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DEVELOPMENT STRATEGIES AND THE ENVIRONMENT

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Irma Adelman and Habib Fetini

DEPARTMENT OF AGRICULTURAL AND RESOURCE ECONOMICS

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CALIFORNIA AGRICULTURAL EXPERIMENT STATION

University of California

DEPARTMENT OF AGRICULTURAL AND RESOURCE ECONOMICS
DIVISION OF AGRICULTURE AND NATURAL RESOURCES
UNIVERSITY OF CALIFORNIA AT BERKELEY

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California Agricultural Experiment Station
Giannini Foundation of Agricultural Economics
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Irma Adelman
University of California at Berkeley
and
Habib Fetini
University of California at Berkeley

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Are there systematic associations between environmental conditions and develoment strategies? There are reasons to expect that there might be, in view of the fact that development strategy choices influence variables which, in turn, influence environmental conditions. In particular, development strategies affect the structure of domestic production, the nature of the most binding constraints facing the economy, technological and investment choices, institutional structures, income distribution, and domestic relative to international prices. These variables affect energy consumption and patterns of land use in the agricultural system, which, in turn, affect the extent of environmental degradation.

We approach the study of interactions between development strategies and environmental degradation from several different angles. We start by reviewing the types of environmental damage in developing countries. In section two, we discuss development strategies and their likely impacts on the environment. In section three, we present the results of cross-country regressions linking energy consumption per unit of GDP with trade strategies in developing countries. In section four, we use simulations with an economywide model of a single country (Mexico) to link energy consumption with development strategy choices. In section five, we turn from the easily quantifiable energy-related environmental damage to the analysis of a more significant, but hidden, type of environmental damage -- soil degradation. We develop a microeconomic model of the likely impact of agricultural intensification on the economy of a village in a sub Saharan African country, in the peanut basin of Senegal, to trace out the likely technological and institutional responses to agricultural intensification. We conclude by suggesting that environmental concerns should play a central role, along with income distribution concerns, in the design of development strategies, especially agrarian ones.

I. ENVIRONMENTAL DAMAGE IN DEVELOPING COUNTRIES

This section contains an overview of the types of major environmental issues affecting developing countries, their economic sources, and their relative severity. It provides a background for the discussion of links between environmental issues and development strategies in the next section.

1.1 Air and Atmospheric Pollution

Energy generation and energy utilization emit hydrocarbons, nitrogen oxide, sulphur dioxide and ozone into the air. The concentration of these pollutants is greatest in urban centers, where energy producing and consuming activities are concentrated. In developing countries, air pollution is aggravated by the use of energy-inefficient technologies with no pollution controls and by the use of cheaper, high-sulfur content, low-quality coal and fuel oil, especially for heating and transport. High sulfur dioxide levels and acid precipitation are the result in many developing-country cities. So is seasonal photochemical smog in many large tropical and subtropical urban centers.

Air pollution is particularly severe in developing-country cities. Of the twelve cities with the worst pollution in the world only two (Madrid and Milan) are in developed countries. Average daily emissions of SO2 exceed the World Health Organization's safe daily mean standards in over fifty percent of developing-country cities reporting levels of sulfur dioxide emissions.[1] Even on good days, Beijing, Teheran and Rio have mean daily concentrations of SO2 about 2.5 times the World Health Organization safe standard[2]! Furthermore, while, in the last two decades, air quality has improved in most developed-country metropolitan centers , it has continued to deteriorate in throughout urban centers of developing countries.

Rural air pollution, in the form of particulates, polycyclic organic matter, carbon monoxide, nitrous oxide, and nitrogen oxide, results seasonally from burning grasslands and forest-clearing for cultivation and grazing, especially in sub-Saharan Africa. Indoor air pollution from cooking with organic fuels or coal on energy-inefficient stoves without proper venting is endemic and leads to dangerous indoor concentrations of carbon monoxide, particulates and hydrocarbons.

Greenhouse gases, especially CO2, result from both industrial and farming practices. Carbon dioxide is generated by the combustion of fossil fuels in urban areas and by deforestation and methane from rice production, rotting vegetation and livestock in rural

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[1] Computed from Smil, 1990

[2] World Health Organization, 1987.

areas. Currently, the contribution of developing-country energy-production to CO2 emissions worldwide is small, but it is likely to increase quite rapidly. By contrast, developing countries are responsible for about 90% of global CO2 emissions resulting from deforestation, biomass fuels, and vegetation burning[3], with deforestation being responsible for over 80% of this total. As a result, about 28% of global CO2 emissions most probably originate in developing countries. Developing countries are also responsible for more than half of methane and nitrous oxide emissions worldwide[4].

Energy use, and hence contributions to air pollution, vary across sectors of economic activity as well as by level of development. In developed countries, industry typically accounts for 40% of commercial energy use; commercial and residential uses for 30%; and transportation for 20%.[5] The pattern of commercial energy use in newly industrializing countries is roughly similar to that of OECD countries. In Brazil, for example, the analogous percentages are 34, 39 and 25. By contrast, in the poorest developing countries transport accounts for about 75% of commercial energy uses with industrial uses about 8-9% and commercial and residential uses for the rest[6]. Across industrial sectors, fertilizer, cement, paper and pulp, chemicals, metal industries, and petroleum refining are the heavy energy users. In these industries energy accounts for about half of total intermediate costs. It is the uneven use of energy across sectors which makes for the main link between development strategies and energy consumption.

Poor air quality hurts human health, crops, forests, and water resources. But, as experience in OECD countries indicates, it is a reversible process, amenable to policy-intervention.

1.2. Water Pollution and Depletion

The two major water-related environmental problems are contamination and depletion.

