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Note

Economic Policy and Desertification in Arid and Semi-arid Developing Countries

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Environmental degradation in arid and semi-arid regions often results from trade-offs between immediate and long-term needs. Ecological (and ultimately economic) benefits of restrained, sustainable resource use are well-understood by scientists, and are usually apparent to local farmers and herders as well. However, immediate economic needs often conflict, and excessive exploitation of resources may be necessary to subsistence producers' survival. Such issues are illustrated in a variety of settings. Solutions to problems containing important economic components require appropriate economic policies, as well as technical action. Long-term sustainable resource utilisation rather than short-term exploitation must be made more attractive to local producers in their daily lives.

INTRODUCTION

Environmental degradation is a very serious issue in most countries of the arid and semi-arid Third World. Fragile desert biospheres are easily damaged, but developing nations rarely have sufficient resources to cope with resulting problems, such as desertification. Part of the cause of desertification is undoubtedly broader climatic patterns, even climatic change [Hulme and Kelly (1993)]. But socio-economic and institutional factors invariably lurk behind a great many cases of environmental degradation. Often the real problem lies in the kinds of choices people must make concerning the environment.

Such choices involve a conflict between long-term, environmentally sound decisions on resource use and short-term economic necessities that inhabitants face. In many cases, people at all levels, from policy-makers to small producers, recognise beneficial environmental policy and understand that their actions may be detrimental to it, but they may not have the luxury of following a beneficial policy. Food and fuel are requirements for survival today, even if the environment may be harmed tomorrow.

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Author's Note: An early draft of this paper was presented at the Third International Conference on Desert Development, Beijing, China, July 1990. Many of the ideas about economic causes of desertification were conceived in the early 1980s while at the Office of Arid Lands Studies, University of Arizona, where I spent three years on a U.S.MAB/U.S.AID project to compile profiles of the environmental problems in arid Third World countries. Some of the ideas were refined in 1985 while working for the Western Sudan Agricultural Research Project in 1985, a World Bank/U.S.AID project which was implemented by Washington State University.

We illustrate these issues in a variety of settings: rangeland degradation in the Sahel; desertification from local agricultural development in Southern Arabia; deforestation for firewood in gum arabic stands in Sudan; and salinisation from large-scale river irrigation projects in Egypt and Pakistan. Each of these factors which contribute to desertification differs widely, but each contains a similar economic issue at its core. This note examines similar kinds of hard economic choices behind these diverse physical desertification problems.

Purely technical approaches to fighting desertification are rarely successful by themselves. Planting replacement scrub trees or repairing neglected terraces does not change the economics of the situation. New trees will be cut, new terraces will deteriorate, unless local people see short-term benefits in making sure that they are not cut and do not deteriorate. Purely legal approaches—setting up laws and regulatory structures—rarely help either. Arid and semi-arid landscapes are vast and sparsely populated and Third World governments lack resources. Laws and regulations cannot usually be enforced, as Ellis, Taylor, and Masood (1993), for example, noted for Pakistan.

Of course, such technical and/or legal approaches may be needed as components of more comprehensive anti-desertification policies. But economic problems require economic solutions, and comprehensive policies must address the difficult economic choices behind man-made desertification. Technical and/or legal approaches alone cannot succeed without solutions to the economic problems behind actions which contribute to desertification.

RANGELAND DEGRADATION IN THE SAHEL

Desertification is a major continuing and increasing problem throughout the Sahel. Between 1955 and 1975, vegetation zones characteristic of increasing aridity shifted south by 150 to 200 km. in parts of the Sahel. The mean amount of land area classified as hyper-arid over the period 1961–1990 increased by 50 million hectares as compared to the previous 30-year period. Land classified as arid also increased by over 3 million hectares [Hulme and Kelly (1993)].

