

SOIL LOSS IN DEVELOPING COUNTRIES AND ITS RELATIONSHIP TO
MARINE RESOURCES: EXAMPLES FROM EAST AFRICA*

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Abstract

The direct economic and social effects of soil loss in developing countries are generally recognized. Massive upland soil erosion also, however, affects coastal and marine systems through sediment transported by major rivers. Such sedimentation can affect a range of human activities, including coastal lifestyles, fishing, and maritime and tourist development. East Africa sustains high rates of soil loss due to human subsistence activities, and major changes are observable and predictable in coastal natural systems. The viability and effects of major dam projects in relation to siltation are of special concern. These factors call for improved monitoring and assessment of the effects of coastal sedimentation as well as serious nation-wide campaigns to reform rural subsistence living practices and implement forest, soil, and rangeland conservation programs.

I. COASTAL GEOGRAPHY OF EAST AFRICA

The coastal areas of the countries of East Africa -- Somalia, Kenya, Tanzania, and Mozambique -- and the large island of Madagascar share broad similarities. With the exception of Mozambique, these countries are characterized by coastal plains 10-25 km in width which slowly rise to interior highlands, which are the primary productive areas of the nation; the populations of the coastal strip are generally below 10% of the national total.^{1/} In Mozambique, in which the coastal strip is generally some 40 km wide and nearly half of the entire national area has an elevation of under 1000 m, fully three-quarters of the population live in the coastal zone.^{2/}

From approximately Cabo del Gado, Mozambique in the south, extensive nearshore fringing coral reefs characterize the coastline of East Africa, including almost the entire eastern coast of Madagascar and portions of its west coast^{3/} -- except where the influence of major river systems is felt.^{4/} A large number of rivers reach the coast from the highland regions; the riverine influence along the coast is most pronounced in Mozambique, in which fully 25 major rivers enter the Indian Ocean (Mozambique Channel).^{5/} By far the largest of these, as well as the largest river in East Africa, is the Zambesi, which reaches a maximum sustained flow of some 20,000 m³/sec. in the rainy season.^{6/} The major river of Tanzania, the Rufiji, has a seasonal flow which reaches some 1,130 m³/sec.^{7/} In Kenya, the Tana and Sabaki (Galana) Rivers reach the sea north of the city of Mombasa, causing significant effects on the local

marine environment.^{8/} In Somalia, two major rivers affect the coastal zone in the south, the Juba and Shebelle; except during flood periods all the water of the latter is extracted for irrigation before the river reaches the sea.^{9/} The major rivers of Madagascar by and large flow westward along the more gently sloping highlands west of the East-Central mountain range; these rivers cause major effects where they enter the ocean, especially in the Northwest and at other places along the west coast, including Toleara (Tuléar) in the southwest.^{10/}

By and large, the coastal regions of East Africa are characterized by degraded forest and scrub and are generally unfavorable for agriculture and livestock raising.^{11/} Rainfall regimes are unfavorable; heat and humidity are relatively extreme; and insect vectors such as the tsetse fly are widespread.^{12/} A number of cash crops are, however, grown along the coast; these include cashews, rice, and copra, and pineapple in Kenya.^{13/} With the exception of relatively large commercial shrimp fisheries in Mozambique and Madagascar,^{14/} and a small commercial fishery in Kenya, fishing is generally limited to subsistence efforts using a variety of methods. Commercial fishing is impeded by low biological productivity and limited continental shelves that are unsuitable for trawling except in the more extensive muddy areas such as the Bight of Sofala (Mozambique), the Mafia and Zanzibar Channels (Tanzania), and the Lamu Archipelago (Kenya/Somalia).^{15/}

The coastal zones of East Africa are nevertheless important for national social and economic development, both at present and for the future. Primary urban centers are located on the coast in three countries -- Dar es Salaam in Tanzania, Maputo in Mozambique, and Mogadishu in Somalia. There are several secondary urban centers, associated with major ports -- including Mombasa in Kenya; Beira in Mozambique; and Toamasina (Tamatave), Antseranana (Diégo-Suarez), Mahajanga, and Toleara in Madagascar. A variety of tertiary settlements are located along the coast, especially where they were established in connection with periods of trade and colonization by Arabs and later Europeans. These include Merka and Kisimayu (Somalia); Lamu and Malindi (Kenya); Tanga, Zanzibar, Bagamoyo, Mtwara and Lindi (Tanzania); Nosy Be and Faradofay (Fort Dauphin) (Madagascar); and Pemba, Nacala, Quèlimane, Inhambane, and Xâi-Xâi (Mozambique).

Populations along the coast are ethnically and linguistically distinct from the populations of the interior, exhibiting an Arab influence; Kiswahili is widely spoken along the coast.^{16/} Coastal residents are involved in extensive decentralized artisanal

