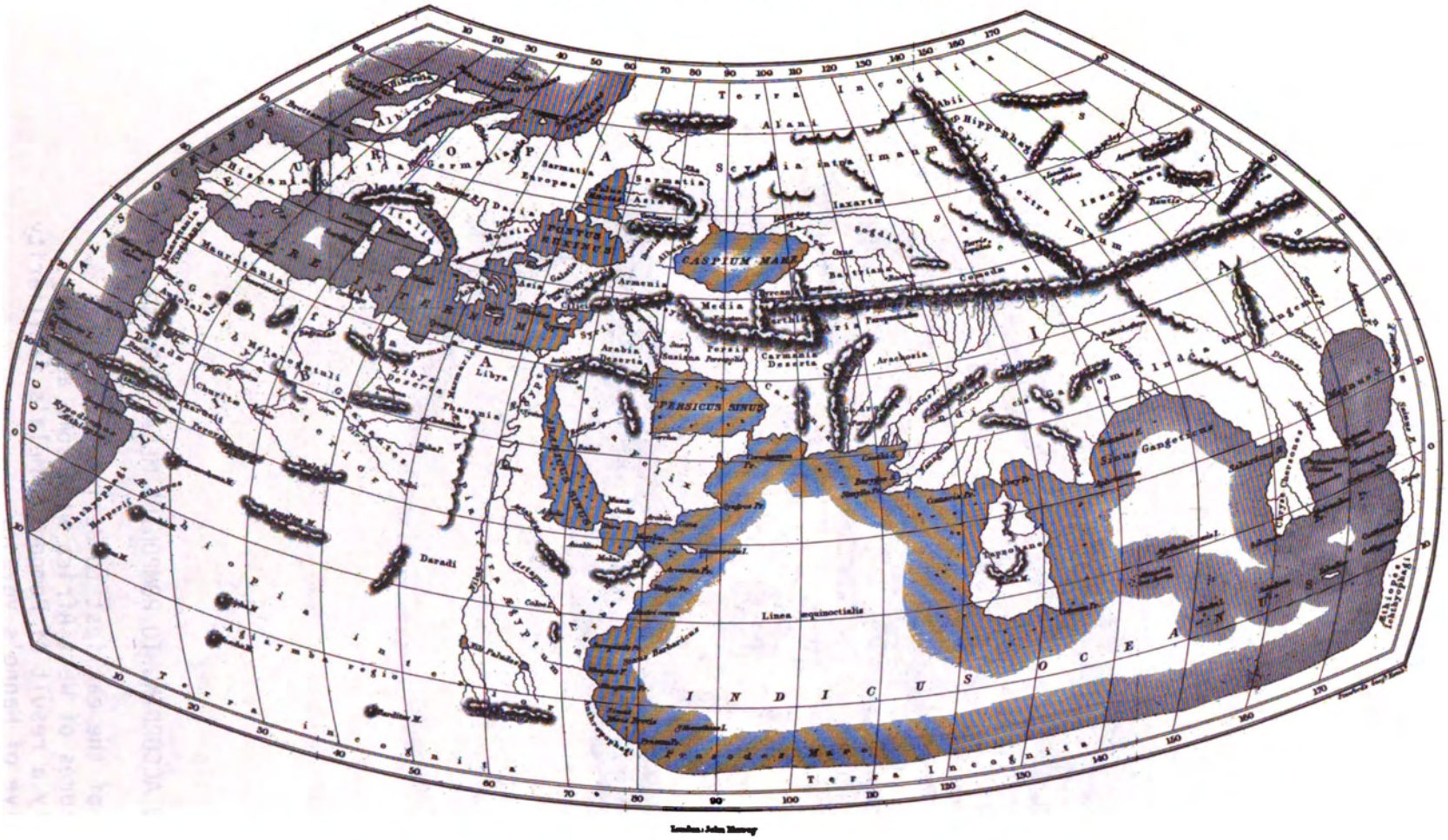


MAP OF THE WORLD ACCORDING TO POMPONIUS MELA, A.D. 43

This map is one of the earliest to depict the islands and coastal features of West Africa with some accuracy. This is evidently a result of Pomponius Mela's familiarity with the narrative of Hanno's voyage.

Reprinted from E.H. Bunbury, A History of Ancient Geography, Dover Publications, Inc., (New York, 1959).

MAP OF THE WORLD ACCORDING TO PTOLEMY



Ptolemy's representation of the Mauritanian coastal zone, A.D. 150, is relatively accurate. His map is among the first to include the streams (perhaps intermittent) which historically flowed from the acacia woodlands of the coastal zone. The disappearance of these woodlands as a result of uncontrolled gum-arabic production has reduced the watercourses to wadis.

Reprinted from E.H. Bunbury, A History of Ancient Geography, Dover Publications, (New York, 1959), p. 578.

confederacy, which consisted of the Lamtuna, Masufa, and Godala tribes, arrived in the Mauritanian Adrar during the latter half of the 8th century. They then moved southward under the leadership of the Lamtuna to gain control of Awdaghast as a prerequisite to their broader objective of controlling the trade routes of the western Sahara.

Deforestation

Although volumes have been written on the Saharan trade, relatively little is known of the direct contribution of this trade to the widespread deforestation of the desert margins. Evidently, as Alexander von Humboldt noted in 1848, travelers unfamiliar with arid lands are "easily...led to adopt the erroneous inference that absence of trees is a characteristic of hot climates." Some insight into the environmental impact of the Saharan trade is provided by Sidi Hamet, a Moroccan trader familiar with the Mauritanian routes. In describing a caravan "of about three thousand camels and eight hundred men," Sidi Hamet recalls that "we stopped ten days, and let our camels feed on the bushes, while half the men were employed in getting wood from the mountain, and

Charcoal production

burning it into charcoal, which we put into bags, as it was light, and laid it on the camels over the other goods." The charcoal was apparently used for roasting the flesh of desert antelopes and camels, for trade, and as emergency rations for camels. Finding "nothing for (the camels) to feed on," the cameleers "had been obliged to give them of the coals to eat, once a day for many days: this kept them alive." Again passing through Mauritania, Sidi Hamet notes that "before we struck off N.W. on the desert for the seacoast, we stopped in the hill country, and fatted our camels, and burned wood to make charcoal to carry with us." Describing a later journey involving "four thousand camels, and more than one thousand men, all well armed," Sidi Hamet again remarks that the caravan stopped at the desert margin "and cut wood and burned coals for the camels, for the caravans never attempt to cross the desart [sic] without this article."

It is perhaps noteworthy that various sources indicate that axes were standard equipment for cameleers engaged in the Saharan trade. The

writings of Marsh, Bobek, Jorgensen, Darby, Mikesell, and others who have explored the question of deforestation in antiquity leave little doubt that charcoal production in relation to the Saharan trade could have had a most profound impact upon the ecology of the Sahel region. Further, with the depauperization of the desert margin, the dry-season mechanisms of seed dispersal within Sahelian ecosystems--effective northeasterly winds, southerly trending animal movement, etc.--would encourage a progressive southward shift of dry-steppe vegetation leading to a compression of the zone. This, in turn, would alter ecological relationships, lead to decreased genetic diversity and, ultimately, amplify the impact of hazards such as drought.

Zonal compression

This problem has been further aggravated by declining wildlife populations in the Sahel, as birds and desert herbivores formerly played critical roles in the stimulation and seed dispersal of desert plants, prominently including large-seeded legumes such as Acacia, Albizzia, Bauhinia, Cassia, Entada, Parkia, Prosopis, Tetrapleura, and other allied genera. The wildlife populations of the Mauritanian Sahel have declined as a result of the substantial meat requirements of oasis dwellers and cameleers involved in the Saharan trade, as well as through sport hunting with the introduction of more advanced firearms and the commercialization of tishtar, jerked antelope flesh.

Wildlife losses

Al-Ya'qubi, 9th century

Awdaghast first enters the literature of the region in al-Ya'qubi's Kitab al-Buldan, a volume written in 891. Following a general description of the Sanhaja, al-Ya'qubi continues: "Then one comes to a place called Ghast, an inhabited valley in which are dwellings and a king of theirs who has neither religion nor revealed law. He raids the country of the Negroes, whose kingdoms are numerous."

Sanhaja presence

Al-Muhallabi, 10th century

The observations of al-Muhallabi, preserved in the works of Yaqut and Abu'l-Fida', describe 10th-century Awdaghast as a large, active commercial and administrative oasis inhabited by Berbers. He refers further to the planting of wheat, millet (dukhn), sorghum, cowpeas, and peas at the onset of the summer rainy season; to fig

Commerce

Agriculture

trees and numerous date palms; and to the intense heat of the region. The agriculture was presumably practiced by the subject cultivators of the ascendant Berbers.

Ibn Hawqal

Livestock

No mention is made of livestock, although al-Muhallabi's contemporary, Ibn Hawqal, notes that the nomadic Berbers of the Awdaghast region subsisted largely on camel's milk, and that they consumed very little meat. This account is consistent with the later recollections of Sidi Hamet that the people of the desert "subsist entirely on milk of their camels; it is the milk of an animal that we call sacred, and it caused long life: those who live on nothing else, have no sickness nor disorders, and are particularly favoured by heaven; but only carry the same people off the desart [sic], and let them live on meat, and bread, and fruits, they then become subject to every kind of pain and sickness when they are young, and only live to the age of about two Zille and a half at the most, while a great many die very young, and not one tenth part of men or women live to the age of one Zille." (A zille is given as forty lunar years of twelve moons in each year, or roughly 39 years in Gregorian equivalency.)

Natural environment

Although al-Muhallabi's observations provide little information regarding the natural environment of the Awdaghast area, he does refer to acacias and wild palms, to the sandy surface of the area, and to the springs found along the access routes.

Geographical profile: Awdaghast

The site of Awdaghast is associated with the igneous Rkiz plateau northeast of Tamchekket (17°23'N, 10°37'W). The elevation of the site is perhaps 120 meters (m) higher than that of Tamchekket (175 m above sea level) and, because of local topographical influences upon patterns of precipitation, the average rainfall at the site is somewhat greater and more consistent than the 264.9 mm average recorded at Tamchekket. The soils of the Awdaghast area include Argids and various Entisols. The flora of the area is currently dominated by Acacia senegal (declining)

and Balanites aegyptiaca. Leptadenia spartium is also found in the area, as are grasses such as Cenchrus biflorus and Chloris prieuri.

Controlled by Gana

In 990, Gana, an empire then dominated by the Mande-speaking Soninke, gained control of Awdaghast. Writing in the 11th century, al-Bakri follows al-Muhallabi in describing Awdaghast as a large, active trading center. His narrative indicates that while Berbers, now presumably Zanata Berbers, were particularly prominent, the population of the oasis had become highly heterogeneous. The gardens of the oasis, irrigated through the use of leather buckets, produced dates, wheat, cucumbers, figs, some grapes, and henna. Al-Bakri notes that the garden produce was utilized only by the aristocracy and other notables. The rest of the population subsisted largely on sorghum (dhurra). Al-Bakri also notes that the population of Awdaghast had become dependent upon the importation of additional wheat, dates, and raisins, as well as honey. (In citing al-Bakri, it should be noted that al-Bakri himself had not visited Awdaghast and drew heavily from the lost writings of al-Warraq and from other sources.)