Even though climatic change may be partly to blame for the advance of the desert, it is clear that modern pastoral systems in the Sahel are also a major factor behind desertification. One of the chief causes is rangeland degradation due to over-grazing. Standard explanations of the process usually blame pastoralists for increasing herd size beyond the carrying capacity of available range resources. Livestock consume forage vegetation faster than it can regenerate, and eventually inedible vegetation or no vegetation at all remains. With degraded ground cover, soil erosion becomes serious and any chance of restoring the range becomes remote because of massive topsoil loss.

A common variation of this explanation maintains that nomads cluster at wells during drought, concentrating their herds around wells. The range deteriorates around

the wells and these individual areas of devastation gradually expand and link up. It is difficult to criticise this general model. The process has been examined in the Sahel and elsewhere countless times over the last several decades, and it does, in fact, usually proceed as outlined [e.g., Ormerod (1978); Solbrig and Young (1992)].

However, the question is why the process happens. Pastoral economies have existed in the Sahel for millennia, but serious environmental degradation characteristic of this century has not been present throughout all of Sahel history. In most periods, traditional economies were in much better balance with ecological conditions [Ford (1992)]. Solbrig and Young (1992) even maintain that traditional pastoral economies were much more productive than modern ones, while still doing far less damage. Rangeland degradation seems to have been a serious problem only during periods of severe social and economic disruption, such as have occurred in this century.

Traditional trade, subsistence agriculture, and pastoral economies gradually disintegrated under the impact of colonial governments and the world economy. Farmers had to shift to cash crops to raise tax money or to buy what they formerly obtained through barter. Often cash cropping was imposed by colonial regimes to supply foreign markets. Farmers had to expand cropping into marginal areas to maintain food production, since prime lands were used for cash crops [Frank and Chasin (1980)]. Expansion did bring in extra cash or food in the short-term. Failure to expand would have meant less food and less cash. To farmers living at the subsistence level, less of anything often translated into the difference between survival or starvation.

Pastoral nomads faced a similar situation. They also needed more cash for new taxes and to buy supplies they had once gotten through barter. Traditional means of raising some cash, such as the caravan trade, declined, but cash requirements increased. As farmers shifted to cash crops, they produced less fodder and grain, so prices rose rapidly. To adapt to changing economic conditions, nomads had to expand their economies, which, of course, meant increased herd size.

But agriculture had moved into areas where nomads had formerly pastured animals, so the larger herds had to go to areas which were more arid and less suited to grazing. Sometimes wells would be drilled in the new areas to provide drinking-water for livestock, since it was difficult to find water year-round in these drier regions. Nomads began to concentrate their herds around such wells, because elsewhere there was no water and little for animals to eat [Ormerod (1978); Frank and Chasin (1980); Ford (1992); Solbrig and Young (1992)].

These changes in the pastoral economy brought increasingly rapid desertification. Planners began to decry the irresponsibility of pastoral peoples for "causing" desertification. But herders know perfectly well that areas they have been forced into cannot sustain large numbers of animals in the long run. They did not normally utilise these areas until forced out of zones where pastoralism was economically and ecologically sustainable. To pastoral herders, the short-term choice is

very simple and very stark: die now, or attempt to carry on even though doing so will cause conditions to deteriorate in the long term.

DECLINING TRADITIONAL AGRICULTURE IN SOUTHERN ARABIA

Traditional agricultural systems in Yemen are based on capture of surface runoff. In the Tihama coastal plain, wadi spate irrigation systems divert flood flows, which normally occur only a few times a year during the rainy season. In wadi floors, an elaborate network of weirs and barrages directs runoff into canals for distribution to fields lying along wadi courses. Variations of these diversion systems are also used in the highlands, where linear terraces are constructed in wadis parallel to stream flow. Distributive canals channel water to these terraces, rather than to larger fields as in the Tihama [Bernhardt *et al*. (1981); Speece (1982)].