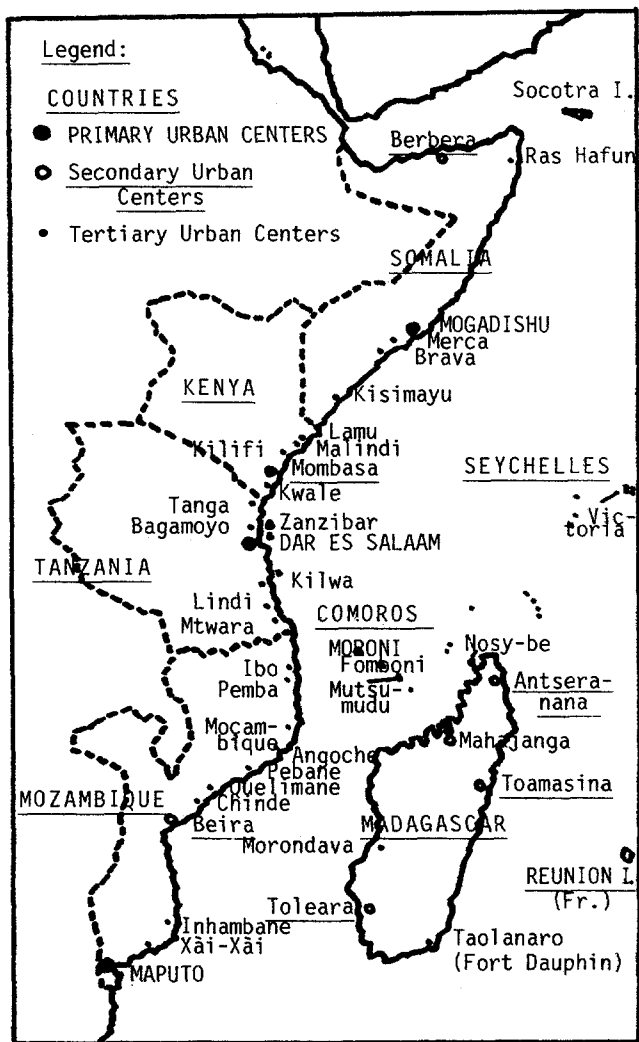


FIG. 1. COASTAL CITIES AND TOWNS

fishery efforts although development of this fishery has been impeded by infrastructural constraints such as lack of equipment and facilities such as for freezing and storage, and also by transportation difficulties which prevent ready marketing of catch in urban centers either along the coast or in the interior.^{17/}

The population of the major urban centers along the coast has grown rapidly in connection with maritime commerce and associated industry -- both large- and small-scale.^{18/} Tourist development has attracted new residents, especially in expanding destinations like Malindi in Kenya, which has experienced fully 20% annual population growth in recent years.^{19/} Major effects on natural systems at the coast resulting from increased sedimentation originating in the basins of the major rivers could affect the resource base of such coastal activities as exist today as well as the future development of the coastal economy.

One coastal resource of special significance is the extensive mangrove forests that are well established in favorable (i.e., relatively low-energy) areas subject to riverine influence. Extensive man-

groves occur along the northwest coast of Madagascar and near the mouths of major rivers on the mainland, especially the Zambesi and Rufiji Rivers. Estimates of the total area of mangrove forest are as follows: Madagascar, 3,207 km² (on 1,150 km, or 28.7% of total coastline); Mozambique, 850 km² (on 1,194 km, or 48.3% of coastline); Tanzania, 500-820 km², and Kenya, 587 km².^{20/} Aside from providing valuable habitat for other marine species and supplying useful products, the mangrove forests form the basis of the great shrimp productivity that characterizes areas in the Region adjacent to the large mangrove forests.^{21/} In northwest Madagascar, some 5,000 MT/yr. of shrimp are harvested in shallow nearshore waters. In Mozambique, catches are reported to have been running at 6-7,000 MT/yr. before 1976 but have declined since then, to perhaps 2,000 MT in 1978.^{22/} Little information is available for the shrimp fishery in Tanzania, since there is little commercial organization, but the mangrove forests of the Rufiji delta are thought to be capable of supporting a mean annual productivity of over 2,500 MT, of which perhaps some 700 MT is harvested currently.^{23/} In Madagascar and Mozambique the shrimp catch has been a major contributor to national earnings.^{24/} Since the vitality and extent of the mangrove forests are a major determinant of the shrimp productivity, every effort should be made to ensure that man-induced changes do not affect them in ways adverse to the fishery.

II. DIMENSIONS OF THE SOIL LOSS PROBLEM

Economic and resource planners have begun to stress the tremendous implications for national development of the large-scale loss of soil that is occurring in developing countries due to the increasing pressure on rural resources produced by continued high rates of population increase accompanied by reliance on traditional methods of livestock raising, crop cultivation, and fuelwood harvesting.^{25/} Soil loss directly affects the material basis of rural life and the continued availability of essential products for urban populations, such as firewood and charcoal -- in addition to agricultural products. The dimensions of this problem are staggering. In Madagascar, for example, where officials have identified soil erosion as the key domestic problem, soil loss averages some 25-40 T/ha./yr. for all areas and reaches as much as 300 T/ha./yr. in certain highland areas.^{26/} (Soil formation varies widely according to conditions but is on the order of 15 T/ha./yr. on a global basis.)^{27/} Fully 65% of the surface of the entire country is thought to be insufficiently covered by vegetation to prevent soil degradation, especially during intermittent heavy rains, as a result of shifting cultivation, brushfires, pasturing, and other factors.^{28/}

In East Africa soil erosion in the interior is heightened by high rates of population growth, unfavorable soil and climatic conditions, and the marginality of large areas for agriculture and other rural activities due to slope and other factors. The absence of technical assistance and adequate support for rural development has compounded these limitations, as have difficulties in national social and political organization. Soil loss has become a major concern in the immediately affected areas. Its effects, in the form of siltation, along the major rivers

are magnified by their large drainage areas, many of which include high-rainfall regions in the interior. It would be difficult to assign a priority to the various causes of soil loss; rather the problem arises from a complex of factors operating in the context of continued population growth.

A. Subsistence agriculture

Patterns of shifting cultivation and associated practices (such as burning of original vegetation) continually bring new or former areas into cultivation in order to exploit short-term agricultural potential; systematic cultivation has also been extended into increasingly marginal areas.^{29/} It is difficult to see how existing and future populations relying on subsistence agriculture in the prime upland areas of the Region will be able to avoid large-scale soil erosion without sufficient technical and material assistance to adopt more modern and systematic methods of agriculture -- which would involve improved crop selection, rotation, and handling; improved equipment; more fertilizer and other agricultural chemicals; and in some areas irrigation.