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[3] World Resources Institute, 1987.

[4] David Rind, 1989.

[5] Joy Dunkerley, William Ramsey, Lincoln Gordon, and Elizabeth Cecelski, 1981.

[6] International Energy Agency 1979.

Surface and ground water are being contaminated by agricultural, industrial, urban and human wastes. Intensive farming pollutes water through leaching of nitrogenous fertilizer and pesticides into streams and lakes and into underground water supplies. Industry discharges heavy metals, phenols, hydrocarbons, nitrates, sulfates, and even cyanide into water supplies. The production of energy pollutes water through acid drainage from mines, and through the release of solids and hydrocarbons from coal preparation and refineries. Oil transport produces oil spills. Finally, the discharge of untreated human wastes into surface water is general in developing countries, where sewage facilities serve only a small proportion of towns.[7] As a result, safe drinking water and sanitation are a major urban environmental problem in most of the developing world. Pollution of rural water supplies by human and animal wastes is ubiquitous in developing countries. Depending on the developing country, between 25 and 75 percent of the rural population therefore has no access to safe drinking water[8]. Chronic diseases, microbic infections, aggravated malnutrition, greater infant mortality, and shortening of life expectancy are the result.

Water resources are also being depleted by overdrawing of groundwater, primarily as a result of irrigation. In addition, in areas located downstream from deforested areas, heavy erosion is silting water supplies. Typically, in both developing and developed countries, the major use of water is in irrigated agriculture (73%); industrial uses account for (21%) and domestic uses accounting for the rest (6%)[9]. Developing countries account for 75% of the world's irrigated land area, require about twice as much water per acre as do developed countries, and manage their water resources more inefficiently and with greater environmental damage. Irrigation is also increasing most rapidly in developing countries.

Water contamination is a reversible process, amenable to policy. Water management problems can be ameliorated and some, but not all, of their environmental effects reversed.

1.3. Land Degradation, Soil Erosion and Desertification

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[7] In India, for example, only 7% of cities and towns had even partial sewage treatment facilities in 1980. Center for Science and Environment, 1982.

[8] Wollman, N. 1987.

[9] Office of Technology Assessment, 1990.

Cultivable land is the basis of the livelihood of 80% of the population of developing countries. Population pressure on land is very severe in Asian countries[10] and, while land is not currently scarce in Africa, extremely rapid population growth is leading to unsound agricultural practices whose results are land degradation, land erosion, and desertification.

Soil erosion through the loss of topsoil that is either washed away or blown off the land affects over one third of the world's total rainfed croplands.[11] Estimates of the extent of desertification, the extreme end of a gradual process of loss of soil fertility and soil erosion, vary substantially. According to the United Nations' Environment Program, two fifths of Africa's non-desert areas, one third of Asia's and one fifth of Latin America's are at risk of desertification[12]. According to estimates by Mabbut (1984), at least 40% of total productive drylands are currently impacted to a significant degree by desertification. And the problem is worsening rapidly.

The world's poor are most seriously affected by land degradation since they depend on the most marginal lands for their livelihood. Population pressures, agricultural practices, poverty, price policies and economic institutions interact to produce this devastating effect in mutually reinforcing cycles.

Increases in population density, poverty, lack of alternative income-earning opportunities, and land degradation lead to reducing fallow-time below that required for natural restoration of soil nutrients. This interacts with the use of biomass for fuel to reduce soil fertility. Attempts to respond to reduced yields by clearing more marginal lands that are highly erodible lead to further land erosion and greater loss of land productivity. The clearing of lands coupled with shorter fallow periods also results in deforestation. Deforestation increases water runoff, and leads to siltation and flooding in downstream areas, thus widening and reinforcing the cycle of environmental degradation and poverty.

Wood is the preferred fuel of the rural population. But deforestation and population

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[10] China averages only about .09 hectares of arable land per capita, Indonesia .12 and India .20 as compared to the US with .55. William C. Clark, 1989.

[11] Lester Brown 1989.

[12] United Nations 1987 and Postel 1989.

pressures have made wood increasingly scarce, starting yet another cycle of poverty: fuelwood scarcity leads to burning of dung and crop residue whose plowing under would have maintained the fertility of croplands and protected them from erosion. The consequent decline in organic matter and nutrient content results in lower water retention, greater soil compaction and reduced bacterial activity. Loss of productivity of land and soil erosion, in turn,lead to further impoverishment and set in motion technological and institutional changes which reinforce the other negative trends on agroecology.

Under the impact of commercialization, monoculture replaces traditional mixed cropping patterns that were necessary for soil fertility. More intensive agriculture leads to greater use of animal power. Larger herds lead to overgrazing, increased soil erosion and desertification.

Land tenure patterns change due to agricultural intensification and commercialization. There are: enclosures of commons; loss of free access to gathering of biomass fuels; shifting from traditional tenure patterns in Africa with well-defined, widely-shared, communal rights, to modern land tenure patterns, which, while they strengthen the rights of some, deprive other customary claimants of their rights to the usufruct of land. These tenurial changes lead to greater rural inequality and intensify both absolute and relative poverty.

And so the vicious cycle of environmental degradation and poverty continues and intensifies... Can it be reversed or mitigated? The answers are not obvious, especially for Africa, where appropriate technologies are not in hand. The traditional "agricultural modernization" recipes are the triad: fertilizers, irrigation and mechanization. But these technological fixes often lead to short-term improvements in yields in exchange for long-term fundamental damage to the quality of the soil. The substitution of the more expensive chemical fertilizer for fermented nightsoil, manures and crop residues restores soil nutrients, and increases yields per acre in the short run. But chemical fertilizers do not provide a substitute for the soil-and-moisture-retention services provided by crop residues. Soil fertility is maintained but soil erosion continues.