Al-Bakri, 11th-century

Commerce

Heterogeneous population

Agriculture

Livestock

Although the camel possibly remained the principal herd animal, cattle and sheep apparently increased in importance as a result of the settlement of peoples from the savannah zone in Awdaghast.

Water supply

Nieger, Bovill, Briggs, Davidson, and others have explored the question of water supply in relation to Saharan commerce. Hence, it is not surprising to find a network of wells serving the way stations of the Saharan trade routes. Al-Bakri attributes a significant number of the wells to the efforts of a single individual, 'Abd ar-Rahman b. Habib, the independent governor of Ifriqiya from 745 to 755. These wells were spaced at convenient distances from the Jabal Bani region to Awdaghast. They were typically on the order of eight meters (four qama) in depth. As savannah peoples were attracted to the oases of the Sahel with the expansion of Gana, al-Bakri notes the added importance of these wells in supporting the

herds of cattle and sheep that accompanied them. It is of possible interest that recent studies of medieval wells in Mauritania have led to the conclusion that ground-water levels were in some instances as much as eight meters higher than they are at the present time. Al-Bakri's description of Awdaghast contributes a measure of explanation to the conclusion of these studies, as the combined hydrological impact of the wells themselves, widespread devegetation, surface sealing, and soil compaction by livestock would very likely result in local water tables being depressed to a level equal to or greater than the depth of the wells in question.

Natural environment

With regard to the natural environment of the area, al-Bakri describes Awdaghast as a "city... in the sand," and notes that the nearby mountains, earlier covered by acacia trees, were "without life and without vegetation" -- presumably as a consequence of charcoal production. Oryx (lamt) were found in the area, and shields fashioned from their hides, lamta, were highly prized. Further references to wildlife are rather general in nature. Al-Bakri does not mention the springs described by al-Muhallabi.

Murabitun control

Gana directly controlled Awdaghast for 64 years. In 1054-1055, the Murabitun, a body composed of the former ruling class of Awdaghast, reestablished control over the oasis. Al-Bakri's description of this event provides additional insight into the character of Awdaghast: It is described as a large center in a populous country. Within the oasis, "there were many markets, palm groves and henna trees as large as olive trees.... It is a solidly built town with fine residences,...Zanata and Arabs lived in this town in a state of mutual hatred and opposition. They were very wealthy and possessed many slaves, some having a thousand or more. The Murabitun declared all that they found of women and goods to be lawful booty."

Al-Idrisi, 12th century

Little water

Livestock

Truffles

Al-Idrisi, writing during the 12th century, referred to Awdaghast simply as "a small community situated in the desert. There is little water." He continues, noting that Awdaghast is not an important commercial center, and that "the population maintains camels, from which they derive their subsistence." An additional environmental clue provided by al-Idrisi is mention of the importance accorded truffles (kam'a) in the local diet. He notes that they are found in quantity near the playas of the Awdaghast area, and that "they are cooked along with camel meat." He adds that the people of the area believe that this dish is "the best food in the world, and they are correct in this belief."*

Ad-Dimishqi, 13th century sources

Inhabitants

Finally, ad-Dimishqi described Awdaghast as "a town in the sand with palm-trees. The region is very unhealthy. The inhabitants consume sorghum and meat." According to ad-Dimishqi, the population of Awdaghast was composed of Mulaththamum (literally "muffled," an Arabic term applied to the veiled Sanhaja Berbers) and Murabitun, with the Sanhaja Lamtuna dominant. According to Ibn Khaldun, within the social context of the 14th century, the association of Awdaghast with the Sanhaja, ancestral Kel Tamacheq (Tuareg), carries certain broad environmental implications. Similarly, the reappearance of the Masufa among the Mulaththamum is of interest, as Ibn Battuta identified the Masufa with the historical Namadi hunters of the Majabat al-Kouba.

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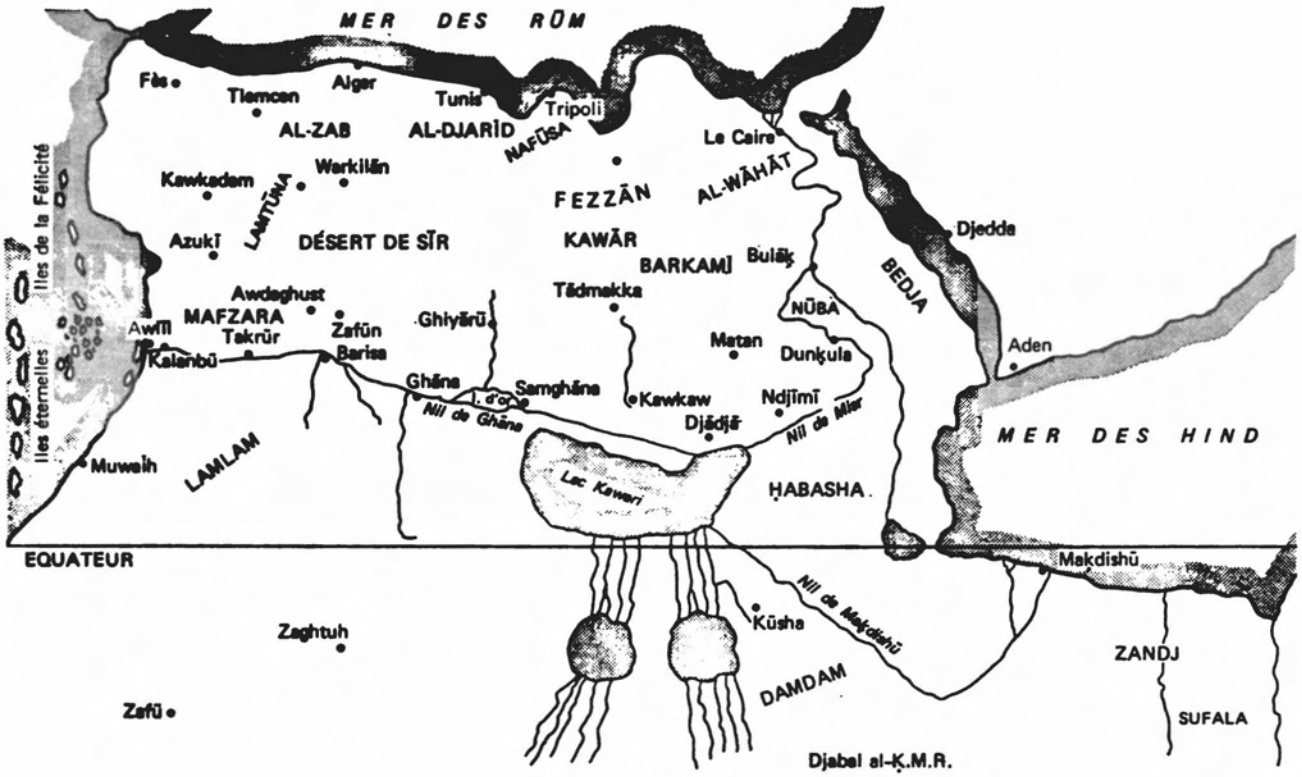
*Truffles have long served as a highly regarded resource for desert peoples in Africa. Al-Bakri refers to the gathering of truffles around the Libyan oasis of Ghadames. The 14th century geographer Ibn Battuta notes an abundance of truffles in the desert around the west-central Saharan salt-mining community of Taghaza. Gustav Nachtigal, writing in 1869, observes that they are "found fairly frequently, and are very popular" around Murzuq, and they are still gathered and eaten by the bushmen of the Kalahari. Similarly, F. R. Chesney, writing in the 1830s, lists truffles among the products in Arabia.



IBN SA'ID, FL. 1286

Reprinted from Recueil Des Sources Arabes Concernant L'Afrique Occidentale Du VIIIe au XVIe Siècle, L'Institut de Recherche et d'Histoire des Textes, (Paris, 1975), p.2.

Although the reliability of some of the sources cited might be questioned, and while the details of many descriptions undoubtedly reflect social factors and historical circumstances as well as environmental conditions, certain general conclusions can be drawn regarding environmental change in medieval Awdaghast:

One of the most important, and certainly one of the least discussed, sources of environmental degradation during the Mauritanian Middle Ages was the felling of trees on the desert margins for charcoal production. Not only were vast areas affected, but the pressure has been continuously exerted well into modern times.

Al-Muhallabi seemingly indicates that the agricultural needs of Awdaghast were largely satisfied by dry farming during the 10th century. This would be consistent with the crop complex mentioned (particularly dukhn), with the apparently greater availability of ground water suggested by the presence of springs, and by the relatively abundant natural vegetation of the region. Archaeological evidence suggests that the oasis was also supported by irrigated gardens maintained by various Aramaean water-harvesting techniques historically associated with Zanata Berber penetrations of the Sahara during the Abbasid and Aghlabid periods in North Africa, and therefore possibly related to the 8th-century efforts in water supply ascribed to 'Abd ar-Rahman b. Habib.

Although it is probable that some recessional cultivation of sorghum was still practiced in the Awdaghast area after the 10th century, al-Bakri and subsequent sources refer to irrigated gardens and a growing dependence upon imported goods, rather than to dry farming. Further, the springs mentioned by al-Muhallabi are not noted in the writings of subsequent visitors to Awdaghast. The impression one gains is that devegetation incurred through fuelwood gathering and charcoal production, in combination with increased grazing pressure, had severely depressed the ground-water table in the Awdaghast area by the 11th century. The probable impact of increased grazing pressure is discussed below.

As the population of Awdaghast was composed largely of Sanhaja Berbers at the time of al-Muhallabi's visit, it is reasonable to assume that camels were the only prominent herd animal.

As the camel is well adapted to the Sahel and possesses foraging habits compatible with the ecology of the region, the environmental impact of the camel was probably modest.

As noted above, when al-Bakri described Awdaghast in the 11th century the oasis was attached to the Soninke-dominated kingdom of Gana. He observed that "cattle and sheep (were) so numerous there that for a mithqal one may buy ten rams or more." Both cattle and sheep are poorly adapted to Sahelian conditions: their conversion efficiency is poor; they require substantial quantities of water; and they are highly subject to stress. More important in environmental terms, their feeding habits easily disrupt the ecological equilibrium established over the millennia through the coevolution of plants and animals. Perhaps most of the native herbivores of the region are predominantly browsers. Cattle and sheep, both largely grazers, greatly increase the pressure upon climax perennial grasses, often resulting in their elimination.

The reduction or elimination of late dry-season grass cover triggers a number of degradative sequences once the rains commence. Raindrops striking a wet soil surface raise mud spatters, first sealing the surface and then mobilizing soil particles that are subject to transport by overland flow. This results both in reduced infiltration leading to depressed ground-water tables and in soil removal. A mat of grass, on the other hand, intercepts the raindrops and controls overland flow, as the water is forced to filter through a tangle of stems, grass blades, dead leaves, and root hairs. Meanwhile, infiltration is encouraged and the rooting network serves to stabilize the soil. This problem is naturally more severe on true soil surfaces than on sandy surfaces that permit infiltration.