In Kenya, for example, population has grown at a world-champion 3.5% annual rate.^{30/} With 90% of the population practicing subsistence farming and other rural subsistence activities, cultivation has been expanded into areas of marginal rainfall, dry-season pasture, slopes, and river margins.^{31/} The higher-potential areas that include only about 20% of total national territory have also come under more intensive cultivation and soil conservation programs have not been applied adequately.^{32/}

In Mozambique, high population growth has combined with unfavorable soil and rainfall conditions to destabilize soils over large areas.^{33/} Lack of technical support and organization largely prevent satisfactory control over the establishment of new centralized agricultural projects.^{34/}

In Madagascar, it is estimated that some 200,000 ha. are converted to agricultural use each year through slash-and-burn agriculture, or "tavy".^{35/} This problem is especially severe in the forested and precipitous areas of the eastern highlands due to the large population and agricultural limitations.^{36/}

B. Direct deforestation

Throughout the Region, large amounts of forest resources, including degraded forest and scrub, are deliberately harvested to provide domestic fuels in the form of fuelwood or charcoal.^{37/} The domestic fuel harvest is organized on both a subsistence and commercial basis, and it is thought that relatively little of the take is controlled through quotas or permits. In Kenya, for example, total consumption of wood for fuelwood and charcoal is estimated to be some 15 mil. m³, or 90% of the total national consumption of forest products. Of this, only some 200,000 m³ is obtained by purchase from the Forestry Department.^{38/} As a result, it is estimated that only some 2.5% of the total 3.3% of national area officially gazetted as forest actually remains in forested condition.^{39/} FAO estimates of fuelwood collection (1977/78) have been developed, as follows: Madagascar, 5.1 of a total national forestry of 6.6 mil. m³; Mozambique, 9.9 of a total 11 mil. m³; Tanzania, 39 mil. m³.^{40/} As a result of deforestation, vegetative cover has been lost and soil

erosion increased. The availability and price of domestic fuels for urban dwellers has increased with greater distances to remaining sources of supply, and rural residents have to devote a greater and greater amount of time and energy to collecting domestic fuels. In Kenya, the charcoal sources for Nairobi have moved to the slopes of Mount Kenya, and in Somalia charcoal is currently obtained from an area fully 500 km south of Mogadishu.^{41/}

C. Livestock raising

Throughout East Africa there are extremely large stocks of domesticated animals, which actually rival human populations in total numbers. FAO estimates for national cattle herds are as follows (1978):^{42/} Kenya, 9.8 mil.; Madagascar, 9.0 mil.; Mozambique, 1.3 mil.; Somalia, 4.0 mil.; Tanzania, 15.2 mil. Overpasturing has caused soil degradation over wide areas, and considerable soil loss has occurred, especially on slopes and around the banks of rivers where animals congregate for watering.^{43/} The effects of animal movements and grazing is magnified by the practice of burning pastures to clear mature vegetation and produce edible shoots for forage. In Madagascar, for example, it is estimated that fully 1 mil. ha. of vegetative cover was lost annually in 1979 to brushfires intended to prepare areas for pasturage; officials claim that this level has been reduced to 100,000 ha./an. since 1980 through government action implemented on the local level.^{44/} In Somalia, where there is a system of reserves intended to regulate the time and extent of grazing,^{45/} large-scale destabilization of pastures has nevertheless occurred -- especially along the coast where coastal bluffs have been desertified and converted into shifting dunes as a result of seasonal overgrazing during a drought period in 1978. Some 5,000 km² of shifting dunes have been created, of which 48 km² have been restabilized, but indefinitely lost to pasturage, through systematic replanting of dune vegetation such as the prickly pear cactus.^{46/}

D. Rural settlement patterns

National population growth combined with the traditional practices described above would themselves place constantly greater stress on the forest and soil resources of East Africa. Political and social developments in this Region have also, however, influenced the pattern of settlement in rural areas so that even greater stresses could result unless careful planning and control are practiced. In Mozambique, Tanzania, and to a lesser extent Madagascar, villagization campaigns have been organized to improve the quality of rural life. In most cases, this has involved regrouping of existing rural populations into villages, but sometimes resettlements of rural or even urban populations have occurred.

Concentration of rural populations into villages can result in overcultivation of land in the immediate vicinity of the village -- sometimes regardless of its suitability for agriculture -- and withdrawal of more remote but desirable areas from cultivation. In the villages, cultivation is intensified and practiced in a more limited area. But in many cases adequate technical assistance, infrastructure, equipment, and supplies are not available to support such intensified effort. As cultivated areas become depleted, new areas may be brought into cultivation or the traditional cycle of cropping

shortened. Natural areas adjacent to villages also become subject to intensified pasturage and collection of forest products.