Inappropriately managed or excessive irrigation leads to waterlogging, salinization and alkalization of soil, and to depletion of groundwater resources, with the loss of land or land degradation the eventual result. Even currently, irrigated areas suffering from salinization are estimated by the United Nation's Environment Program at 100 million acres worldwide and areas affected by waterlogging at 40 million hectares. The UN estimates[13] that agricultural land surface removed from cultivation through salinization is currently about the same as that added by irrigation. Yields from irrigated lands go up, but arable land diminishes. And the incidence of benefits and costs is borne by very different populations.

Mechanization is inappropriate for most sub Saharan farming, which still relies on bush-fallow or grass-fallow cycles. It also generates other deleterious side effects. Mechanization relying on animal power leads to overgrazing while mechanization relying on tractors increases energy-use.

Degradation of soil fertility can be reversed in the short run. But reversibility of soil erosion and salinization have to rely on prevention. Once topsoil has disappeared, soil erosion becomes almost impossible to reverse. Once soil has become sufficiently saline it becomes permanently incapable of cultivation.

But prevention requires an integrated approach to poverty, rural development, and the environment. This approach is hard to design (it is not even clear that the knowledge is there for some ecological environments); more expensive than the now-in-disrepute-because-considered-too-expensive integrated rural development projects; more demanding of very scarce leadership talents and administrative skills; and requiring more foresight and staying power than human societies have evinced so far, at least without coercion.

1.4. Deforestation

Deforestation, in the sense of unsustainable tree clearing, interacts with land degradation in a mutually reinforcing vicious cycle. According to FAO estimates[14], about 1% of tropical forests are destroyed each year; furthermore, the rate of deforestation is accelerating. Almost 80% of tropical forests are in developing countries[15]. Two thirds of

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[13] United Nations, Department of International Economic and Social Affairs, 1990.

[14] World Resources Institute, 1990.

[15] Howard Levinson, 1989.

LDC tropical forests are concentrated in only three countries: Brazil, Indonesia and Zaire.[16]

The causes of deforestation are numerous: the evolution of agricultural systems, development of particular sectors (livestock, logging and hydroelectric projects), industrial fuelwood consumption, increase in accessibility, and human and natural calamities (war, forest fires).

The major single source of deforestation is the shift in subsistence agriculture from systems with long periods of fallow to ones with shorter periods. Under the impact of rapid population growth, the traditional agricultural system of forest-fallow[17], which can support population densities below 4 people per square kilometer and requires period of fallow exceeding 15 years, is almost universally being displaced by a shorter fallow-cycle of eight to ten years, which is capable of supporting population densities of between 4 and 64 people. Ten years is too short for forests to regenerate themselves. The forests are therefore replaced by bush, leading to bush-fallow cycles. Even higher population densities require fallow periods of less then 3 years and lead to a grass-fallow cycle. It is estimated that this process of shortening fallow periods accounts for about half of all forest-land conversions worldwide.

Expansion of cattle ranching, especially in Latin and Central America, is the second major force leading to forest destruction. It accounts for about half of the tropical forests cleared annually[18]. Logging for hardwoods without reforestation and hydroelectric projects are globally less significant, but geographically considerably more concentrated, sources of deforestation[19]. Commercial and industrial fuelwood consumption often entail felling large expanses of forests without proper replacement. (Domestic fuelwood consumption rarely leads to deforestation, as fuelwood is almost universally culled by gathering rather than felling). Finally, the opening up of roads to forests that had been previously inaccessible leads to an

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[16] The Economist, 1989.

[17] The numbers in this paragraph are based on Ruthenberg 1980.

[18] Office of Technology Assessment 1990, Ch 5.

[19] Hardwood exports lead to an annual loss of 5 million hectares of tropical forests out of a total of 1.65 billion. This loss is concentrated in Malaysia, Indonesia, the Philippines, Ivory Coast and Gabon.

inflow of farmers, settlers and loggers, whose activities destroy forests.

The deleterious effects of deforestation are serious. Primary among them are soil erosion, flooding and desertification. The removal of tree cover exposes the soil to erosion and degradation by removing nutrients and organic matter, decreasing moisture retention, reducing soil stability, and increasing water runoff to lower-elevation plots. The damage ranges from a loss of soil fertility to desertification. Water control is diminished, increasing the risks of both flooding and drought, and exposing subsistence farmers to increased risks of famine, malnutrition and poverty. Fuelwood becomes scarcer, making it expensive (in time or money) to cook meals and heat water for disease control. The poor are hardest hit, since they live on the most marginal soils, in the areas that are the most prone to runoffs and flooding, and prefer to rely on gathered wood for cooking.

The loss of tropical forests leads to adverse effects not only locally but also globally. Foremost among deleterious global effects are species extinction and emission of greenhouse gases. The loss of species entails loss of genetic material important to medicine. This loss is no small matter since it is estimated, for example, that about one quarter of prescription drugs in the United States are based on chemicals derived from plants in tropical forests[20]. The loss of species diversity is also important to agriculture, since it provides recimes for engineering plants with particular traits. Finally, deforestation leads to emission of greenhouse gases, by releasing CO2 into the atmosphere both immediately and through subsequent burning or decomposition.

With proper forest management, forests are renewable resources. Temperate-forest deforestation is a reversible process. But many of the adverse immediate effects of unsustainable deforestation discussed above are not reversible.