Surface exposure and reduced organic content also disturb the soil ecology through altered soil-water relationships and a greater amplitude in soil temperatures. It is probable that the victims of this altered soil ecology would include critical soil organisms, such as the rhizobial bacteria that are associated with leguminous plants such as the Sahelian acacias, and that fix atmospheric nitrogen, increase productivity, and reduce the impact of stress. As use pressure, depressed ground-water tables, and altered soil ecology directly eliminate certain plant species and frustrate the regenerative processes of others, further losses occur through disruptions in plant dependencies and affinities.

In summary, charcoal production, both in association with the Saharan trade and local needs, contributed greatly to deforestation. With the subjugation of Awdaghast by Gana, and the settlement of savannah populations in the Awdaghast area, cattle and sheep were introduced into the region for the first time on a large scale (according to the sources consulted). In an area already largely deforested, the selective pressure exerted upon the perennial grasses would have led rapidly to a reduction of ground cover, surface sealing, lowered ground-water tables, and a greatly disturbed soil ecology. The conditions created would greatly complicate the restoration of the region without human intervention or a substantially altered climatic regime. The lessons of Awdaghast apply equally to many other medieval Mauritanian urban centers.

During the early centuries of the Middle Ages, rural Mauritania was dominated by the Berber Sanhaja confederacy. The Arab presence in Mauritania was largely limited to traders active in the various commercial centers of the region. This situation was to change dramatically during the course of the 13th century.

Early in the 11th century, Fatimid Egypt received the Arab Banu Hilal and Banu Sulaim, nomadic groups allegedly driven from Arabia by drought. The Fatimid khalifa, al-Mustansir, dissatisfied both with the instability created by these nomadic groups within Egypt

and with the abdication of Shi'ism and declared independence by the governor of Ifriqiya, attempted to resolve both problems by encouraging the Banu Hilal to invade Ifriqiya and depose the governor, al-Mu'izz ibn Badis. Upon leaving Egypt, the Banu Sulaim remained for a time in Tripoli, but the Banu Hilal, after overrunning Tunis, continued westward. Around 1270, certain groups of the Banu Hilal, the Ma'qil, were driven south of the Dra'a by the Marinid forces of Abu Yusuf. It is believed that the Ma'qil then drifted southward into Mauritania where, according to oral tradition, they supported themselves by raiding caravans and their Sanhaja neighbors. Led by the Banu Hassan, the tribes of the Ma'qil established their supremacy as a warrior aristocracy over the Sanhaja of northern Mauritania during the 15th century over western Mauritania, Waddan, and Tagant during the 16th century, and over the Adrar and lower Mauritania during the 17th century.

Although the social consequences of the Ma'qil ascendancy are relatively well known, comparatively little is known of the environment impact of the Ma'qil expansion. One might be tempted to turn to Ibn Khaldun's depiction of the Banu Hilal impact upon North Africa for guidance. According to him, the Banu Hilal and their livestock "devoured and devasted all forms of vegetal life," reducing the region to a desert and creating severe shortages of timber. Thirteenth-century authors describing areas of southern Morocco inhabited by the Ma'qil do in fact refer to substantial concentrations of livestock. Subsequent descriptions of Mauritania following the Ma'qil migrations into the region do not, however, associate these groups with unusually large herds, and the herds described are composed largely of camels. (These same sources associate cattle, goats, sheep, camels, and other forms of livestock with Takrur and other savannah kingdoms and dependencies to the south.)

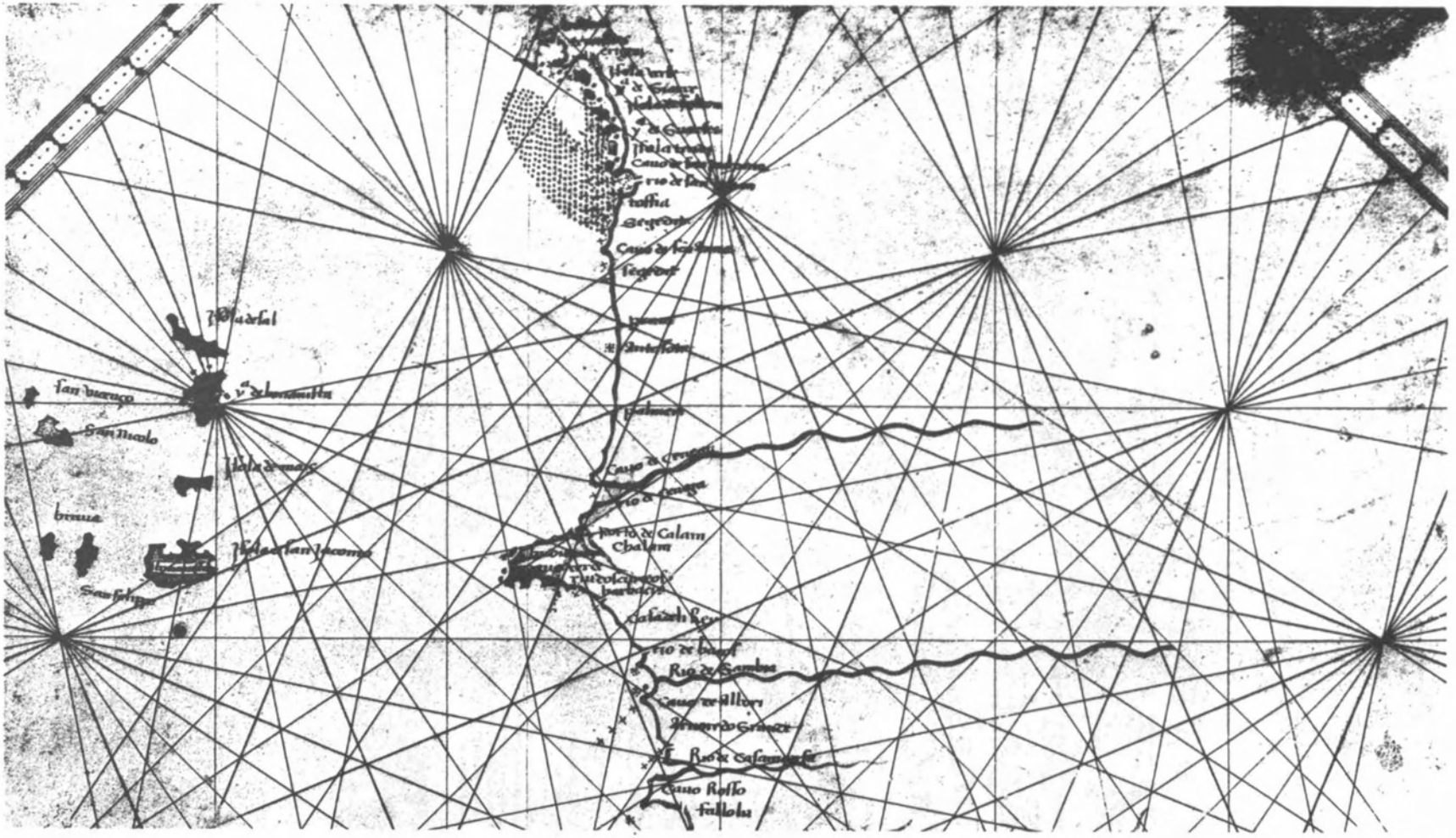
It would appear that prior to European contacts early in the 15th century, the principal causes of environmental degradation in Mauritania were: (a) bush fires; (b) charcoal production; (c) the introduction of cattle and sheep into Sahelian ecosystems during periods of Soninke expansion; and (d) site preferences for Berber and Arab settlements. Of these, the probable impacts of bush fires, charcoal production, and maladapted livestock upon the Mauritanian environment have been discussed in the preceding pages. The suggested fourth cause of degradation, site preferences, refers to Berber and Arab traditions of establishing their settlements on elevated sandy surfaces (see p. 16). Characteristically, such surfaces in medieval Mauritania were stabilized sand dunes, and the consequence of this preference has been the reactivation of these dunes through devegetation and physical disturbance. Problems relating to site preference are discussed in Chapter II of this report.

The medieval Arabic literature contains several possible references to early European contacts with Mauritania. Al-Mas'udi (fl. 947) refers to an account "well known in Spain" of a young man from Cordoba who led several ships southward into the Atlantic and returned with great wealth. Al-Idrisi refers to a similar party of merchant venturers who sailed from Lisbon and visited the West African coast. Ibn Sa'id (fl. 1286) was told of the discovery of Cape Blanc by a party later shipwrecked near Cape Non. Finally, al-'Umari (fl. 1337) describes an account of a ship driven southward from Spain, and the exploration of the African mainland by its company.

Early European Contacts: 1400-1900

Relatively frequent Portuguese contacts with Mauritania were begun early in the 15th century. Initially, the Portuguese judged the interior to be inhospitable and concentrated on exploiting the rich fishing grounds of the Arguin Bank. According to Alvise Ca' da Mosto, they subsequently began purchasing "slaves whom the Arabs bring from the land of the Blacks, and gold tiber [dust]." Arguin was therefore selected as a suitable base for the Portuguese fishing fleets and for trade with the interior. The construction of a fort was initiated on the island in 1448, and a commercial center was eventually established at the oasis of Waddan around 1487. Late in the 16th century, the trading center at Arguin was taken over by the Spanish who, in turn, were displaced by the Dutch in 1638.