In Mozambique, villagization has had a strong mass basis which dates from the revolutionary period in which FRELIMO, the liberation party, reorganized rural life in securing its rural basis of support. Villagization continues to be largely implemented at the local level although central political authorities have a role in deciding whether to establish new villages and how to support them. (The National Commission for Communal Villages currently approves the formation of new villages and the National Directorate of Housing in the Ministry of Public Works and Housing provides physical planning services and infrastructure.)^{47/} Villages in Mozambique range 1,000-5,000 in population and include an area of cir. 8,300 ha. within a circle of 5 km diameter, a distance established in order to prevent peasants from having to walk more than an hour to reach their fields.^{48/} Absence of adequate technical assistance and localized decisionmaking has led to many inappropriate decisions about the siting of villages.^{49/} Limited equipment and supplies have forced village residents to continue to rely on traditional agricultural practices. This has led to shortening of the crop cycle and potentially severe degradation of soil resources. Many peasants apparently continue to work their traditional plots outside village boundaries. Outside advisors are concerned about the implications of these developments -- especially in conjunction with official encouragement of maize cultivation, which is much more susceptible than traditional crops such as cassava to fluctuations in rainfall and soil degradation.^{50/}

In Tanzania, the formation of "ujamaa" (family-hood) villages also is subject to strong political impetus, but is much more centrally directed, with ultimate planning and approval being exercised by the Office of the Prime Minister; physical planning services are provided by the Ministry of Lands, Housing and Urban Development (the "Ardhi", or Lands, Ministry).^{51/} Village size in Tanzania is set at 240-300 families; village populations are in the range of 2,000-5,000. Village area lies within a 7 km radius to the outer limit of the grazing fields, and 5 km for the agricultural area.^{52/} Individual families are reported to continue to maintain private plots outside this area. As a result of inadequate technical assistance and material support, inappropriate siting and supply decisions have been made, and many villages have turned out to be unviable even though numerous new residents were drawn to them. An especially unfortunate example of the consequences of villagization is the loss of agricultural productivity in the traditional rice-growing areas of the Rufiji floodplain due to abandonment of the river plain in favor of permanent village location on the sides of the valley. These villages have been plagued by agricultural limitations and the absence of infrastructure and material support, which have led to a substantial out-migration to Dar es Salaam.^{53/}

In Madagascar, calls for the radical transformation of Malagasy rural life led to the formation of fokolonona's based on the traditional village community of the dominant Merina tribe. Some 10,000 such villages were created 1973-75 and about the same number appear to exist today.^{54/} The formation

of socialist villages in Madagascar does not seem to have entailed a basic change in population settlement patterns. Rural collectivization in Madagascar is a two-step process which in the first instance involves land reform, which is carried out by the State through condemnation and redistribution of areas over 600 ha. Collectivization of production and other functions, if it occurs, results from a distinct political movement among the local population.^{55/}

III. SCALE AND EFFECTS OF COASTAL SEDIMENTATION

A large amount of sediment resulting from upland soil loss enters the major rivers of East Africa and produces a range of effects along their courses and at their mouths. Little firm information is available concerning the extent of total sediments reaching the coast, but it has been estimated that some $4.81 \times 10^{14} \text{ m}^3$ of sedimentary material enters the Western Indian Ocean from continental sources.^{56/} Sedimentary discharge through Stiegler's Gorge on the Rufiji R. in Tanzania (the site of a proposed dam) alone has been estimated at some 15-25 mil. T/yr.^{57/} As a result of massive sedimentation resulting from human activities, the nature of the entire coastal ecosystem in large parts of East Africa could be irreversibly altered. River deltas could expand in favorable areas while sandy beaches and reefs could be lost. The configuration of the shoreline could be changed in response to new inputs of sediment accompanied by the weakening and breakdown of reefs in some areas. The large inputs of sediment into major rivers could result in a variety of specific, socio-economically significant effects in the coastal zone and in coastal waters.

A. Effects on beaches and reefs; loss of tourism potential

Sedimentary discharges from major rivers can have significant effects on the characteristics, form and quality of the coastline. Sedimentation from the Sabaki R. in Kenya, for example, has seriously affected the beaches and coral reefs at Malindi, a major center of coastal tourism. There has been considerable beach accretion at Malindi, reportedly as much as 500 m over the last 10-15 yr., with a marked acceleration during the last eight years. The beachfront by major hotels and the town pier has receded; the quality of the sand and clearness of the water have been adversely affected. Hotel rates have had to be significantly reduced in consequence.^{58/} In addition to effects on the beaches and the shoreline, sediment has been deposited onto reefs and into the nearshore lagoon; this is of special concern because the Malindi and Watamu Marine Parks are located just south of Malindi. Other tourist areas in the Region have been similarly affected. Beaches and reefs at Nosy-Be in northwest Madagascar, for example, have become subject to considerable terrigenous sedimentation, which has facilitated the growth of mangroves near tourist beaches and caused other aesthetic disturbance.^{59/} Aside from such effects, sedimentation of coral reefs and nearshore lagoons could affect the vitality of coral through turbidity and smothering; the protective functions of the reefs could be lost and the form and characteristics of the shoreline affected as a result.

B. Stormwater flooding in coastal areas

Siltation of river channels and mouths can cause increased flooding in river plains and deltas. Increased flooding of this nature has been observed in the Rufiji R. valley and floodplain commencing in the late 1940's.^{60/} Accelerated surface runoff rates due to deforestation in river basins could also change the pattern of stormwater discharge by rivers, potentially affecting marine organisms in estuarine areas. Due to the limited current utilization of coastal areas in East Africa, little attention has been focused heretofore on flooding and freshwater discharge problems. The heavily populated (cir. 700,000 pop.) highland plain around antananarivo has become subject to attention, however, due to the widespread flooding and sedimentary accumulations caused by surface runoff and soil erosion in the surrounding highlands.^{61/} (A soil loss of 260 T/ha./yr. has been recorded in this area.)^{62/}