1.5 Summary of Overview

The above review of environmental problems in developing countries is discouraging. It indicates that all patterns of economic development lead to environmental damage. Furthermore, the beginnings of accelerated development lead to the most rapid increase in

[20] Office of Technology Assesment, 1984.

environmental degradation. Industrialization and urbanization are responsible for air and water pollution. Agricultural intensification is responsible for water pollution, water depletion, soil degradation, soil erosion, desertification, and deforestation. Of the two, one cannot escape the conclusion that, in developing countries, the environmental problems generated by agricultural intensification are the most severe. Some environmental effects are reversible (of course, at a not-insignificant cost) but many, especially many land-use related ones, are not. All environmental effects are amenable to policy-influence at the margin. But environmental policy has to combat the invisible hand and the short term self-interest of those who benefit from resource-mining policies at the expense of the longer-run and, generally, at least some of the poor. It therefore involves swimming upstream.
Are there some development strategies that are environmentally better than others? Are there some that are decidedly worse? This is the question we attempt to answer in the next section.

II. DEVELOPMENT STRATEGIES

Development strategies are distinguished from each other along several, interrelated, instrumental dimensions: sectoral emphasis of economic growth; trade posture; method of financing development; pace; and primary engines of growth. While there are differences along these dimensions among countries pursuing the same development strategy, the differences in how countries cluster along these dimensions are larger among countries engaging in different devlopment strategies.

It is customary to distinguish among country-strategies along major sectoral lines: industrialization, balanced-growth and agricultural development. Within these sectoral strategies, it is customary to distinguish along the lines of trade strategies: outward-orientation and inward orientation. In principle, there are therefore six pairs of strategies. But, in practice, some combinations (e.g. import-substitution agricultural development) are infrequent. Furthermore, most countries pursue mixed strategies, with import-substitution characterizing some sectors while export-orientation characterizes others. Also, especially recently, many countries have been switching frequently among industrialization and trade strategies, in a stop-go fashion.

2.1 Import Substitution

Industrialization strategies have been chosen by virtually all developing countries since the early post World-War two period. The two major industrialization strategies are import substitution and export-led growth.[21] With import substitution, industrialization occurs behind high, and variable, tariff walls and with overvalued exchange rates. The primary growth-impetus in import-substitute countries is the growth of domestic demand, which imposes a major limit on the rate of industrialization and economic growth. Generally speaking, countries engaging in import-substitute strategies have lower than average[22] rates of economic growth, have a more input-intensive, and capital-intensive growth process, and exhibit lower than average rates of total factor productivity growth. Their structure of production is more heavy-industry oriented, though they are not necessarily more industrialized. Countries following the import substitute strategy discriminate more against agriculture through lower agricultural terms of trade and (generally) lower rates of investment in domestic agriculture, and rely more on primary exports to finance the imports necessary for their development. These countries have relatively more subsistence-agriculture and exhibit a more dualistic structure of agricultural growth. They rely more on input-intensive, commercial agriculture for food production and exports. In the non-socialist import-substituting countries, the distribution of income is generally worse than average even though they invest more heavily in education. The average income and productivity gap between urban and rural areas is higher. Despite higher urban unemployment rates, migration to cities is more rapid and they are relatively more urbanized. Their growth is also more balance-of-payments constrained, and, somewhat paradoxically, countries engaging in import-substitution growth have had greater difficulty in adjusting to the major external shocks of the nineteen seventies. As a result of all of these characteristics, one would expect

[21] The description of the characteristics of import substitution development strategies in this paragraph is based on the work of Chenery and coauthors, particularly Chenery et al 1979 and 1975.

[22] The term "average" used in this and subsequent paragraphs is standardized for their level of per capita GNP and population, a la Chenery.

import-substitution strategies to be worse for the environment than export-led growth.

All developing countries and all currently developed countries other than Great Britain have engaged in an early phase of import-substitute industrialization.[23] During this "infant-industry", first import-substitution stage, they generally concentrated on developing the capacity to produce light, consumer-goods manufacturing. (But some developing countries, such as India and China, have started their import-substitute industrialization program by emphasizing producer-goods, and "basic" industries instead). Subsequent to this stage, the import-substituting countries either shift to export-led growth or continue in a second phase of import substitution, in heavy industries. Virtually all Latin American countries chose to shift to the second stage of import-substitute industrialization starting in the late sixties. This stage intensifies all the characteristics enumerated above. One would expect it to be particularly bad for the environment since it emphasizes energy-intensive industries. Also, during the second stage of import substitution, commercial agriculture increasingly relies on large scale irrigation projects, whose management is rarely sound environmentally. The cummulative neglect of the small-farm sector, typical of import substitute countries at this second stage, leads farmers to mine the soil and migrate to city slums. Eventually, the second stage of import-substitution, reached by a large number of Latin American countries in the mid-seventies to early eighties, results in stagnation, since, without major redistribution, even the large countries engaging in this strategy find themselves limited by the growth in domestic markets, by the capital-intensity of growth, and by foreign exchange constraints.

2.2 Export-Led Growth

Export-led growth strategies, started by a few East Asian countries in the mid-nineteen sixties, rely on export growth for their dynamic impetus. The few countries that have shifted successfully to export-led industrialization after the first stage of import substitution have more labor-intensive patterns of industrialization, a higher share of consumer-goods manufacturing, and have achieved higher rates of economic growth, productivity growth, and

[23] Morris and Adelman, 1988.

export-growth[24]. Except for the city states pursuing this strategy, the export-led growth countries have also pursued unimodal (rather than bimodal) patterns of agricultural development. Early redistributive, universal land reforms were supplemented by small-farmer agricultural strategies and there was early emphasis on agricultural investment in extension and in technology dissemination[25].