The Dutch were apparently the first to recognize the commercial potential of the gum arabic produced by the Acacia senegal forests of Mauritania. The gum arabic exported through Arguin was used largely for printing in the important Dutch textile industry. The French later became interested in the gum arabic trade and, in 1677, the Dutch were forced to cede Arguin to the French following the Peace of Nimegue. In 1690, the Dutch recovered Arguin and held it for 31 years before again losing it to the French. During this period, the Dutch had established commercial ties with 'Ali Shandora of the Trarza which resulted in the founding of Marsa (later Portendik), a commercial outpost located some 40 kilometers to the north of modern Nouakchott. The French captured Portendik in 1723, and it was subsequently regained by the Dutch, recaptured by the French in 1724, and taken by the English in 1762. By 1763, the English were in complete control of the Mauritanian gum arabic trade. Twenty years later, the Treaty of Versailles, which



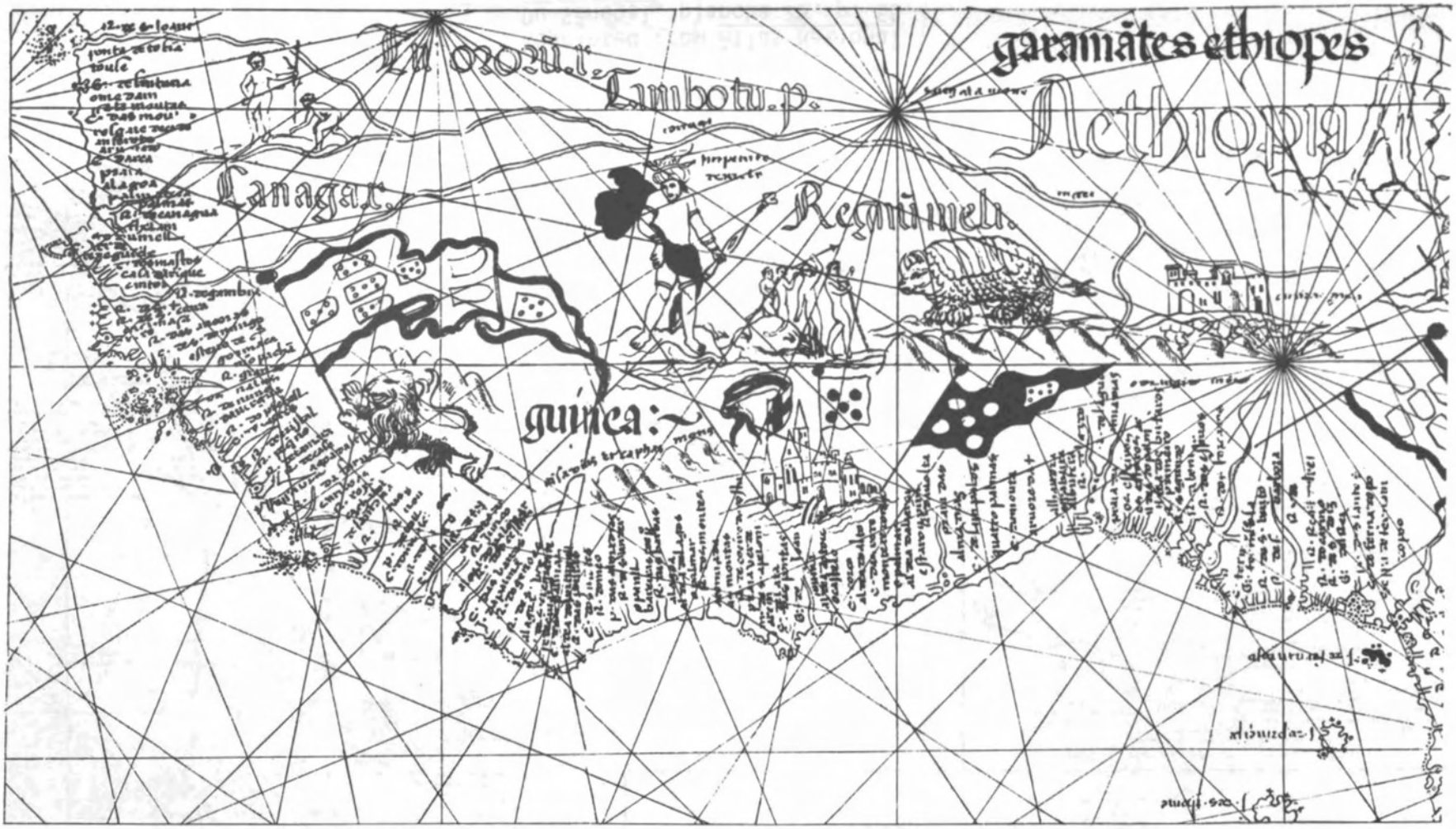
GRAZIOSO BENINCASA, 1468

Reprinted from The Voyages of Cadamosto, translated and edited by G.R. Crone, The Hakluyt Society, (London, 1937), p. 84.

AFRICAE TABVLA.

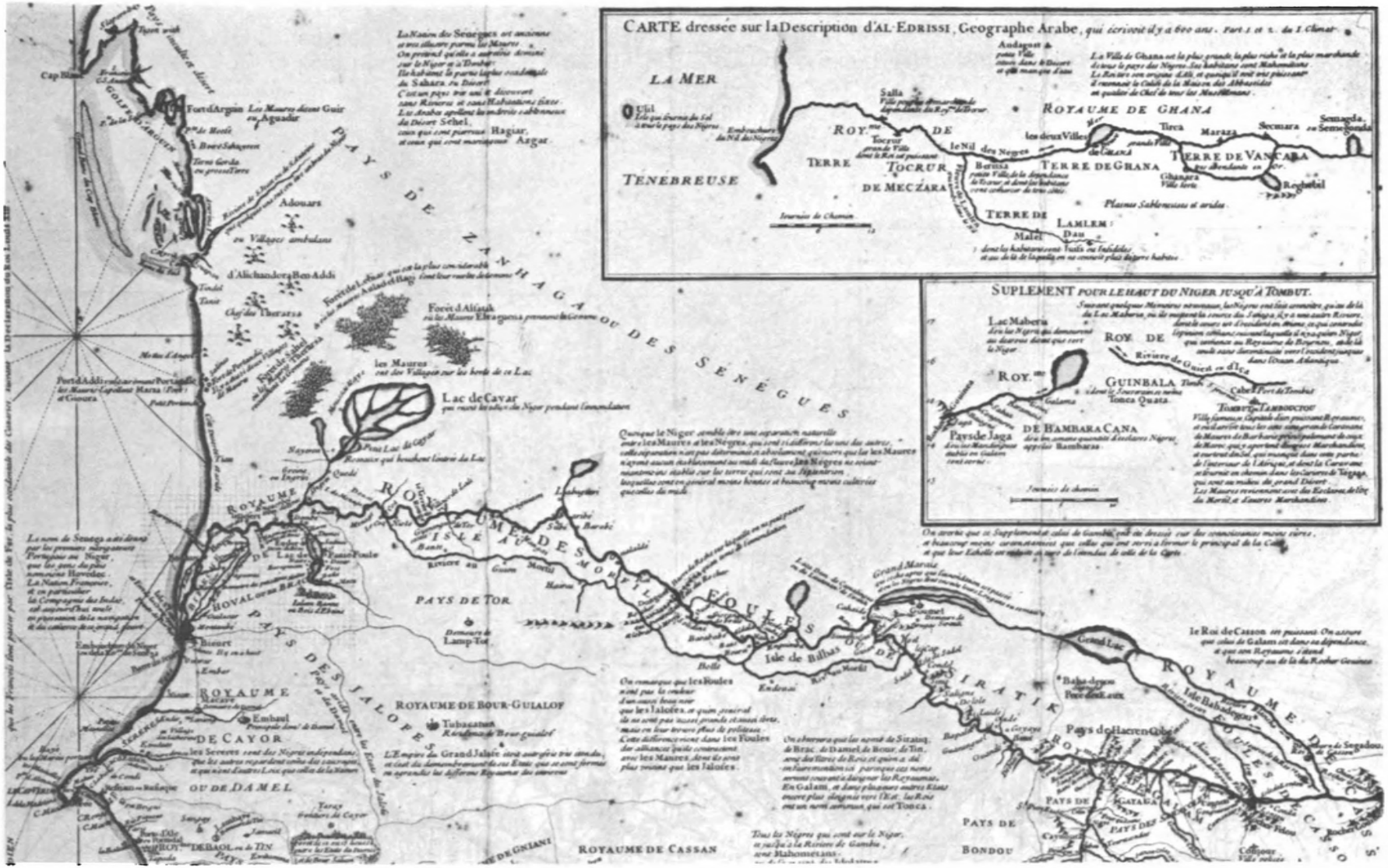
WOODCUT MAP OF AFRICA, MUNSTER, 1540

Reprinted from R.V. Tooley, Maps and Map-Makers, Bonanza Books, (New York, 1961) p. 97.



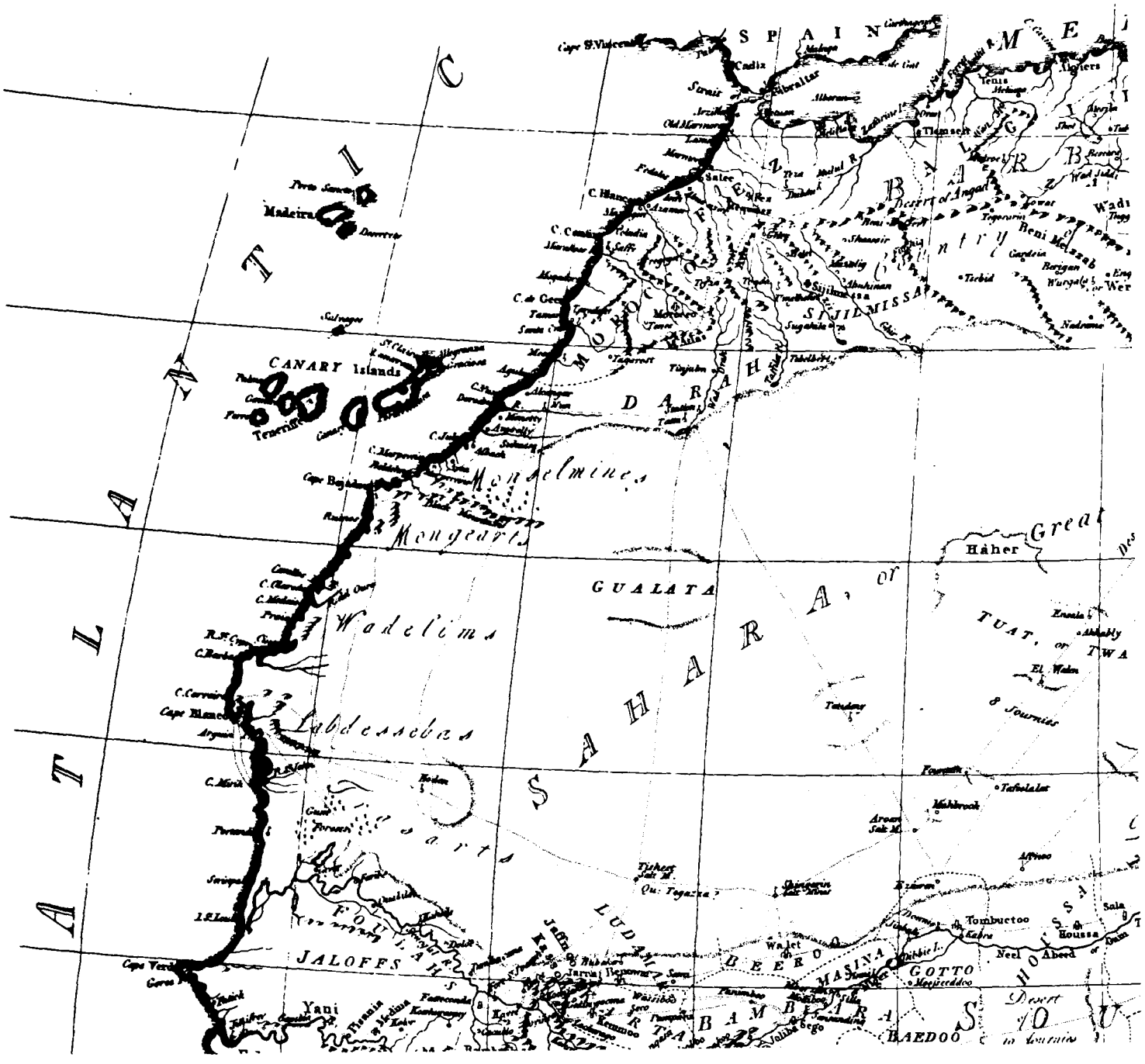
DIOGO HOMEN, 1558

Reprinted from Europeans in West Africa, 1450-1560, translated and edited by John William Blake, M.A., The Hakluyt Society, (London, 1942).