C. Deposition of sedimentary material on the continental shelf

Similarly to the organic matter which accumulates in estuaries, especially deltas, as a result of riverine siltation, terrigenous sediment reaching the continental shelf contributes to marine productivity, especially for the shrimp which inhabit shallow areas of the shelf during their adult lives. Extensive sedimentary depositions on the shelf, like major coastal estuaries, correspond to primary shrimp habitats. These include the sedimentary deposits on the sofala Bank off the mouth of the Zambesi R. in Mozambique, in the Mafia Channel adjacent to the mouth of the Rufiji R. in Tanzania, and along the west/northwest coast of Madagascar.^{63/} Significantly increased sedimentation in such areas could, however, have adverse effects on fisheries, including shrimp. Overly rapid sedimentary inputs could reduce light penetration and inhibit phytoplankton productivity. Accumulation of sediments on the seabed can result in the creation of large areas of unconsolidated bottom subject to turbidity and the formation of sand waves, disrupting biological productivity and interfering with fishing efforts. It has been reported that some areas of the Bight of Sofala have become a kind of dead sea as a result of the presence of overly great amounts of unconsolidated sediment.^{64/} On the other hand, huge volumes of sediment impounded in the deltas could actually lower the elevation of these areas through down-pressing of underlying sedimentary strata, resulting in local sea level rise and consequent coastal erosion; this phenomenon is thought to have occurred in the Zambesi delta.^{65/}

D. Siltation at river mouths; effects on ports and navigation

Sedimentation from major rivers accumulates at their mouths, often adversely affecting existing or potential port sites. Ongoing maintenance dredging is necessary at Beira, near the mouth of the Zambesi R.^{66/} Perhaps the most severe problems of port siltation in the Region have occurred at Mahajanga, Madagascar. This important port has become entirely unusable due to the immense volume of sediment reaching its location at the mouth of the Betsiboka R. -- estimated at some 100 mil. m³ (1 mil. T) over the last twenty-five years.^{67/} The loss of port functions at Mahajanga is forcing the Malagasy govern-

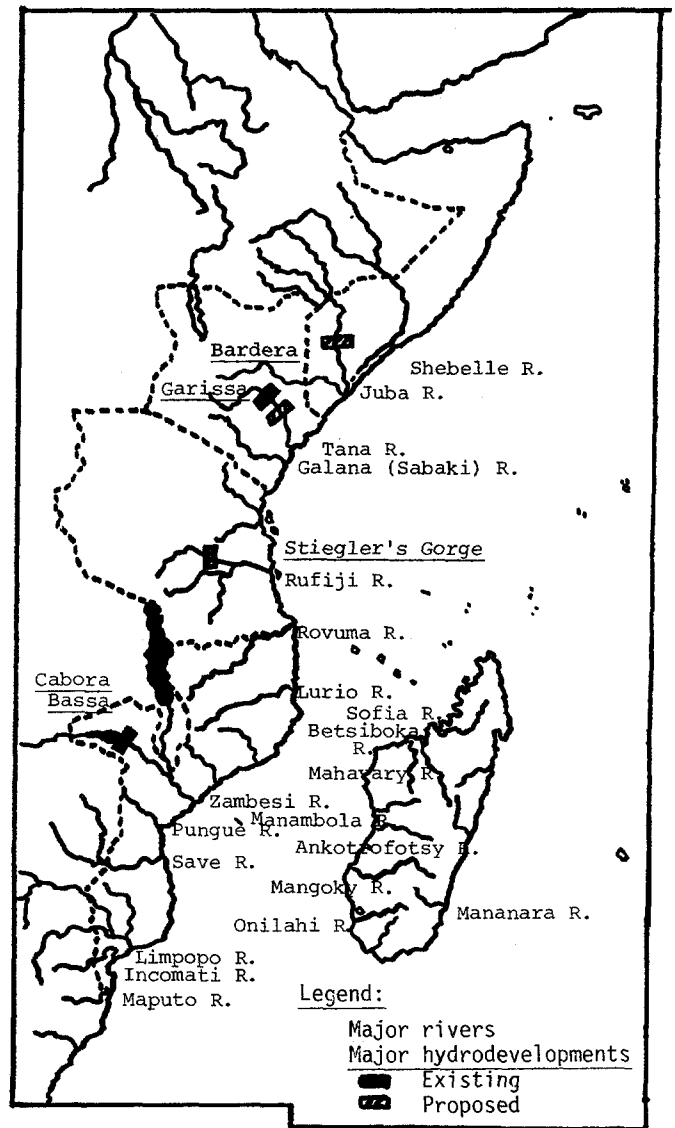


FIG. 2. MAJOR RIVERS AND HYDRODEVELOPMENT PROJECTS

ment to plan the construction of a substitute port nearer the ocean coastline to accommodate the expected continued growth of mineral production in the interior in this region.^{68/} Again in Madagascar, the Pangalanes Canal linking the internal lagoons formed by barrier islands and beaches along the eastern coast has become largely unusable due to sedimentary accumulations; the canal was once navigable for fully 700 km.^{69/} It is also reported that biological productivity in the lagoons and adjacent coastal waters has been severely diminished due to choking off of the exchange of water due to sedimentation.^{70/}

Similarly, siltation from the major rivers could affect the operation and even viability of large dam projects. This is, however, not specifically a coastal problem; the coastal effects of dam projects are discussed in the following section.

IV. EFFECTS OF MAJOR HYDRODEVELOPMENT PROJECTS

The countries of East Africa, especially Madagascar, have some of the world's greatest potential

hydropower resources since their major rivers drain large, rainy upland catchment areas -- often originating in the lakes of the Great Rift Valley system -- and fall through considerable elevation before reaching the sea. But construction of large hydrodevelopment projects on the major rivers of East Africa for electric power generation, irrigation, or flood control could have severe effects on river valleys, floodplains, and estuaries.