In the highlands, terraces are the most distinctive feature of Yemeni traditional agriculture. They consist of small, hand-constructed plots of flat land on steep mountain slopes. Terraces trap rainfall and runoff from upslope areas. This moisture allows them to be cultivated or used for grazing, so that terraces allow production in Yemen's arid highlands which would otherwise go unused. Terraces are equally important for runoff control function. Peak flood flows are moderated, which both helps prevent damage to downstream spate irrigation systems, and allows more infiltration for ground water recharge. In addition, soil erosion is checked by trapping sediment on hillside terraces [Bernhardt *et al*. (1981); Speece (1982)].

In Oman most traditional agriculture utilises ground water. In the Batinah coastal plain, there are some spate irrigation systems in wadis similar to those in Yemen's Tihama. But Oman receives far less precipitation than does Yemen, and agriculture is more extensive than just at wadi mouths. For most irrigation in the Batinah, draft animals draw water from shallow, hand-dug wells by means of a hoist and bucket. The water is dumped into a basin and channelled to fields or gardens. One well, with hoist and bucket operated by animal power, can produce approximately enough water to irrigate one hectare of land [Speece (1981)].

The interior of Oman also has terracing similar to Yemen. But much agriculture is in wadis and alluvial fans, and most irrigation water is obtained by means of a *falaj* (plural *aflaj*). *Ghayl aflaj* tap perennial flow below surface gravels of wadis (*ghayl* refers to this perennial flow). They use low bunds or short collector galleries to divert sub-surface water to terraced or cleared fields along wadis. *Qanat aflaj*, also known by many other names from North Africa to western China, consist of horizontal tunnels dug into alluvial fans. They tap the water-table in the upper reaches of the fan and transport it to the mouth of the shallow gradient tunnel much farther down the fan. From there, it is distributed to fields [Wilkinson (1977)].

All of these systems are compatible with the arid conditions under which they have evolved. Spate systems utilise only flood water which would otherwise flow into

the sea. Terraces prevent soil erosion, and by trapping runoff, allow more water to infiltrate to water-tables. Water cannot be extracted by hand from the shallow wells of the Batinah rapidly enough to deplete water-tables. *Aflaj* tap only renewable shallow aquifers for high-quality water, and are incapable of causing any rapid drawdown of the water-table. Many sub-surface flows could not practically be tapped at all by wells or pumps, and the water could not be used at all without *ghayl aflaj*.

But traditional systems are labour-intensive, and both countries have experienced massive migration out of rural areas. The systems are deteriorating because there is insufficient labour to maintain them [Birks and Sinclair (1979)]. In Yemen, unmaintained diversion systems eventually become clogged or wash out. Terraces crumble and no longer prevent soil erosion. Eventually entire hillsides are stripped of any productive capacity. Even worse, without terraces, downstream areas are subject to increased flooding and sedimentation. This only hastens the decline of downstream spate irrigation systems [Bernhardt *et al*. (1981); Speece (1982)]. In Oman, water flow declines as *aflaj* deteriorate, and land irrigated by them may go out of production [Birks and Sinclair (1979); Speece (1981)].

Modern pumps only compound problems. In interior Oman, over-pumping lowers water-tables and leads to *aflaj* failure, so that even more pumps are required. In both the Tihama and the Batinah coastal plains, pumping leads to sea-water intrusion in coastal aquifers. Heavy use of pumped water for irrigation has caused serious soil salinisation, loss of agricultural production capacity, and then desert encroachment. Along the Batinah coast, for example, date-palm groves are dying because of salinised water, even though the date palm is a relatively salt-tolerant tree [Speece (1981, 1982)].

Most farmers understand these problems. Again, they face hard choices. Those who migrate know that traditional systems will deteriorate if they leave their villages to work abroad. We cannot really fault people, though, for wanting to improve the lives of their families and share other benefits of modernisation along with the rest of the world. Those who stay back have learned by now that pumping, where possible, draws down water-tables and leads to salinity. But without pumps, agriculture would have to be abandoned, because traditional irrigation systems no longer function. Then even more people would have to leave, and traditional systems would decline even more rapidly.