D'ANVILLE, 1727

Reprinted from Atlas National
Du Sénégal, planche 20, p. 55.



JAMES RENNELL, 1798

Reprinted from Mungo Park, Travels in the Interior Districts of Africa, Arno Press, 1971.

terminated Anglo-French rivalries in America, also returned control of the Mauritanian coastal zone to the south of Cape Blanc to the French. Renewed hostility between France and England again resulted in an English presence in the region. This presence was maintained until the peace settlement following Napoleon Bonaparte's defeat at Waterloo returned the region to France in 1816.* Despite the apparent finality of this transfer, one finds reports of Moors selling gum arabic to the English in defiance of the French as late as 1834. In 1857, in exchange for the formal renunciation by the English of their gum trade at Portendik, the French ceded their remaining rights at Albreda on the Gambia.

The intense European competition for gum arabic resulted in increased demand and higher prices. As the exploitation of gum arabic became more profitable, production increased apace. The environmental consequences of increased production were evidently profound. Gum arabic is a storage product of the Acacia senegal. The more stressed the tree, the greater the yield of gum. Unfortunately, the tapping methods employed in the Trarza to stress the trees and increase production also reduce the resistance of the trees to disease and drought. The Trarza experienced severe droughts in the 1680s, around 1738-1756, the 1770s, the 1790s, the 1820s, and the 1830s. Given the historical southward shift in gum production within the Trarza and the sequential decline in importance of Arguin and Portendik, it would appear that the droughts of the 1700s and 1800s effectively destroyed the gum forests found inland from these important trading centers. The same highly destructive tapping methods have continued to be employed to the present day, and their use has led to the further disappearance of the well-known gum forests around Boutilimit, Togba, and elsewhere in Mauritania.

Further to the south, along the Senegal, slaving had already had a profound impact upon the repartition of the population. As early as Ca' da Mosto's visit in the 1460s, the river served as an acknowledged boundary between blacks and Moors. He notes that "it appears to me a very marvellous thing that beyond the river all men

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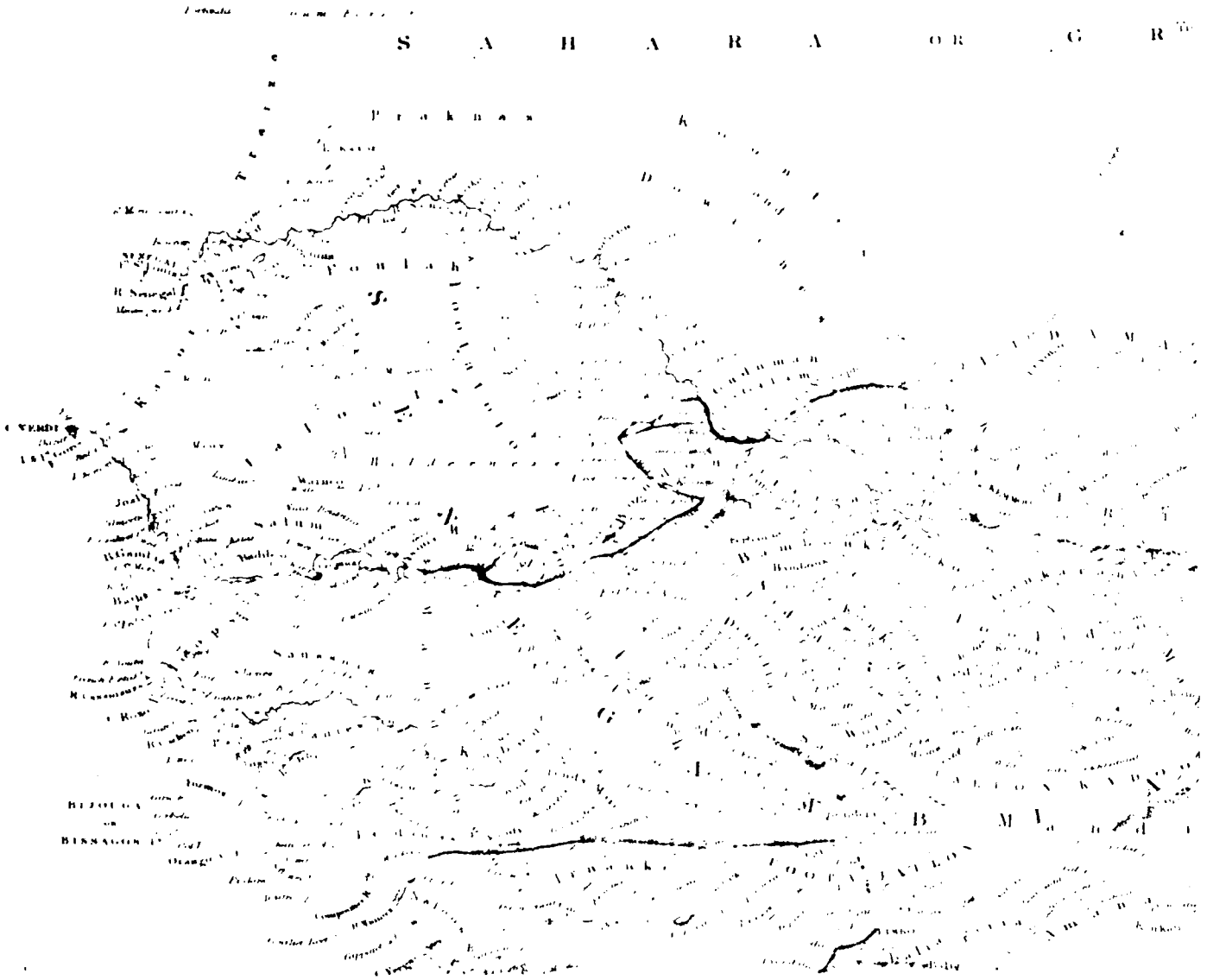
*It is of some interest that the English delayed the transfer of Saint-Louis, which was supposed to occur early in the year, in order to profit from an additional harvest of gum arabic. Had this delay not taken place, the ships dispatched to Saint-Louis to reestablish a French garrison and a French administration would not have had to sail under such adverse conditions, and it is quite possible that the tragic wreck of the French frigate, the Méduse, on the Arguin Bank, would not have occurred.



SOCIETY FOR THE DIFFUSION OF USEFUL KNOWLEDGE, MID-19TH CENTURY

The relatively late inclusion of gum forests to the east of Portendik is of some interest, as the Society made every effort to include only verified information on their maps.

are very black, tall and big,...while on this side, the men are brownish, small, lean, ill-nourished, and small in stature." The peoples of the various cultural groupings associated with the Chemama, the Senegalese (Serer-Tokolor), the Soninke-Manding, and others, were those most threatened by slavery. Hence, there was a general withdrawal of these peoples to regions south of the Senegal River. As these groups also practiced agriculture and maintained substantial village-based herds of cattle and goats (and, in some cases, sheep), their withdrawal southward reduced use pressure in southern Mauritania, and was therefore presumably beneficial in environmental terms. Because the regenerative dynamics of the Chemama are linked largely to the regime of the Senegal River (this being explicitly true of the dominant Acacia scorpioides var. nilotica the "gonakier" forest species dependant on periodic flooding for water supply and seed dispersal), the restoration of this region has historically occurred rapidly during periods of normal flooding.

An adverse environmental impact of the slave trade emerged from the form of payment commonly provided by the European traders to their Moorish associates. Reporting on his visit to West Africa in 1456 (or 1457), the Portuguese voyager Diogo Gomes reported "that there were caravels there which carried arms and swords to the Moors" in exchange for slaves. Writing in the 1790s, Mungo Park notes that the Moors obtained "their fire-arms and ammunition...from Europeans, in exchange for the Negro slaves which they obtain in their predatory excursions. Their chief commerce of this kind is with the French traders, on the Senegal river." James Riley, writing in 1817, recalls that "most of the Arabs are well armed with good double-barrelled French fowling pieces."

Both the Moorish literature and that of the Kel Tamacheq commonly refer to camels, to wildlife, and to hunting. No apparent affinities are expressed for cattle, goats, or sheep. An appreciation of bush meat is reflected in the commercial importance of tishtar in Mauritania, and bush meat has long figured prominently in the coping strategies employed by most Sahelian populations during periods of scarcity. Similarly, P. Cremoux maintains that as recently as the late 1950s, wildfowl and game animals contributed more to the diet of the peoples of the Chemama than did beef, the former constituting 3 percent, and the latter 2.4 percent of all consumed animal products (fish contributed 83.4 percent).

Many medieval authors have written of the abundant game of the Mauritanian Sahel and, in a work published in 1563, Joao de Barros described the wildlife of the Chemama as follows: the area produces "a great variety of fish and aquatic animals, such as sea-horses [hippopotamus], very large lizards, which in shape and nature are

like the Nile crocodiles,... and also serpents. The animals which drink the waters of [the river] are so numerous, and of so many varieties, that even elephants go in herds, as our cattle do here. Gazelles, pigs, panthers, and all kinds of game, of which we do not know the names, are found here in as great numbers and varieties."

Given numerous examples from other regions of Africa, it can be assumed that hunting pressure increased dramatically following the introduction of improved firearms. Travelers' reports indicate that wildlife populations have declined steadily since the 16th century, and Bigourdan and Prunier indicate that the addax and oryx populations of the Mauritanian Sahel were already threatened by extinction before the conclusion of the French pacification in the 1930s.

As the wild herbivores declined in number, their contributions to local diets and to the regenerative dynamics of Mauritanian ecosystems (plant stimulation and seed dispersal) similarly declined.

As some references can be found to goats, cattle, and other forms of livestock in association with Moors before the 1930s, it is tempting to suggest that the newly acquired animals were introduced in part to compensate for wildlife losses. It might also be noted that once domesticated livestock are established in an area, additional losses of wildlife usually occur through direct competition.

With regard to the introduction of the goat, it might be added parenthetically that many livestock advisors in the Sahel respond to the goat much as did Fundanius, Varro's father-in-law, in On Farming. He asserts that she-goats "are hostile to cultivation and poisonous to plants for by nibbling at them they ruin all young plants." It should be noted, however, that domesticated goats were largely introduced into the lands of the Mediterranean from the environmentally dissimilar highlands of southwestern Asia. Hence, the equilibrium established through the coevolution of plants and animals in the Mediterranean basin was easily disturbed by the goat.

In the Sahel, the foraging habits and conversion efficiency of the goat approximate those of the oryx and similarly adapted species and are therefore relatively compatible with the native vegetation. In the course of the environmental workshop, it was noted that goats were generally quite well controlled in Mauritania, and further, that there seems to be a direct relationship between "spontaneous" Prosopis regeneration and holding areas for goats in Nouakchott, suggesting that the animals might contribute to seed dispersal much as the oryx and allied wild herbivores had in the past.