As with import-substitution, one can also distinguish distinct phases of export-led growth. In the first phase of export-led growth, manufacturing exports consist of labor-intensive consumer goods, especially clothing, textiles, processed food and leather and footwear. In the second stage of export-led growth, there is a shift from labor-intensive to skill-intensive exports. Electronics, engineering industries, small machinery and consumer durables become important export items. At later stages in the export-led growth process, the countries following this strategy also usually combine some import substitution in heavy industries with export-led industrialization in consumer goods and skill-intensive products. But in fostering this second stage of import substitution, the export-led growth countries do not rely primarily on trade incentives, so as not to interfere with their open development strategies. Rather, they tend to use investment incentives to encourage the growth of heavy industries.

2.3. Balanced Growth

The balanced-growth countries both contemporarily and historically[26] have been small, densely populated, countries that have pursued open development strategies. The countries pursuing balanced-growth strategies combine wage-goods industrialization with the fostering of high-productivity, diversified, high value-added specialty agriculture (e.g. Denmark and Switzerland historically). In the agricultural sector, the countries that have pursued this strategy historically have engaged in careful resource-husbandry and have

[24] Chenery, Robinson and Syrquin, 1986.

[25] Ranis, Fei and Kuo, 1979.

[26] The description of the historical profile of the balanced-growth countries is based on Morris and Adelman (1988).

followed technological strategies of agricultural-conservation.[27] Historically, the balanced-growth countries did not protect their agricultural sectors from the influx of cheap grains from overseas.[28] This open trade policy forced their farmers (after some decades of pain) to shift away from grain production into specialized, high-value agricultural activities such as commercial dairying. The nineteenth-century balanced-growth countries achieved high standards of living and shared the benefits from economic growth more widely than did other countries. Historically, this strategy led to even better environmental effects than did export-led growth as it combined environmental conservation technologies in agriculture with non-energy-intensive manufacturing industries.

One can also consider the small, densely populated, East Asian export-led-industrializing countries of Taiwan and South Korea to be balanced-growth countries. In these export-led growth countries, land reforms of the land-to-the-tiller type preceded their major industrialization thrust. They also emphasized agricultural development early in their industrialization processes. South Korea and Taiwan have consistently had a smaller net financial-resource outflow out of agriculture than average for their levels of development. They have maintained better agricultural terms of trade than other industrializing countries (usually through dual price policies). They have also had higher rates of investment in agricultural infrastructure other than large-scale irrigation projects and better extension networks than the import substitute countries. They have also achieved higher levels of agricultural productivity, higher rates of agricultural-productivity growth, and more equitable distributions of income. But by contrast with the historical balanced-growth countries, the agricultural technology of Korea and Taiwan has been based more on input-intensification than on resource conservation. One would nevertheless expect them to have better environmental profiles than the import-substitution countries for reasons described.

[27] Ruttan (1984) describes this strategy as consisting of increasingly complex land and labour-intensive cropping systems, the use of organic manure and labor-inetnsive capital formation.

[28] Morris and Adelman, 1988.

2.4 Staple Export Strategies.

These were the traditional primary-export oriented growth patterns of the colonial economies[29]. Most of the least developed developing countries are continuing to follow this path. Countries following this path concentrate their agricultural systems primarily on producing export crops. Some countries following this strategy export wood logged without proper forest-conservation practices. They use either estate and plantation patterns (as in tea, cotton, or sugar) or medium size commercial farms (as in coffee or cocoa). Production technology is commercial, employing input-intensive methods, and agricultural mechanization. Food agriculture is generally neglected, and technology in agriculture is dualistic. Marketing of exports is usually in the hands of parastatals, that pay below-world-market prices to producers. Staple exports are used to finance industrial development by providing foreign exchange and through low terms of trade. Industrial sectors are usually in the first stage of import-substitution. But commercial policy varies, since low effective exchange rates are needed to support the export of staples. This strategy is bad for soil and forest conservation practices but it is likely to consume less energy per unit of GDP than do industrialization strategies, except where bulky staples require long-distance. hauling.

2.5 Agricultural Development Led Industrialization (ADLI)

This strategy has been suggested by Mellor (1976) and Adelman (1984) to provide a substitute dynamic for economic development in a world in which exports are not expanding as rapidly as they were up to 1973. The Adelman version of the strategy is discussed here. The first step with this strategy is to increase the productivity of food agriculture, focussing on medium and small farmers. The economic linkages of income expansion in the countryside would then provide a stimulus for the expansion of a mass market for domestic wage-goods manufactures. Critical to the success of the strategy are: appropriate agricultural terms of trade strategies, which allow farmers to retain some of the income benefits of productivity expansion; and strengthening of tenurial rights of tenants and semi-subsistence farmers, to avoid possible increases in landlessness due to increases of the value of land due to increased

[29] For a description of these strategies see Baldwin, 1956.

productivity. Simulations with this strategy performed by Adelman (198x) and Yeldan (198x) indicate that, if terms of trade policies are carefully managed and/or open trade policies pursued, the strategy leads to higher rates of growth of GNP, more equal income distributions, and higher shares of light industry than the export-led alternatives.

Developed countries experienced agricultural revolutions lasting several centuries prior to their industrial revolutions[30]. No country attained the developed state before 1914 that had not improved the productivity of its agriculture[31]. Some developing countries, such as Indonesia, are pursuing this strategy with substantial success. The successful socialist reform strategies (e.g.in China, and Hungary) are of the ADLI type.

With respect to the environment, the ADLI strategies reduce energy requirements. But they have the potential for substantial damage to soils, in the absence of specific attention to soil and forest conservation in technologies propagated to increase agricultural productivity. We shall return to this theme in the conclusion.