DEFORESTATION OF *ACACIA SENEGAL* IN SUDAN

Acacia senegal is a desert scrub tree, very well-adapted to arid conditions. It has a very deep tap root, but also an extensive lateral root system, making it quite effective at stabilising soil, preventing wind erosion, and trapping surface water runoff. It also produces gum arabic, a natural gum widely used in food processing and many other industries. While *acacia senegal* can be found throughout much of the Sahel region, Sudan is the world's major producer of gum arabic, accounting for approximately 80 percent of world supply in the early 1980s. The main gum arabic areas in Sudan stretch

across the central part of the country, with el-Obeid as the centre of Sudan's gum arabic trade [Pearce (1988); Anderson (1993)].

Some *acacia senegal* is actively cultivated, and sometimes it is used as a fallow crop or for intercropping. But the majority of gum arabic is collected from non-cultivated trees. Recently, growing areas have declined as fallow periods are reduced and the trees become less important in fallow cycles. Where they were cultivated, land has been cleared for more profitable cash crops. But more importantly, outside of cropped areas, gum-producing trees are cut for firewood, charcoal, and building materials. Since the trees are an important component of the barrier against the desert, their loss not only cuts productive capacity for gum, but also aggravates the severe desertification problem [Hammer (1983); Pearce (1988)].

Because nearly all gum arabic is exported, and provides a significant portion of Sudan's foreign exchange, the government attempts to control it. The Gum Arabic Company was created in 1969 and given a monopoly over the export of gum arabic. The primary concern has been government export revenues, not the impact of policy on the environment. Under the GAC, the government's share of gum arabic revenue increased dramatically from 1970 to 1981. In 1970, it stood at 25 percent of export revenue. In 1981, the government's share had reached about 54 percent. Serious declines in production may have been a key factor behind the reversal of this trend in the mid-1980s, and in 1987 the government share dropped back to about 41 percent of export revenue [Louis Berger (1983); Anderson (1993)].

As is the case for other government-controlled crops in Sudan [e.g., Speece (1985)], the prices producers receive stay well below free-market prices. In 1981, the el-Obeid floor price stood at £S 19/kantar [Louis Berger (1983), 1 kantar = 44.9 kg.], which was slightly more than four times higher than in 1970. This constituted only 33 percent of export prices. By 1987, after the severe drought, floor prices were raised substantially, but only slightly offset inflation during the 1980s. But producers only actually receive these floor prices if they take their gum to el-Obeid themselves. Most gum is sold to traders who then transport it to the el-Obeid auctions [Louis Berger (1983); Anderson (1993)].

Pearce (1988) presents sufficient data for us to calculate estimated annual income in 1987 from one hectare. Assuming about 400 trees per hectare, and that the trees are equally distributed in age up to 16 years (maximum productive age), an average of about 52.5 kg. of gum arabic could be produced. At export prices and exchange rates prevailing in 1987, and assuming that they received about 40 percent of export price, producers may have received up to £S 330/hectare if they tapped all trees. After 1987, export prices were lowered by about 20 percent annually for several years because the GAC had misjudged the willingness of customers to pay higher prices [Pearce (1988); Anderson (1993)].

In addition to discouraging many producers, policies also discouraged traders involved in bringing gum to government centres. Government purchase prices at Port

Sudan (the export port) were usually set to give very little margin above floor price. The net result of these pricing policies was that gum arabic production and trading became uneconomic for many producers and merchants. Gum production is down substantially from its peak in the years before the GAC took control. Despite tremendous capacity to expand gum arabic production, farmers and herders do not even tap many trees. Prices give no incentive relative to alternative unregulated crops or alternative activities [Louis Berger (1983); Pearce (1988); Anderson (1993)].