Not only did the early European contacts contribute greatly to increased wildlife losses and the degradation of the western gum forests, they further altered the spatial aspects of environmental degradation in Mauritania. Before European involvement in the gum-arabic trade, Trarza and Brakna were largely unaffected by the more explicit causes of degradation in medieval Mauritania. While the suggested impact of bush fires would presumably be widespread, the losses of vegetation associated with the trans-Saharan trade largely affected the Adrar, Tagant, and Awkar regions. Further losses of vegetation and disturbance leading to the reactivation of formerly stabilized dunes through the establishment of settlements would have occurred in essentially the same regions. Similarly, the destructive impact of cattle and sheep upon Sahelian ecosystems was confined largely to the Awkar and Hawd regions, although the cattle of Takrur may have been pastured occasionally in the southern margins of Trarza. Also, given the social diversity of the various caravan centers of the interior, it is probable that small numbers of cattle would have accompanied Soninkes, and others traditionally dependent upon cattle, to such centers. For example, Ca' da Mosto, drawing upon local sources, refers to the basic dependance of the inhabitants of Waddan upon camel's milk, adding, however, that "they also have cows and goats, but not many, for the land is dry."

This increased spatial extent of degradation in Mauritania would have greatly aggravated the stresses already being exerted upon the region's environmental systems. In addition to the general disruption of ecological processes, centers of genetic diversity had clearly declined markedly in number, extent, and viability. As can be observed at the present time, this would essentially eliminate the possibility of environmental restoration unaided by man.

The French Pacification: 1900-1934

Sustained efforts to establish French control over Mauritania were initiated by the Republic's President du Conseil, Waldeck-Rousseau, in 1901. The process was eventually concluded in 1934. During the process of pacification, severe local degradation occurred around many French military installations. Although the causes of this degradation vary, perimeter clearance, the use of tree trunks in site preparation and building, and the damage inflicted by the herds of cattle, camels, goats, and sheep maintained by the garrisons all contributed to it. Charles Toupet cites the impact of Coppolani's fortification at Moudjeria as a classical example of such degradation.

The successful pacification of the country removed several constraints to further environmental degradation. Perhaps most important, the widespread practice of raiding to compensate for shortages of food, for the acquisition of wealth, or for strategic purposes was brought to an end. The cessation of raiding simultaneously initiated a number of environmentally damaging events: agricultural populations that had abandoned Mauritania in order to avoid enslavement and predation reestablished themselves in southern Mauritania. With them came herds of cattle, goats, and sheep. The disfranchised warrior class was left largely with only herding and commerce as acceptable occupations, and economic considerations resulted in a rather abrupt shift in herd composition from camels to cattle, as the latter were more marketable within the context of the new economic order. Furthermore, the French policy of association, working through traditional leaders, had strengthened the marabouts at the expense of the warrior class, and the new wealth acquired by the marabouts was characteristically invested in herds of cattle. Finally, Tokolor herdsmen interviewed during the environmental workshop described recent changes in their herding practices that have emerged from the virtual eradication of wild carnivores in the pastoral zone. In the past, young herders were instructed to avoid forests and thickets in order to maintain herd control and avoid livestock losses to predators. The fear of such losses passed with the elimination of the large carnivores, and herds were permitted to enter wooded areas. The extension of herding into these areas has resulted in the widespread removal of protective understory and seedlings, reduced wildlife habitat, poorer precipitation interception and decreased ground-water recharge, the elimination of many wild plants and animals central to human coping strategies during periods of scarcity (see below), and a general breakdown in critical ecological processes.

These events, particularly the proliferation of cattle, substantially increased pressure upon the country's environmental systems. The situation was further aggravated by economic incentives and livestock maintenance programs that strongly favored cattle at the expense of better adapted forms of livestock. According to Francis de Chassey, similar economic incentives encouraged agricultural expansion, with emphasis placed upon the production of cash crops. Further environmental degradation has been associated with sedentarization, charcoal production in relation to urbanizaton, increased vehicular traffic and expanded transportation networks, building construction, and mining activities.

Degradation from all of these causes has increased tremendously since independence. Much of it can be attributed directly to uninformed economic development and opportunism. Cattle populations, for example, continued to increase far in excess of local requirements. In 1959, there were approximately 1,250,000 head of cattle in Mauritania; in 1968, there were an estimated 2,300,000, an increase of 1,050,000. During the same period, the human population had increased by only some 170,000 individuals. The relative lack of experience of Moors in managing cattle, combined with a progressive loss of herders to sedentarization and other labor alternatives, resulted in poor herd control. Poor management, in turn, can greatly increase the environmental impact of livestock. While herds of cattle were growing rapidly, other forms of livestock that are better adapted, more easily controlled, and less destructive registered an aggregate decline of approximately 1 million animals.

It is perhaps somewhat ironic that historical use pressure and the traditional focus of developers upon increased agricultural and pastoral production have largely destroyed the very resources that sustained Mauritanian populations during period of scarcity. Geographers, anthropologists, and botanists active in the Sahel have long realized that when drought, disease, warfare, or other mishaps result in agricultural failure (requirements in excess of crop yields and storage) or sharply reduced livestock populations, these peoples were sustained by coping strategies based upon the availability of diverse native plants and animals.

Jacques Trotignon and others have documented the widespread destruction of wildlife in Mauritania in some detail. Corresponding losses of edible plants have occurred as well. Some 20 years ago, surveying an already highly degraded environment, Theodore Monod compiled the following list of particularly well-known wild edible plants in the region:

1. Mushrooms: Terfezia spp.

2. Rhizomas and pulpy stems: Cistanche phelypaea, Cynomorium coccineum, Typha elephantina.

3. Bredes: Gynandropsis pentaphylla, Portulaca oleracea, Rumex spp., Eruca sativa, Schouwia purpurea, Solanum nigrum, etc.

4. Seeds of herbaceous plants: Boerhaavia sp., Chenopodium spp., Aizoon canariense, Cassia italica, Colocynthis vulgaris, Limeum sp., Glinus lotoides, Glossonema boveanum, Rogeria adenophylla, Blepharis spp., etc.

5. Caryopses of graminaceous plants: Panicum turgidum, Panicum spp., Aristida pungens, Cenchrus prieurii, C. biflorus, C. ciliaris, Sporobolus spicatus, Sorghum sp., Echinochloa spp., Latipes senegalensis, etc.

6. Fruits: Salvadora persica, Ziziphus spp., Balanites aegyptiaca, Cordia gharaf, Cocculus pendulus, Boscia senegalensis, Maerua crassifolia, Capparis aphylla, Celtis integrifolia, Rhus oxyacantha, Grewia tenax, Grewia spp., Sclerocarya birrea, Hyphaene thebaica (exocarpe and corozo), etc.

7. Aromatic plants a infusion (often more or less medicinal): Solenostemma argel, Artemisia spp., Brocchia cinerea, Paronychia spp., Cymbopogon schoenanthus, Myrtus nivellei, Mentha spp., Salvia chudaei, Ocimum spp.

8. Gums and nourishing mannas: gum of Acacia spp., manna of Tamarix.

Many of these species, as well as literally hundreds of other useful species recorded in the various biogeographical surveys of Chevalier, Dekeyser, Monod, Monteil, Murat, Naegele, Sauvage, Villiers, and others prior to Mauritanian independence (1960) are now either regionally extinct or occur in numbers so modest that they are no longer capable of guaranteeing the survival of needy populations. As this report has specifically discussed the environmental consequences of the removal of perennial grasses by grazing livestock, it might be worthwhile to comment further upon the social consequences as well. Chevalier, Creac'h, and Simonneau would join Monod in underscoring the importance of grass seed in the diet of various Sahelian populations. Créac'h, for example, writing in 1941, discusses some 30 grasses, ranging from "kreb" to various rices, that were regularly utilized by the Assalé Arabs. Most of these grasses, and several others, were known and presumably utilized in Mauritania. Workshop participant Adama Sy believes that these grasses, important as emergency rations, have been particularly prominent among the casualties of environmental degradation in recent years.

APPENDIX D

Seed Distributed by BOSTID
for Experimental Planting in Mauritania

Acacia berlandieri	Huajillo
Acacia senegal	Gum arabic
Amelanchier utahensis	Serviceberry
Argania spinosa	Argan tree
Cassia artemisioides	Feathery cassia
Casuarina equisetifolia	Horsetail oak
Cercidium floridum	Blue palo verde
Chilopsis linearis	Desert willow
Cowania stansburiana	Cliffrose
Dasylirion wheeleri	Sotol
Dodonaea viscosa	Hop bush
Encelia farinosa	Brittlebush
Eucalyptus camaldulensis	River red gum
Fraxinus anomala	Singleleaf ash
Grayia brandegei	Spineless hopsage
Larrea tridentata	Creosote-bush
Leucaena leucocephala	Hawaiian Giant (K8) leucaena

L. leucocephala	Leucaena (unspecified)
L. retusa	Golden-ball leadtree
Linum lewisii	Rocky Mountain flax
Lysiloma microphylla	Littleleaf lysiloma
Melia azedarach	Indian lilac
Olneya tesota	Desert ironwood
Orthocarpus purpurasiens	Owl clover
Parkinsonia aculeata	Horsebean
Penstemon parryi	Desert penstemon
Phaseolus acutifolius	Tepary bean
Proboscidia sp.	Devil's claw
Prosopis sp.	(UC/Riverside accession no. 0166)
P. chilensis	Algaroba
P. glandulosa var. *torreyana*	Western honey mesquite
P. juliflora	Honey mesquite
P. velutina	Velvet mesquite
Psophocarpus tetragonolobus	Winged bean
Purshia glandulosa	Desert bitterbrush
Salvia gregii	Autumn sage
Simmondsia chinensis	Jojoba
Yucca elata	Soaptree yucca
Zea mays	Pima-Papago 60-day maize

In addition to the preceding, a large shipment of forage species contributed by Cyrus McKell of Utah State University was distributed at the time of the Environmental Workshop. Although a listing of these species is not available through BOSTID or Utah State University, the species are currently undergoing evaluation at the National Agricultural School at Kaédi.

APPENDIX E

Proposal to Establish Two Agro-silvo-pastoral Centers in Mauritania

INTRODUCTION

During the past several decades, the vegetative cover of Mauritania has become severely depleted in many areas as a result of a number of factors, including variation in rainfall and increased pressure by human and animal populations. The depletion is both qualitative and quantitative and, as the variety of cover has decreased, this has greatly impaired the ability of the region to withstand periods of stress. The long-term self-sufficiency and resilience of the area will depend on increasing the diversity of plant species and creating conditions in which the vegetative cover is more in balance with the needs of the human and animal populations.

This proposal follows a number of recent discussions of this problem that have involved officials of the Government of Mauritania, the United Nations Sudano-Sahelian Office (UNSO), the Permanent Interstate Committee for Drought Control in the Sahel (CILSS) Ecology Team, the National Academy of Sciences, and the U.S. Agency for International Development, among others.