III. REGRESSION ANALYSIS

To see whether there are any systematic links between development strategies and energy consumption, we now turn to a regression analysis of energy consumption. Our discussion in the previous section leads us to expect that, *ceteris paribus*, export led growth would lead to less energy consumption per unit of GDP than import substitution and that industrialization would be more energy-intensive than emphasis on agriculture.

The data used in the regressions is taken from *Energy Transition in Developing Countries* (World Bank 1983). It includes all non oil-exporting, non-communist, developing countries for which data on all variables could be obtained, and covers the period 1970-1980. The dependent variable in the regression is energy consumption per unit of GDP, in toe per million dollars (E), in 1980. The independent variables are: GNP per capita in 1980, in dollars (GNP); population in 1980, in millions (POP); level of industrial value added per capita in 1980, in dollars (IND); the share of industry in GDP, as of 1980 (INDS);the growth

[30] Angus Maddison, 1982.

[31] Morris and Adelman, 1988.

rate of GDP between 1970 and 1980 (RGNP); and the rate of growth of the share of industry in GDP, between 1970 and 1980 (RIND). Trade cum industrialization strategies were represented by four dummy variables, taken from the World Bank's 1987 *World Development Report*, characterizing each country's trade postures between 1960 and 1973: strong inward orientation (TO1); moderate inward orientation (TO2); moderate outward orientation (TO3); and strong outward orientation (TO4). The full sample consists of 48 countries. The numbers in parentheses are the t-ratios.

The regression for the full sample is :

$$E = \underset{(2.01)}{205.54} + \underset{(1.18)}{.039}\ GNP + \underset{(2.07)}{.576}\ POP + \underset{(2.13)}{6.93}\ INDS - \underset{(1.72)}{14.73}\ RIND - \underset{(.94)}{33.73}\ TO1 + \underset{(2.74)}{128.87}\ TO4$$

R^2=.47

It indicates that, on the average, over the whole sample of developing countries, energy dependence per unit of GDP increases with the level of GDP and with population size; that energy consumption is higher the more industrialized the country is; but that the faster the rate of industrialization the less the energy-intensity increase; that strong import-substitution decreases energy consumption while strong export-led growth increases energy consumption substantially. The negative dependence of energy consumption on the rate of industrialization may reflect the greater energy efficiency of machinery of more recent vintage. The more rapid the rate of industrialization for a given level of industry, the younger the capital stock.

One of our development strategy conjectures is confirmed-- namely that greater reliance on industrialization strategies increases energy consumption. But the presumption that more outward orientation reduces energy consumption is negated by the regressions. This may be because of the time period to which the regressions refer, which included the two oil shocks. Export-oriented countries weathered this period better than did import-substituting countries. Export-oriented countries had less binding balance of payments constraints than import-substituting countries and did not have to ration oil imports.

We can analyze the semi-industrial countries separately.

$$E = 335.74 + .0015\ IND - 28.8\ RIND + 31.36\ RGNP - 70.355\ TO1 + 578.79\ TO4$$
$$(4.51) \quad (2.97) \quad (2.33) \quad (1.77) \quad (1.01) \quad (4.78)$$

R^2 =.77

This regression is very similar to that for all developing countries. GNP and industrial output (IND) are very collinear, so one of them had to be excluded from the regression. We excluded GNP from the regression because it had an insignificant t-ratio.

For African countries, we have:

$$E = 140.98 + .512\ GNP - 40.08\ RGNP - 10.03\ RIND + 36.2\ TO1 + 190.88\ TO2$$
$$(.68) \quad (2.68) \quad (1.49) \quad (.93) \quad (.49) \quad (1.55)$$

R^2 = .61

For African countries, the extent of industrialization was not significantly related to energy use. The increase of energy use with GNP is very high for countries at the African level of development. Both faster industrialization and faster GNP growth reduce energy consumption. And import substitution increases energy use. One should note, however, that no countries at this level of development were pursuing export-led growth strategies. So, for countries at this level, moderate import-substitution strategies are the moral equivalent of export-oriented strategies at higher levels of development.

Our regressions suggest that there are systematic links between development strategies and energy consumption. Industrialization increases energy consumption, as expected. But the only uniformly significant relationship of energy consumption per unit of GDP with trade orientation is at the extremes. And the increase in energy consumption with strong export-led industrialization indicated by our regression results is counterintuitive.

IV. ECONOMYWIDE SIMULATION EXPERIMENTS

The counterintuitive relationship between greater energy use per unit of GNP per capita and stronger outward orientation found in our regressions may arise because of the specific time period used for the analysis. Or it may arise because, despite the use of some variables to standardize the results, there are some excluded variables that are correlated with trade orientation that turn an inherently negative effect into a positive one. By contrast, simulations have the advantage of enabling precise specification of the counterfactual used for the analysis; precise statement of the nature of the experiment performed in the simulation; and precise statement of what is held constant in the ceteris paribus. They thus enable one to disentangle the effects of strategy choices and their concomitant from the effects of other country-specific variables.

The country whose data is used for the simulation experiments with alternative development strategies in this section is Mexico as of 1980.[32] The methodology is that of Social Accounting Matrices (SAMs).

Mexico is a country that has been pursuing an import-substitution industrialization strategy since the 1950. Its agricultural strategy has been bimodal. Research, input subsidies and infrastructural development were directed towards a commercial farming sector using capital and input-intensive technologies to produce food for middle-income urban Mexicans and (up to 1970) for exports. This commercial farming sector has coexisted with a low-productivity, low-input, stagnant, small-farm, ejido sector that concentrated on the production of low-income staples of corn and beans. In 1976, new oil reserves were discovered, petroleum exports doubled, and a very cheap domestic-oil-price policy was pursued. A brief period of debt-led import substitution followed during which Mexico borrowed heavily against its oil reserves and built up an impressive level of foreign debt. In 1981, the plummeting of oil prices triggered an economic crisis that has continued to the present.