Throughout the Region, large hydrodevelopment projects are completed, under way, or planned. The huge Cabora Bassa Dam on the Zambesi R. now provides about 200 MW of electric power and some 1,000 additional will be developed in 1982, with an ultimate potential of perhaps 3,600 MW.^{71/} In Tanzania hydro-power facilities have been developed on the Pangani and Iringa (Rufiji system) Rivers and elsewhere, and major development of the capacity of the Rufiji is planned for the Stiegler's Gorge area. In Kenya, hydropower potential was rapidly developed during the 1970's, with the result that now over 50% of national centralized energy needs are met through this source. In Somalia, where there is currently no installed large-scale hydropower capacity, a major project is under way to construct the Bardera Dam on the Juba R.^{72/}

By and large, such dams reduce the volume of sediment reaching the coastal zone and the sea from the major rivers. Their construction can also cause more localized effects. Removal of sediment by dams can cause rivers to scour their beds beneath the dam, constricting the extent of flood plains. Depending on the management of water flow, major dams can also disrupt the pattern of inundation at the mouths of the major rivers, interrupting the natural cycle of estuarine productivity. Diminishment of sedimentary inputs at the coast can also cause slowing of the expansion of deltas or even actual contraction of deltaic areas, including valuable mangrove forests; this could disrupt the ongoing cycle of delta replenishment or cause salinity intrusion upstream, adversely affecting the viability of established estuarine habitat. While little firm information is currently available about these problems, there are already indications in the Region that they may be occurring.

Fisheries officials in Mozambique are concerned about the effects of completion of the Cabora Bassa project on the delta of the Zambesi R., since the Zambesi delta provides the primary nursery grounds for the large shrimp stock caught in the Bight of Sofala. Saline influence currently extends some 80 km up the Zambesi; after partial damming at the Cabora Bassa site increased salinity was noticed in the marginal agricultural area along the River. Aerial surveys and anecdotal accounts also reveal the reestablishment of vegetation adapted to saline conditions, including mangroves, in inner delta and estuarine areas. Delta building has apparently stopped or been severely reduced. A lowered water level has also been noticed in the delta. No effects on the shrimp fishery have yet been confirmed, but there are plans for more systematic studies of the effects of continued damming of the Zambesi, including use of satellite imagery.

Studies have been performed concerning probable effects of the Stiegler's Gorge project in Tanzania, which is now scheduled for completion in the year 2000, in connection with planning for this project

by the Rufiji Basin Development Authority (RUBADA), which has governmental responsibility for water management aspects of the Rufiji basin.^{73/} The current salinity intrusion in the Rufiji delta -- reaching 5-40 km depending on conditions -- would be reduced by the proposed dam, which would even out the flow of the river at a higher-than-median level. It is estimated that after the effects of dam emplacement were fully transmitted downstream there would be a recession of shoreline of as much as 1 m/yr. Officials currently believe, however, that there would not be significant accompanying loss of shrimp productivity in view of the extensiveness of the estuarine area and the ability of marine organisms to adjust their location in the estuary according to salinity conditions.

Of the major Kenyan estuaries at Vanga, Mombasa, Mtwapa Mida Creeks, the Sabaki and Tana R. mouths, and the Lamu archipelago, only those at the Sabaki and Tana Rivers have been or are likely to be affected in the immediate future by damming upstream. On the Tana, damming has been reported to have noticeably reduced siltation at the mouth of the river but the marine fisheries in the area actually seem to have improved.^{74/} Decreased sedimentation from the Sabaki would not ameliorate the situation at Malindi in the near term, but could help to prevent siltation of the reefs at the nearby marine parks and reserves.

Little information is known about estuarine conditions in southern Somalia, the only area of the country where significant river flow enters the sea. The Bardera Dam project when completed would likely considerably reduce the flow and sedimentation of the Juba River at its mouth, since the dam is designed to provide water for as much as 220,000 ha. of newly-irrigated agricultural area. Outside assistance has been obtained from the U.N. Environment Program in assessing the likely environmental effects of the dam, including downstream effects.^{76/}

These dam projects, in addition to causing significant effects on estuarine conditions at river mouths, could also cause secondary agricultural development in river plains. In certain cases, expansion of irrigated agriculture in such areas may convert them from prevailing saline to fresh conditions, for example, by the establishment of new paddy-rice cultivation areas. Care will also have to be exercised to ensure that the benefits for agriculture in irrigation and flood control are not counteracted or offset by salinity intrusion resulting from reduction of flow and sediment discharge into estuaries and as a result of faulty irrigation practices in marginally saline conditions.^{76/}

V. CONCLUSIONS AND RECOMMENDATIONS

In East Africa, as elsewhere in the Third World, environmental values and natural resource factors have not been fully integrated into national development planning. In addition, these aspects of national socio-economic conditions are often subject to the severest strains due to the adverse effects of subsistence living activities practiced by large rural populations. The problem of linking governmental policies and regulatory and educational efforts with sound resource management is further impeded in the case of coastal resources by the dynamic and interactive nature of coastal and marine systems, and the

relatively scarce attention paid to these resources to date due to their lesser priority in traditional national economies and societies. The level of development at the coast has been well below that of other areas and with few exceptions serious environmental degradation has not occurred due to human settlements or industry. Disturbing and perhaps irreversible trends are beginning to appear, however, primarily in connection with activities practiced outside the coastal zone -- especially agricultural and pastoral activities in the highlands. The marine dimensions of managing these problems, as well as traditional issues of coastal and marine development, must soon be effectively incorporated into national policy making. Aside from necessary institutional measures to help national officials address general environmental problems and coastal and marine resource conservation issues in particular, the following items should be addressed.