It is proposed to establish two centers--one in the arid Trarza region and the other in the semiarid riverine region--that would serve as pilot locations for the planting and distribution of a large variety of multipurpose tree and shrub species.

OBJECTIVES

The objective of the project is to establish two centers that will serve as pilot efforts for a number of activities relating to revegetation in Mauritania, with a view to supporting ecological

restoration and long-term environmental productivity and stability in the country. This project would include the following elements:

- o Seed collection and distribution
- o Nursery plantings, particularly to identify adapted exotic species, as well as supplying local and exotic seedlings
- o Direct seeding, including trials in aerial seeding
- o Revegetation of wellpoints
- o Identification and dissemination of soil factors, such as Rhizobium and ecto- and endomychorrhizae
- o Involvement of the population in identification of useful species and their traditional uses

Seed Collection and Distribution

A primary function of the centers should be to promote the collection and dissemination of selected seed, with the long-term objective of reestablishing and strengthening the natural mechanisms of species distribution that have been disrupted by drought, by the reduction of wildlife populations, by restrictions on the movement of animals, by the removal of vegetation for firewood and charcoal, or other factors. This function has several elements:

- o There is a need to collect indigenous seed to support a large-scale revegetation effort. In the past, this has been mainly from the more southernly, wetter parts of Mauritania. More effort should be given to collecting seed from plant species better adapted to the drier northern regions.
- o There is need to select useful multipurpose exotic seed from comparable ecological zones, to broaden the genetic diversity within the region, and to provide possibilities for alternative crops and products. This may be particularly useful in specialized needs, such as dune stabilization, where crops such as jojoba may also provide a valuable cash crop as well as stabilizing dunes.

Nursery Planting

The two centers should include agroforestry nurseries in which seedlings of a wide variety of species can be grown for selection and distribution. These nurseries will provide a focus for the introduction of exotic species, and a means of testing such

varieties before their broader distribution. They will also provide a means of ensuring that legumes are already inoculated with Rhizobium prior to planting.

The nurseries should be supervised by a forestry technician, and have sufficient staff (perhaps 6-8) to fulfill the required functions.

Direct Seeding Trials

In addition to the testing and production of seedlings in nurseries, the centers should organize seeding trials. This will provide valuable information on markedly extending the area that may be reseeded with the resources available, since there are limits to the nursery capacity and the ability to transport and plant out nursery-produced seedlings. Direct seeding methods have been widely used traditionally in Africa, although there has been little research on them in the Sahel, and the reduced degree of control over the selection of quality planting material and presumed lower germination and survival that this method entails has not found favor with foresters. On the other hand, in the case of Mauritania, the vast areas to be regenerated outstrip the capacity of conventional nursery technology to meet the needs. It is therefore proposed that the centers organize direct seeding trials (including both dibble/heel and broadcast methods) in selected locations in their environs, where the results can be closely monitored. If properly organized, the results obtained in two plantings should give a good indication of the potential of this alternative. A further variation to be tried should include seeding several large areas (up to 100 ha) from the air with a mixture of species, again with suitable arrangements for identifying the species location and mixture before and after seeding.

Revegetation around Wellpoints

In connection with the need to strengthen natural seed distribution mechanisms, the centers should also arrange for revegetation efforts to be organized with the cooperation of livestock owners and herders in the vicinity of wells. Provision should be made to protect the areas planted or seeded until the plants are large enough to be browsed (3-5 years). At this point they would be opened to livestock to browse and eat the seed pods. This arrangement would reduce degradation of the area, increase infiltration at the wells, allow introduction of new varieties and species along with their symbiotic soil organisms, and provide supplemental fodder for dry-season or drought reserves. It would

also have demonstrable benefit for livestock and encourage integration of livestock and agroforestry activities, an important factor in promoting cooperation between pastoralists and farmers.

Social, Educational, and Outreach Activities

The centers should be more than nurseries and sources of seed and seedlings. There is a wealth of traditional knowledge about the ecology of the region in the insights, customs, and memories of the inhabitants. Much of this knowledge is endangered by the disappearance of traditionally useful species during the devegetation of the area and the migration of young people from their villages or communities. The centers should actively seek out knowledgeable people in the community regarding useful species of plants that have been used for various purposes within the community, and promote the collection and reintroduction or improvement of these species along with their natural products.

The centers should also promote conservation activities, such as improved woodstoves and charcoal production methods, that could help reduce the amount of fuelwood cut. Other technologies, such as biogas generation from human and animal wastes, could be added if conditions permit. The centers could provide a forum for community/donor interaction on other possible technological or cultural innovations.

LOCATION OF THE CENTERS

Centers should cover a range of ecological conditions. The principal criterion is rainfall, and for location of the two centers the 50-200-mm and 200-400-mm annual rainfall regions are perhaps the most critical. While not precisely matched to these regions, Boutilimit (203 mm) and Kaédi (410 mm) are suggested as meeting a variety of needs. The dune fixation problem at Boutilimit is critical and could be part of the center's responsibilities. Kaédi is the location of the Agricultural School and has already been selected by the Mauritanian government as a site of a nursery for species selection.

SCHEDULE

It is important to attempt to make initial plantings in July following the onset of the rainy season. Although seed for many species are already available in Mauritania; at present money is

lacking for the organization and management of the various component efforts--for seed collection, for hiring personnel, for transportation, for fencing and other protective measures, and for minor technical inputs.

During the first year of the project it would be important to:

- o Collect seed from the northern region of Mauritania
- o Organize nurseries at Boutilimit and Kaédi, the first plantings in the nurseries, direct seeding/aerial seeding trials, wellpoint plantings, and sand dune stabilization efforts at Boutilimit
- o Organize and initiate collection and importation of identified species according to the planned objectives
- o Initiate consultations with knowledgeable people in the community regarding use of traditional species

During the second year it will be possible to consolidate the efforts and, to broaden the range of species planted though local collection and the importation of recommended varieties. By the third year, the results of the first two seasons' plantings will be analyzed, and planning for implementation of much larger efforts can be undertaken.

In this context it will be important to assess the experience of the Lutheran World Federation greenbelt project outside Nouakchott for information and technical expertise. It may also be important to consider the revitalization of this project.

DRAFT ESTIMATE OF COSTS

This will have to be worked out in light of real costs in Mauritania, but for planning purposes the following information is included, very tentatively.

Personnel

Each center should have a full-time supervisor and 6-8 workers, perhaps up to 10 depending on the area, number of species to be included, etc. Based on the costs identified in similar projects submitted to UNSO by the Government of Mauritania, labor costs might amount to around $20,000-$25,000 per year for each center. This assumes professional planning, support, and periodic guidance is provided from other sources within the Ministry of Rural Development, Peace Corps, etc.

Transport

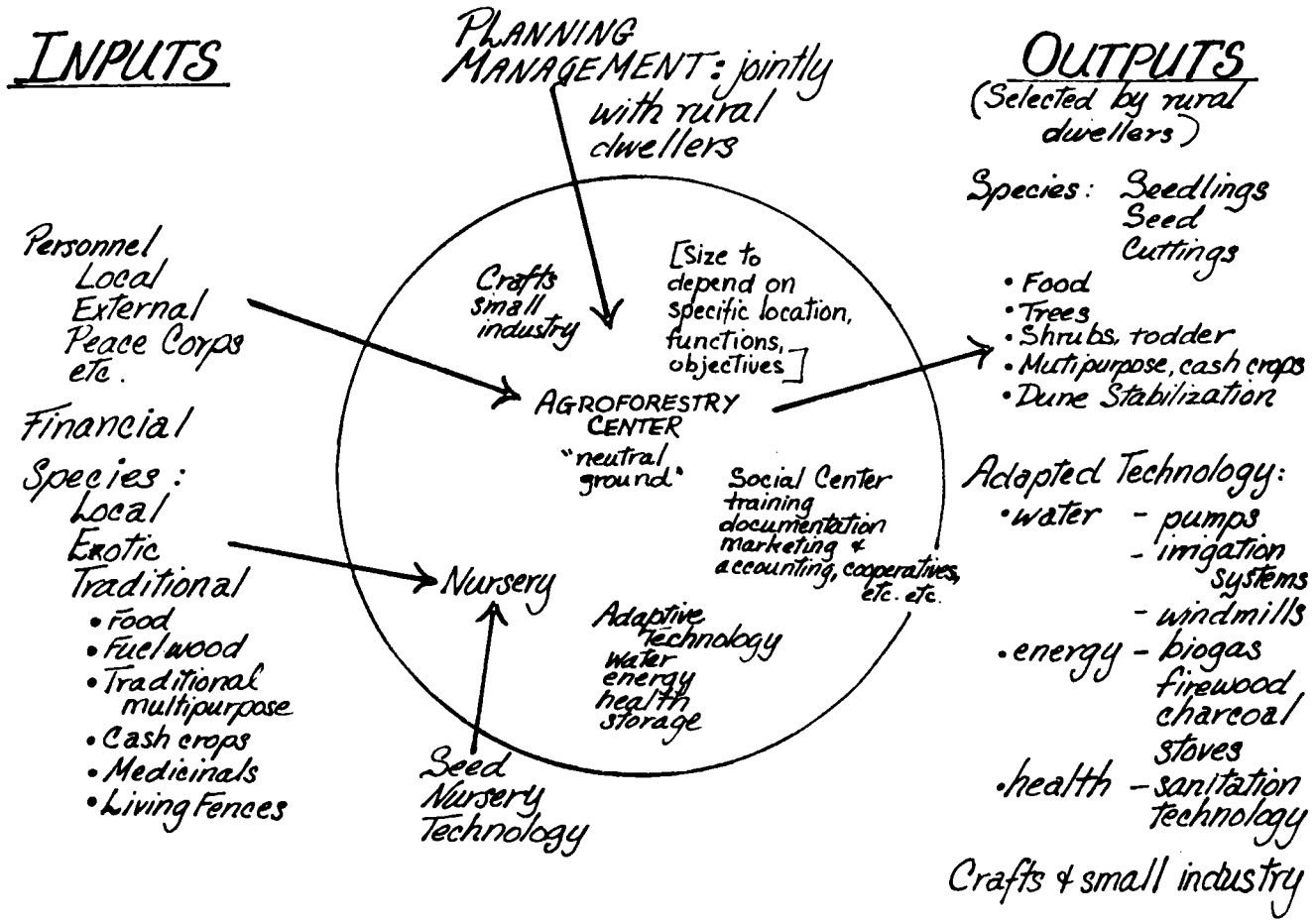
Each center will require a Land Rover, fuel, and spare parts estimated at $35,000 per year for both centers ($15,000, purchase; $50,000, petrol for 3 years [20,000 miles at 10 miles per gallon and $3.00 per gallon]; repairs, spare parts, etc. $25,000 for 3 years = $105,000 for 3 years).

Other Supplies

Seed, fencing, etc. is estimated at $15,000 per year minimum.