The structure of the Mexican SAM reproduced in Table 1 reflects the results of this economic strategy. Eight percent of total domestic production is agricultural, 45% industrial, and 47 commerce plus services; 46% of industry is light ; only 30% of value added in agriculture goes to campesinos and food staples account for only 19% of agricultural output while livestock and high-value agriculture account for 45% and 36% respectively.

The pattern of energy consumption is typical of newly industrializing countries. The

[32] The description of Mexico and its Social Accounting Matrix are taken from Adelman and Taylor 1990.

Table 1: Social Accounting Matrix (SAM) 1980 Mexico.

	1.Basic Grains	2.Livestock	3.Other Ag.	4.Petroleum	5.Fertilizer	6.Ag. Processing	7.Light Ind.	8.Heavy Ind.
1.Basic Grains	4695	7715	0	0	10	26519	0	0
2.Livestock	0	502	72	0	0	146908	1450	0
3.Oth.Agriculture	0	28677	3409	0	32	40624	25708	0
4.Petroleum	406	786	3246	39279	90	2677	1918	38416
5.Fertilizer	812	0	6489	0	147	0	100	296
6.Agr. Processing	0	28946	386	1	8	81443	11055	1460
7.Light Industry	394	3332	5657	0	0	3718	136356	57571
8.Heavy Industry	1572	7772	10056	5560	4328	35173	124749	395237
9.Services	560	4527	4479	8546	418	28758	20373	116446
10.Commerce	888	5811	7094	4058	338	46533	40998	114374
11.Campesinos	59473	31765	44167	0	0	0	0	0
12.Agricultural workers	18109	31657	44017	0	0	0	0	0
13.Agricultural Business	6609	56672	78799	0	0	0	0	0
14.Urban Workers	0	0	0	17529	1656	67092	188485	316025
15.Urban Capitalists	0	0	0	0	0	144232	183540	307735
16.Merchant Capitalists	0	0	0	0	0	0	0	0
17.Urban Marginals	0	0	0	0	0	17036	23536	39462
18.Government	-1260	541	-2500	81576	856	14769	22735	38119
19.Savings	0	0	0	0	0	0	0	0
20.Imports	398	614	3180	6312	926	51253	39567	140285
21.Total	92656	209317	208551	162861	8809	706735	820570	1565426

Source: Adelman and Taylor (1990)

Table 1: Social Accounting Matrix (SAM) 1980 Mexico.

	9.Services	10.Commerce	11.Campesinos	12.Ag. Workers	13.Ag. Business	14.U. Workers
1.Basic Grains	0	0	13305	6122	927	7264
2.Livestock	840	0	3531	2131	1905	16379
3.Oth.Agriculture	896	0	6771	4089	3654	31412
4.Petroleum	23776	2087	290	186	751	2685
5.Fertilizer	84	0	0	0	0	0
6.Agr. Processing	3643	0	35921	26915	20876	202635
7.Light Industry	65639	26902	22708	17006	16483	185409
8.Heavy Industry	58209	26696	5678	1032	3521	26730
9.Services	218412	126912	28326	31014	39956	384806
10.Commerce	37956	12014	33160	26358	26959	262663
11.Campesinos	0	0	0	0	0	9180
12.Agricultural workers	0	0	0	0	0	8395
13.Agricultural Business	0	0	0	0	0	0
14.Urban Workers	567931	176513	0	0	0	0
15.Urban Capitalists	732483	0	0	0	0	0
16.Merchant Capitalists	0	595721	0	0	0	0
17.Urban Marginals	90552	68705	0	0	0	0
18.Government	13888	256378	0	0	10015	103782
19.Savings	0	0	7800	0	13650	197044
20.Imports	32033	2212	3702	2512	3383	38138
21.Total	1846342	1294140	161192	117365	142080	1476522

Table 1: Social Accounting Matrix (SAM) 1980 Mexico.

	15.U. Capitalists	16.Merchant	17.U. Marginals	18.Government	19.Investment	20.Exports	21.Total
1.Basic Grains	4654	2266	7840	0	10100	1239	92656
2.Livestock	10215	5055	4693	88	12957	2591	209317
3.Oth.Agriculture	19591	9695	9000	651	14817	9525	208551
4.Petroleum	2507	985	244	1620	2301	38611	162861
5.Fertilizer	0	0	0	156	45	680	8809
6.Agr. Processing	123225	63034	54892	657	25843	25795	706735
7.Light Industry	84906	28112	31709	5527	74897	54244	820570
8.Heavy Industry	45719	28150	1642	12957	734482	36163	1565426
9.Services	293854	125957	51049	281644	22862	57443	1846342
10.Commerce	180851	81403	48141	4930	152741	206870	1294140
11.Campesinos	0	0	3713	0	0	12894	161192
12.Agricultural workers	0	0	3396	0	0	11791	117365
13.Agricultural Business	0	0	0	0	0	0	142080
14.Urban Workers	0	0	0	168862	0	-27571	1476522
15.Urban Capitalists	0	0	0	23514	0	-97178	1294326
16.Merchant Capitalists	0	0	0	10815	0	-30852	575684
17.Urban Marginals	0	0	0	10109	0	0	249400
18.Government	96418	41986	0	623	0	0	677926
19.Savings	406722	177934	27878	150732	0	225821	1207581
20.Imports	25664	11107	5203	5041	156536	0	528066
21.Total	1294326	575684	249400	677926	1207581	528066	

share of domestically-consumed petroleum-energy purchased directly by agriculture is only 3.7% ; industry, excluding the petroleum sector, accounts for 35% of total domestic petroleum sales; petroleum accounts for 32%; services, including electricity and transport, for 19%; consumer demand for 7.5%, investment for 1.8% and commerce for the rest. Intermediate demand accounts for 69% of total petroleum sales and exports for 23.7%. Within the industrial sector, light industry accounts for only about 5.5% of direct petroleum purchases and the petroleum sector for 48%. The input output ratio for energy-intensive industries is 9.5 times that for light industry.