If low producer prices only resulted in not tapping the trees, this would not be a serious environmental problem. In practice, though, a tree can be worth more if it is cut rather than left standing, so that economic gain from producing gum arabic becomes small relative to using the trees as firewood, for charcoal, or for construction. According to Hammer (1983) *acacia senegal* is the preferred fuel and charcoal wood in Sudan. By the early 1980s, the value of the tree as firewood was more than five years worth of gum by the early 1980s. With firewood price rapidly increasing, increases in the floor price of gum arabic did not improve its relative attractiveness much. At prices noted above in 1987, it fared well, but in the following years the gum price declined while firewood and charcoal prices continued to rise [Hammer (1983); Pearce (1988)].

Surveys among villagers and herders in central Sudan [Hammer (1983)] clearly show awareness of desertification and of its causes, as well as the belief that planting more trees can help combat desertification. But subsistence level families on the edge of the desert must struggle each day to survive. If cutting trees helps people survive more surely than tapping them, they will cut trees. Pearce (1988) notes that production of gum arabic in Sudan is quite sensitive to producer prices. Clearly, protection of *acacia senegal*, which can be an important part of the barrier against desertification, depends upon prices small farmers and herders receive for gum arabic.

SALINISATION IN EGYPT AND PAKISTAN

In the previous discussion, the focus has been on decisions individual farmers and herders must face. Now, we briefly cite examples from Egypt and Pakistan to show that such tradeoffs between short- versus long-term actions also exist at the national level. Agricultural development in these two countries depended upon large-scale irrigation projects on the Nile and the Indus rivers. Water-logging and salinisation became major problems because extension of canal networks and more frequent irrigation allowed vastly increased seepage from canals and increased infiltration from fields. Water-tables rose close to the surface, where they are constantly subject to evaporation, resulting in salt buildup [Wilkinson (1980); Varady (1981)].

The Aswan High Dam, put in use in 1960, enabled Egypt to add over 1.2 million *feddans* (1 *feddan* = 0.46 hectare) to cultivation by 1981. It also allowed perennial irrigation, so that fields could be cropped two or three times annually. However, nearly as much has been lost from extensive soil water-logging and

salinisation due to this extensive irrigation. By the early 1980s, nearly one-third of Egypt's agricultural land had been affected to some degree. Average yields in the affected areas have decreased an estimated 30 percent, and some lands have been abandoned. The Egyptian response in recent years has been directed towards sealing canals to prevent seepage and installing drainage tiles below field surfaces to facilitate drainage. Such programmes are quite expensive and have required massive outside funding.

Many had actually predicted these environmental problems before the dam was ever built. A few had even suggested that the kinds of tiles later installed should have been part of the irrigation expansion programme from the start. The predictions of environmental damage were borne out in the areas first reclaimed, but irrigation expansion nevertheless went forward. To understand why Egypt proceeded with its irrigation programmes when it was warned of substantial environmental deterioration we must look at the socio-economic context of the 1950s, when the decisions were made.

Egypt was faced with a rapidly growing population. Agricultural output had to be increased if famine was to be avoided in the near future. Egypt had already achieved some of the highest yields per unit land in the world, so there were limited prospects for increasing production through improvement of cropping methods. Substantial increases could only come through expanding cropped area and cropping more than once annually. For this, expansion of irrigation was necessary. At the same time, Egypt's access to major funding sources was severely restricted in the 1950s. In essence, the government was left with only one realistic option. It had to proceed with limited funding, which would not allow for expensive environmental protection measures [Waterbury (1979); Wilkinson (1980)].

Pakistan faced similar problems. Agricultural development depended heavily upon development of the Indus and its tributaries for irrigation. By the 1980s, it was estimated that nearly half of Pakistan's irrigated land was affected to some degree by water-logging and/or salinisation; in Sindh Province the figure reached over 98 percent. However, the government had to continue expanding irrigation in order to keep pace with population growth.

Irrigation programmes continue with the full knowledge that they will result in water-logging and salinisation. In fact, nearly 40 percent of the funds for water development in the Fifth Five-Year Plan (1978–1983) were allocated for drainage and reclamation of waterlogged and salinised land, while irrigation received just over 25 percent of those funds. Over 100,000 tube-wells were installed from the early 1960s to the early 1980s in an effort to pump out ground water rapidly enough to lower the water-tables. Even today, salinisation from irrigation remains a serious problem. But just as in Egypt, it is doubtful that any other options are open to Pakistan. To cut back on irrigation expansion would mean that agricultural production would rapidly fall behind population growth [Varady (1981); Rozema (1990)].