This would give a minimum cost per year of $100,000 for running both centers.

Depending on the contribution of the host government, there may be additional capital expenditures on physical plant, office space, provision of budget for expert consultants to assist the centers, and other items. A reasonable provisional figure for the project might be $200,000.



INDIVIDUALS OF POSSIBLE INTEREST IN CONNECTION WITH SURVEYS OR PROGRAMS IN MAURITANIA AND SENEGAL

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APPENDIX F

Aerial Seeding*

In the course of BOSTID's April 1979 discussions in Mauritania, it was stressed repeatedly that the country required a massive effort in reafforestation. For example, it was estimated that at least 20,000 hectares of gonakier forest would be lost in connection with OMVS activities alone. In our report on these discussions, "An Assessment of Agro-forestry Potential within the Environmental Framework of Mauritania," an attempt was made to place this problem in perspective:

> ...the revegetation of 20,000 hectares would be a massive operation. At 1000 trees per hectare, 20 million seedlings would be required. The Nouakchott greenbelt operation has been able to plant only 385 hectares in three years, admittedly under difficult conditions, but with the diverse resources of the national capital at hand, with funding amounting to $3.50 per tree to date, and with a work force of 210 individuals. With present resources and the application of traditional forest management methods, it is estimated that it might take more than 100 years to reforest an area equivalent to that which is threatened.

It was in this connection that aerial seeding was suggested as one element of an experimental "shotgun" approach to reafforestation in Mauritania.

It has become evident in the course of recent discussions that aerial seeding is regarded by many as being somewhat more experimental than it actually is. This might reflect the fact that most efforts in aerial seeding are undertaken rather anonymously by

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*Excerpted from a May 1980 BOSTID report to USAID/Nouakchott.

governmental agencies or private corporations to address specific problems, such as the revegetation of extensive or inaccessible tracts, that cannot be adequately addressed by more conventional approaches. Because of the parochial nature of such efforts, and because their environmental context is assumed to be vastly dissimilar to conditions in tropical Africa, they have been largely neglected or dismissed by individuals dealing with revegetation in the Sahel. It might therefore be noted that successful efforts in aerial seeding have been undertaken in areas of the developing world quite similar to the West African Sahel in terms of precipitation totals and distributions. For example, M. N. Vaishnav, Conservator of Forests in Gujarat, notes that aerial seeding of Prosopis juliflora was successfully employed in dune stabilization efforts in India in the 1950s. Similarly, the Sudanese Forests Department has for years broadcast the untreated seed of Acacia scorpioides var. nilotica to restore sunt (gonakier) forests along the Blue Nile.

With specific reference to Mauritania, reservations regarding aerial seeding have largely related to the adequacy of precipitation and predator pressure.

Given the reputedly intractable nature of Mauritania's problems, it might be worth noting that Kiffa shares its precipitation average (350 mm), summer distribution, and approximate drought frequency with such non-Sahelian communities as Fort Stockton, Texas; Roswell, New Mexico; Denver, Colorado; Williston, North Dakota; and Helena, Montana. Obviously, the comparison is incomplete. The point, however, is that we are dealing with levels of precipitation that are somewhat higher than those often assumed--levels that permit us to relate more directly the proposed trials in Mauritania with successful efforts in the United States, Australia, Canada, and elsewhere.

Mauritania, with a relatively brief rainy season and extended dry season, enjoys certain advantages over areas with the same precipitation totals but with longer rainy seasons (as is the case with all of the U.S. communities noted above). Most of the plant species that would be considered for aerial seeding in the Sahel have rapidly developed tap roots. For such species, the most effective rainfall distribution is when large amounts fall within a short period, preferably at a time of low evapotranspiration. Such rainfall replenishes the deeper moisture reserves that such species are dependent on for their permanent water supply. Because of the extended dry season, there would also be less ground cover and the seed would have a better chance of falling directly onto mineral soil.

With regard to predator pressure; rodents, insects, and birds are regarded as the principal threats. The extended dry season dramatically reduces their numbers. Rodent populations in rural areas were relatively modest during our April visit. The general lack of vegetation also resulted in modest insect populations and a correspondingly limited number of insectivorous birds. The following insectivorous species were recorded in the course of our April travels in an effort to indirectly check potential insect pressure:

Swifts (Apodidae)
Cattle Egrets (Bubulcus ibis)
Ground Hornbill (Bucowers abyssinicus)
Senegal Coucal (Centropus senegalensis)
Pied Kingfisher (Ceryle rudis)
Abyssinian Roller (Coracias abyssinica)
Swallows (Hirundinidae)
Brown-backed Woodpecker (Ipophilus obsoletus obsoletus)
Helmet Guinea-Fowl (Numida meleagris)
Grey Hornbill (Tockus nasutus)
Purple Glossy Starling (Turdus purpureus)
Senegal Hoopoe (Upupa senegalensis)
Spur-winged Plover (Vanellus spinosus)

Most of the insectivorous birds were seen along the rivers. None appeared in large numbers, although several villages supported substantial starling populations.

With regard to direct predation, the following granivorous bird species were recorded:

Pied Crow (Crovus albus)--omnivorous
Red-cheeked Cordon-Bleu (Estrilda troglodytes)
Crested Lark (Galerida cristata)--also feeds on insects
Senegal Fire-Finch (Lagonosticta senegala)
Bush-Sparrow (Petronia dentata)
Senegal Long-Tailed Parakeet (Psittacula krameri)
Chestnut-bellied Sand-Grouse (Pterocles exustus)
European Turtle-Dove (Streptopelia turtur)
Vinaceous Dove (S. vinacea)
Mourning Dove (S. decipiens)
Bruce's Green Pigeon (Treron waalia)

Again, none appeared in large numbers and, collectively, the granivorous species would not pose a threat to seeding early in the rainy season. Most granivorous species migrate into southern Mauritania in late July or August as seed becomes available.

Finally, it should be stressed that we are proposing aerial seeding as an experimental approach to extensive revegetation. It is viewed as being complementary to more traditional approaches, not as a replacement for them. The experiment may fail. Should it succeed, however, the implications for the Sahel and for similarly degraded areas obviously would be tremendous.

APPENDIX G

A Representative Listing of Organizations
Collaborating with ACOS Staff

Academy of Educational Development
The African-American Institute
AFRICARE
American Association for the Advancement of Science (AAAS)
American Friends Service Committee (AFSC)

American University
Appropriate Technology International (ATI)
University of Arizona
Botswana, Ministry of Mineral Resources and Water Affairs
Caesar Kleberg Wildlife Research Institute (Texas A&I University)

California Institute of Technology
University of California at Berkeley
University of California at Davis
University of California at Riverside
University of California at San Diego

University of California at Santa Cruz
CARE
Catholic Relief Services
Cell Culture and Nitrogen Fixation Laboratory (USDA)
Center for Disease Control (Atlanta, Georgia)

Centre Regional African de Technologie (CRAT, Dakar)
Centro Internacional de Agricultura Tropical (CIAT)
University of Chicago
Clark University
Club du Sahel Secretariat

Colorado State University
U.S. Department of Commerce
Commonwealth Scientific and Industrial Research Organization
(CSIRO, Australia)
Connecticut Agricultural Experiment Station
Coordination in Development (CODEL)

Cornell University
University of Dar-es-Salaam

Délégation Générale à la Recherche Scientifique et Technique (DGRST, France)
Desert Botanical Garden (Phoenix, Arizona)
Desert Research Institute (Cairo)

Desert Research Project (Biosearch Trust, Cambridge, England)
Earth Satellite Corporation
Empresa Brasileira de Pesquisa Agropecuaria (EMBRAPA)
Environment Training Programme (ENDA, Dakar)
Family Health Care, Inc.

University of Florida
Food and Agriculture Organization of the United Nations (FAO)
Forest Service (USDA)
French Scientific Mission (Washington, D.C.)
University of Georgia

German Forestry Mission to Senegal (GTZ)
Greenhills Center and Experimental Station (Cedar Hill, Texas)
Harvard University
University of Hawaii
Hebrew University of Jerusalem

Holcomb Research Institute (Butler University)
University of Illinois
India, Forest Research Institute and Colleges
Institut Pasteur (Paris)
Institute for Development Anthropology

Institute for Land Rehabilitation (Utah State University)
Institute for World Forestry (Hamburg)
Institute of Behavioral Science (University of Colorado)
Instituto Nacional de Investigaciónes sobre Recursos Bióticos (INIREB, Mexico)
International Agricultural Development Service (IADS)

International Center for Arid and Semi-Arid Land Studies (Texas Tech University)
International Council for Research in Agro-forestry (ICRAF)
International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)
International Development Research Centre (IDRC)
International Forest Service Consultancy (Midlothian, United Kingdom)

International Institute for Environment and Development
International Livestock Centre for Africa (ILCA)
International Monetary Fund
International Resources Development and Conservation Services (Boise, Idaho)
International Science and Technology Institute (Washington, D.C.)

International Technology Development Group (London)
International Tree Crops Institute

International Union for Conservation of Nature and Natural Resources (IUCN)
Johns Hopkins University
Lafayette College

Land Institute (Salina, Kansas)
Louden Cattle Company (Branson, Colorado)
Université de Lyon
Man and the Biosphere Programme (UNESCO)
University of Maryland

University of Massachuetts
Meals for Millions Foundation
Mexico, Subsecretaria Forestal y de la Fauna
Michigan State University
University of Michigan

University of Minnesota
University of Montana
University of Nairobi
National Center for Atmospheric Research
National Defense University

National Park Service
National Science Foundation (NSF)
Native Plants (Salt Lake City, Utah)
University of Nebraska
University of New Mexico

NifTAL (University of Hawaii/USAID)
The Nitragin Company
North American Plant Breeders
North Carolina State University
University of North Carolina

NUS Corporation (Denver, Colorado)
Office of Science and Technology Policy (Washington, D.C.)
Office of Technology Assessment (Washington, D.C.)
Oklahoma State University
University of Oklahoma

Organisation de la Recherche Scientifique et Technique d' Outre-Mer (ORSTOM)
Organization for Rehabilitation through Training (ORT)
OXFAM
Oxford University (Commonwealth Forestry Institute)
Peace Corps

University of Pennsylvania
Permanent Interstate Committee for Drought Control in the Sahel (CILSS)

Peter McLaughlin Associates (Camox, British Columbia)
Purdue University
Remote Sensing Institute (South Dakota State University)

Research Centre for International Agrarian Development (West Germany)
Rockefeller Foundation
Universidad Provincial de la Rioja
Rural America
Smithsonian Institution

Solar Energy Research Institute (SERI)
Tennessee Valley Authority
Texas A&M University
United Nations Development Programme (UNDP)
United Nations Educational, Scientific, and Cultural Organization (UNESCO)

United Nations Environment Programme (UNEP)
United Nations Sudano-Sahelian Office (UNSO)
Virginia Polytechnic Institute
Washington University
University of Washington

The World Bank
World Health Organization (WHO)
World Wildlife Fund (WWF)
Yale University

NB. This listing does not include contacts within the governments of the Sahel region.

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