(1) Control of upland agricultural, pastoral activities

Upland land use patterns and practices must be controlled in order to reduce soil loss resulting in siltation at the coast and increased fluctuation of fresh water flow in rivers due to loss of the retentive properties of upland vegetation. Specifically:

(a) Soil conservation practices

Sound soil conservation practices must be adopted, implemented, and enforced on a national level. Considerable educational effort will need to be devoted to this task, as well as technical assistance and improved equipment and supplies. Soil conservation practices should be accompanied by the construction of works, primarily on a local basis, to combat already serious soil erosion.

(b) Range management

Improved planning and management of rangelands must be undertaken, with strong enforcement when necessary. Destructive grazing practices such as allowing large numbers of animals to congregate near water bodies should be actively discouraged. Some effort should be made to control total numbers of animals on a local basis.

(c) Prevention of deforestation

More rigorous management will be required for forest resources, including both forests in public ownership and other forested areas. Cutting by commercial concerns (such as charcoal vendors) and by subsistence harvesters must be controlled through licensing so that active replanting efforts can have full effect.

(d) Afforestation

Large-scale afforestation programs should be commenced, both on a centralized and a popular basis.

(e) Rationalized fuelwood utilization systems

Increased efforts, including research and development prior to dissemination, must be focused on the fuelwood cycle in order to find better means of managing fuelwood resources. The entire fuelwood cycle should be restructured through improving the efficiency of domestic and charcoal-producing stoves, establishing centralized or local fuelwood plantations, and improving government management of state forests including the issuance of fuelwood collection permits.

(f) Alternative sources of domestic energy

Priority attention should be given to the development and dissemination of alternative sources of domestic energy, including solar and wind power, biogas production, new forms of biomass conversion, and low-head hydropower.

(g) Marine resource assessment

Studies should be undertaken to ascertain baseline conditions in areas subject to siltation and to monitor and predict the extent and effects of increased sedimentary depositions.

(2) Rural development in the coastal zone

Certain human activities in the coastal zone, although perhaps not as great in net effect as those occurring upland, should be controlled because they may have severe localized effects on the dynamics and productivity of coastal systems; these effects can be irreversible if practiced continuously or if they change the prevailing equilibrium in natural systems.

(a) Conversion to agriculture or other uses

When coastal areas, especially floodplains and wetlands, are converted to agricultural or other use, such as saltponds, there should be careful consideration of the effects on the habitat of marine species.

(b) Soil management

There should be careful control of rural activities in the coastal zone, such as cultivation, livestock raising, clearing, and if necessary human traffic, that could lead to erosion of coastal dunes and bluffs, especially in areas that are prone to destabilization or where geological instability or storm hazards could result.

(c) Mangrove protection

Special efforts should be made to protect mangrove forests from overcutting to obtain charcoal, dyes and other natural products, and especially poles for the national market or for export. Ongoing overcutting of mangroves could reduce the delta-building process which allows the productive areas of the coast to accumulate rich organic sediments.

(3) Hydrodevelopment projects

The likely effects of major upstream hydraulic works, including major hydropower projects and irrigation facilities, should be assessed in terms of their effects on coastal and marine natural systems. The results of this assessment should be factored into decisions concerning the design and operation of such works. Special attention should be paid to the problem of loss of deltas characterized by mangroves as a result of reduced sedimentary inputs, and to potential effects on valuable marine organisms of altered fresh water regimes in estuaries. Consideration should be given to managing the water flow through dams so that adverse effects on marine organisms or habitats are avoided.

NOTES

* The research for this paper was performed in connection with the author participation in an exploratory mission to the East African region sponsored by the United Nations Environment Program (UNEP), Regional Seas Program. The mission included visits

to eight countries (Kenya, Mozambique, Tanzania, the Comoro Is., Mauritius, Madagascar, the Seychelles, and Somalia) during October-December, 1981 and led to the preparation of six sectoral reports on various aspects of marine problems, with the author contributing a report on coastal zone management. The reports resulting from the mission will be published by UNEP in 1982 as part of its Regional Seas Reports and Studies series, in preparation for a conference of governmentally-designated specialists to be held in the Seychelles in October; an overview document will also be issued in connection with the conference. The author's sectoral report will be released by UNEP under the title "Coastal and Marine Development in the East African Region". It contains a much more extensive analysis of problems with terrigenous sedimentation as well as a range of other coastal zone management issues. The author wishes to express his sincere appreciation to UNEP and the officials in the countries visited who shared so generously their time, perspective and information.

** This report is entirely based on observations and materials obtained in connection with the research period noted above. No part of this research or the conclusions therefrom is related in any way to the author's current responsibilities.