CONCLUSION

The examples discussed here illustrate that very similar kinds of economic choices lie behind very many different causes of desertification. Herders, farmers, and government officials are usually well-aware that their actions may contribute to environmental degradation. But they often have little choice, because solutions which are sound for long-term resource management may not address short-term problems of survival. We cannot condemn rural people's desire to survive or even to improve their lives, and neither can we fault policy-makers' attempts to help them do so.

Rather, policy-makers must recognise that good environmental policy must address economic issues to have any chance of successful implementation. People will not support programmes which do not improve their lives. In fact, they will actively oppose programmes which actually cause a decline in living standards. The best way to get short-term cooperation in sound management of fragile arid ecosystems is to incorporate economic measures so that good practice leads to immediate benefits. Environmental policies will be supported with enthusiasm if they improve peoples' lives now, not just in some vague, distant future.

The first step in formulating sound policy is analysing economic motivations within the socio-economic context where people make choices. For example, livestock herds represent income and savings in traditional nomadic economies of the Sahel and Sudan. Production of animal products is both for consumption and for market sale to obtain what the nomadic economy cannot produce. Live animals also represent stored wealth, an insurance against hard times in the future. Nomads want to increase herd size because that is how a family's living standard and security are improved. Farmers who keep livestock have similar considerations. Even though less dependent on livestock overall, increasing herds may be one of the only ways to improve living standards, because often there is too little and too poor land to gain much by expanding farming.

In overpopulated agricultural areas such as Egypt and Pakistan, agriculture is becoming ever more crowded. Farmers must expand into new areas because their is not enough land to maintain living standards in traditional agriculture without expansion. They cut back on rotation or increase the number of crops because there is simply not enough food production with traditional timing. In areas such as Oman and Yemen, the problems are not from population pressure, but from lack of manpower in rural areas to maintain traditional agricultural systems. Families can achieve higher living standards by sending family members to work abroad and using labour-saving pumps at home. With labour migration, families are better off even if they do not farm at all.

To have an impact, policy must offer rural people tangible benefits now or the realistic hope that benefits will come soon. People will not support initiatives that seem to have only cost without providing anything in return. Livestock policies must protect wealth and security represented by herds, because herders will not voluntarily give up wealth and security now for some intangible benefits in the future years. Rangeland

vegetation must have some value to nomads if left in place, as well as if used for firewood. Living standards of farmers must be raised so that they do not need to expand into marginal areas, over-irrigate, or over-crop. Fields must produce as much income even if not cropped as intensively. Using and maintaining traditional systems must yield as much income as sending labour abroad and utilising pumps at home.

Usually, a whole package of economic policies is needed, along with technical and regulatory methods for dealing with desertification. Exactly what policies will work depends, of course, on economic and social conditions in specific countries. Many countries may need to introduce market reforms, so that farm-gate prices increase, allowing rural people to improve living standards without having to expand agriculture or herding. Subsidies may be needed to encourage environmentally beneficial actions, such as payment for maintaining terraces and irrigation systems, or for protecting and tending trees. Policies must be very carefully implemented. Simply making farming more profitable can increase environmental degradation if policies are not carefully thought out. Similarly, livestock subsidies may simply encourage herd growth.

Whatever the policy, though, the basic principle is that rural people must benefit immediately. Environmental protection must become more important to them in the short-term than their current, destructive activities. If proper policies are implemented, rural producers will become enthusiastic allies in preserving arid and semi-arid environments. After all, they know better than anyone that it is in their interest to preserve their environment, if they can do so without sacrificing their short-term chances for survival. Planners must begin to view rural people as allies in the fight against desertification, and allies need support so that they can help more effectively. In most arid regions, the world needs all the help it can get in holding back the desert.

REFERENCES

Anderson, D. M. W. (1993) Gum Arabic: Recent Developments—Pros and Cons. *British Food Journal* 95:2 30–32.

Bernhardt, C., R. Griffin, R. R. Hawkins, D. Hendricks, and M. Norvelle (1981) Water Policy Initiatives for Yemen: Recommendations by CID Water Team. Consortium for International Development, Tucson. (CID Yemen Report 052-1981-1.)

Birks, S., and C. Sinclair (1979) Aspects of International Labour Migration in the Arab Near East: Implications for U.S. Aid Policy. U.S. Agency for International Development, Washington, D.C. (Contract No. AID/ne-c-1593.)

Ellis, S., D. Taylor, and K. R. Masood (1993) Land Degradation in Northern Pakistan. *Geography* 78:1 84–87.

Ford, R. E. (1992) Humans and the Sahelian Environment. *National Geographic Research and Exploration* 8:4 460–475.

Frank, R. W., and B. H. Chasin (1980) *Seeds of Famine: Ecological Destruction and the Development Dilemma in the West African Sahel*. New York: Allenheld, Osmun and Co.

Hammer, T. (1983) *Wood for Fuel Energy Crisis Implying Desertification*: The Case of Bara, the Sudan. Bergen: Chr. Michelsen Institute, Development Research and Action Programme (DERAP Publication 160).

Hulme, M., and M. Kelly (1993) Exploring the Links between Desertification and Climate Change. *Environment* 35:6 4–11; 39–45.

Louis Berger International, Inc. (1983) Sudan: Kordofan Region Agricultural Marketing and Transport Study. Louis Berger International, East Orange, NJ. (Contract No. 650-AID.)

Ormerod, W. E. (1978) The Relationship between Economic Development and Ecological Degradation: How Degradation has Occurred in West Africa and How its Progress Might be Halted. *Journal of Arid Environments* 1:4 357–378.

Pearce, D. (1988) Natural Resource Management and Anti-Desertification Policy in the Sahel-Sudan Zone: A Case Study of Gum Arabic. *Geo Journal* 17:3 349–355.

Rozema, J. (1990) Agricultural Problems of Saline Arable Land in Pakistan. In J. Rozema and J. A. C. Verkleij (eds) *Ecological Responses to Environmental Stresses*. Kluwer. 277–288.

Solbrig, O. T., and M. D. Young (1992) Toward a Sustainable and Equitable Future for Savannas. *Environment* 34:3 6–15; 32–35.

Speece, M. (1981) Draft Environmental Report on the Sultanate of Oman. Office of Arid Lands Studies, University of Arizona, Tucson, AZ; for U.S. Man and the Biosphere, U.S. State Department.

Speece, M. (1982) Environmental Report on Yemen (Yemen Arab Republic), Revised Draft. Office of Arid Lands Studies, University of Arizona, Tucson, AZ; for U.S. Man and the Biosphere, U.S. State Department.

Speece, M. (1985) Agricultural Marketing Structures and Marketing Constraints in Kordofan, Sudan: Recommendations for WSARP Research and Implementation. International Projects Office, Washington State University, Pullman, WA.

Varady, R. (1981) Draft Environmental Report on Pakistan. Office of Arid Lands Studies, University of Arizona, Tucson, AZ; for U.S. Man and the Biosphere, U.S. State Department.

Waterbury, J. (1979) *Hydropolitics of the Nile Valley*. Syracuse, NY: Syracuse University Press.

Wilkinson, J. C. (1977) *Water and Tribal Settlement in South-East Arabia: A Study of the Aflaj of Oman*. Oxford: Clarendon Press.

Wilkinson, M. J. (1980) Draft Environmental Report on the Arab Republic of Egypt. Office of Arid Lands Studies, University of Arizona, Tucson, AZ; for U.S. Man and the Biosphere, U.S. State Department.