1. See generally geographic summaries contained in Africa South of the Sahara 1980-1981 (Europa Publishers, 1981). 2. See R. Pelissier, in id., at 695 ff. 3. See n. 1. 4. Id. 5. See n. 2. 6. Information provided by Mr. R. Nicolau, National Directorate for Energy [Mozambique] (Oct. 1981). 7. See L. Berry, in Africa South of the Sahara, supra, at 1023. 8. See text at n. 58, infra. 9. See I. Lewis, in Africa South of the Sahara, supra, at 885 ff. 10. See V. Thompson, in id., at 593 ff. 11. See n. 1, supra. 12. Id. 13. Id. 14. See text at nn. 21-24, infra. 15. See generally "Report of the FAO/IOP Workshop on the Fishery Resources of the Western Indian Ocean South of the Equator" (Proc. Wkshop Mahé, Seychelles, Jan. 1979). 16. See n. 2. 17. Based on conversations with fisheries officials in Kenya, Mozambique, Somalia, and Tanzania (Oct.-Nov. 1981). 18. See, e.g., Ardhi Ministry [Tanzania], Uhuru Corridor Regional Physical Plan, Main Report I, prepared with Ministry of Foreign Affairs, Finland (Aug. 1978). 19. Discussion with district commissioner (Malindi) and other local officials (Oct. 1981); see also E. Martin, Malindi -- The Historic Town on Kenya's Coast (1975). 20. See esp. W. MacNae, "Mangrove Forests and Fisheries", FAO/UNDP, Indian Ocean Programme, (Rome, 1974), FAO Rpt. No. IOFC/DEV/74/34. 21. See, e.g., (1) RUBADA, "Study of the Impact of the Stiegler's Gorge Multipurpose Project on Fisheries in the Rufiji Delta and Mafia Channel", prep. by Atkins Land & Water Management (Aug. 1981); (2) Serviço de Investigações Pesqueiras [Mozambique] and Institute of Marine Research [Norway], The Marine Fish Resources of Mozambique, Reports on Surveys with the R/V Dr. Fridtjof Nansen (Sept. 1979). 22. See generally n. 2, supra. 23. See n. 21(1). 24. See nn. 2 & 10. 25. See, e.g., L. Brown, Building a Sustainable Society (Norton, 1981), at 13-56. 26. Discussion with officials of the Division of Water and Forests [Madagascar] (Oct. 1981). 27. See n. 25. 28. See n. 26. 29. See, e.g., D. Kinyanjui & P. Baker, "Report on the Institutional Framework for Environmental Management and Resource Use in Kenya", published by National Environment Secretariat [Kenya] (Nov. 1980), at 3. 30. See W. Morgan, in Africa South of the Sahara, supra, at 518 ff. 31. See n. 29. 32. Id.; see also Ministry of Environmental and Natural Resources [Kenya], Report of the GOK/UNEP/UNDP Project on Environment and Development, Vol. 1, chap. 9 (Draft, Jan. 1981); National Environment Secretariat [Kenya], Environmental Management Report (Dec. 1977), at 48. 33. See n. 2; see also Tinley, "Determinants of Coastal Conservation: Dynamics and Diversity of the Environment as Exemplified by the Mozambique Coast", in SARCCUS Symposium on the Parque Nacional da Gorongosa (1971), at 125-152. 34. Discussions with FAO officials, Mozambique (Oct. 1981). 35. See n. 26. 36. Id. 37. See generally n. 2. 38. See Republic of Kenya, Development Plan 1979-1983,

Part I (1979), at 270. 39. See GOK/UNEP/UNDP Draft Report, supra n. 32, at 203. 40. See generally n. 2. 41. Discussions with national officials (Oct.-Nov. 1981). 42. See generally n. 2. 43. See Kenya Institutional Framework Report, supra n. 29, at 3-4. 44. See n. 26. 45. Information provided by Dr. A. Karani, National Range Agency [Somalia] and other national officials (Nov. 1981). 46. Id. 47. Information supplied by Mr. A. Forjaz, National Directorate of Housing [Mozambique] (Oct. 1981). 48. Id. 49. See nn. 34 & 47. 50. See n. 34. 51. Discussions with officials of the Ardhi Ministry [Tanzania] (Oct. 1981). 52. Id.; also discussions with staff at BRALUP [Tanzania] (Oct. 1981). 53. See H. Bantje, "The Rufiji Agricultural system: Impact of Rainfall, Floods and Settlement", BRALUP Research Paper No. 62 (Dec. 1979). 54. See n. 10. 55. Discussion with officials of the Directorate of Planning [Madagascar] (Nov. 1981). 56. See A. Hove, "Some Aspects of Current Sedimentation, Depositional Environment and Submarine Geomorphology of Kenya's Submerged Continental Margins", in C. Odiidi Okidi, ed., Management of Coastal and Offshore Resources in Eastern Africa (Proc. Wkshop Nairobi, 26-29 Apr. 1977), Institute for Development Studies, Univ. of Nairobi, Occasional Paper No. 28 (1978), at 128. 57. RUBADA, "Rufiji Basin Multipurpose Development: Stiegler's Gorge Power and Flood Control Development", Report on Hydraulic Studies in Lower Rufiji River, Vol. 1, prep. by Norwegian Agency for International Development & VHL River and Harbor Laboratory (Norway), at II. 58. See n. 19; also discussion with Mr. Iitus Ngaamba, Chief Tourism Officer [Kenya] (Oct. 1981). 59. Personal observations (Oct. 1981). 60. See n. 53. 61. Discussions with officials of Ministry of Population and the Social Condition [Madagascar] (Oct. 1981). 62. See n. 26. 63. See n. 21; also discussion with Director, Centre National de Recherche Oceanographique, Nosy Be (Madagascar) (Nov. 1981). 64. See n. 33. 65. Id. 66. Discussions with officials, Mozambique (Oct. 1981). 67. See n. 26. 68. discussions with UNDP advisors, Madagascar (Nov. 1981). 69. Id. 70. Id.; also n. 26. 71. See n. 6. 72. Discussions with national officials (Oct.-Nov. 1981). 73. See nn. 21(1) & 57. 74. Discussion with staff of Marine Science Institute [Kenya], Mombasa (Oct. 1981); see also n. 19, discussions. 75. Discussion with Mr. A. Elabeh, Director General, Ministry of National Planning [Somalia] (Oct. 1981). 76. Discussions with national officials and FAO and UNDP representatives in Mozambique and Tanzania (Oct. 1981).