The SAM multipliers, which include indirect demand through consumer demand due to the distribution of value added as well as backward and forward production linkages, tell a different story however. The indirect linkages generate considerably more uniformity in response to changes in activity levels among sectoral commercial energy demands than comparison of input-output ratios would suggest. Excluding the own-multiplier of petroleum with respect to petroleum, the sectoral-activity multipliers range between .07 (for the energy-intensive heavy industries) to .04 (for light industries). And the final-demand consumption multipliers are fully comparable in magnitude to the production multipliers and range from .03 to .05. The much smaller spread among sectoral-activity multipliers and between them and the institutional-income multipliers explains why cross section regressions have difficulty in capturing development-strategy effects.

The first simulation experiment is designed to answer the following counterfactual question : what would domestic demand for petroleum have been had Mexico attained the same level of income but pursued an export-led industrialization strategy instead ? The export-led industrialization strategy is simulated by using the Chenery et al regressions[33] to transform the structure of output in Mexico to that of a typical export-oriented, large, semi-industrial country at the same level of per capita income. This entails: First, reducing the output of heavy industry by 26%, to the Chenery et al 1975 average ratio of heavy industry in an average export-oriented large country at Mexico's level of per-capita income. Second, increasing total exports by 32%, the Chenery difference between the import-

[33] Chenery 1979.

substitution export-level and the export-led-growth level for large countries at Mexico's level of per capita GNP, while leaving petroleum exports unchanged. And, third, increasing the output of light industry enough so as to keep total gross output unchanged. (Gross output was kept unchanged so as not to muddy up the counterfactual). The implied increase in the output of light industry was 33%.

This counterfactual simulation indicates that the consequences for energy consumption of the structural changes in the economy implied by a shift from a closed to an open development strategy are a 6.7% decline in petroleum consumption. While this decline is large enough to be significant, it is also small enough to be swamped by other effects in cross country regressions. For example, since the average petroleum multiplier across all sectors[34] is .062, a 1.08% proportionate increase in total gross production (or a 1.84 % increase in GDP) would be sufficient to negate the calculated 6.7% reduction in petroleum consumption due to a change from import-substitution to export-led growth.

The second simulation experiment asks a different counterfactual development-strategy question: what would domestic demand for petroleum have been had Mexico pursued an agricultural-development-led-industrialization strategy ? There are no country typologies to base the simulation on, so a counterfactual had to be constructed on an ad hoc basis. We chose a 25% increase in the output of each of the three agricultural sectors (basic grains, livestock, and other agriculture) counterbalanced by a decrease in heavy industry sufficient to keep total output constant (10%). The result is a small, 1.9%, decrease in energy consumption. The energy savings of the agricultural strategy are so small in Mexico because, on the average, Mexico's agriculture is energy-intensive. The direct plus indirect petroleum-multiplier of an average agricultural sector is 7% higher than that of the fertilizer industry, and 93% of that in heavy industry (excluding petroleum). So, energy savings is not a major argument in favor of agricultural strategies in Mexico.

The results of these simulations confirm our a priori expectations concerning the existence and direction of potential links between development strategies and energy intensity of GNP. However, the simulations also make it clear why cross-country regressions

[34] This multiplier is weighted by gross output.

do not indicate large development-strategy effects on energy consumption: the **ceteris paribus** effects are small, and intercountry variations in, for example, energy-pricing policies, energy-efficiency of the capital stock, geography or climate can be more than enough to counterbalance them.

V. A MODEL OF AGRICULTURAL INTENSIFICATION

Our discussion of economywide development strategies suggested that the strategy of agricultural-development-led-industrialization is one that has considerable merit from both income distribution and economic growth perspectives. The potential merit of the ADLI strategies is greatest at two junctures in the development process. The first juncture occurs in the initial stages of import-substitute industrialization typical of the lowest levels of economic development. The second juncture occurs as a late accompaniment to industrialization in semi-industrial countries, when food imports compete with industrial-input imports for scarce foreign exchange and when further industrialization is limited by the narrowness of domestic markets. Our previous simulation experiments dealt with consequences for energy consumption of the second type of agricultural development. They concerned an input-and-energy-intensive dualistic agricultural system, characterized by commercial agricultural production of food for the urban middle-class, by maize and bean production in non-commercial small plots, and by import of grain and feed.

We now turn to a simulation of agricultural intensification in an agricultural system at a very early stage of development. From an environmental point of view, this is a more critical question for developing countries, especially those that have not yet becomes semi-industrial countries. The simulation underscores the dangers for the village economy, especially the poor, arising from the adoption of environmentally unsound agricultural systems.

The simulation pesented in this section is based on data collected in an African village in Senegal in 1987 by Elise Golan[35]. It is intended to highlight the economic and social

[35] The description of the village economy and the SAM are based on Elise Hardy Golan's PhD dissertation, University of California, Berkeley, 1988 and on Golan 1990.

effects of population-growth-induced intensification of cropping patterns leading to degradation of land-fertility. Again, the analysis is based on a SAM model. But this time, the SAM refers to a village economy[36] rather than to a national economy.

The village whose economy is represented in the SAM, Keur Marie, is located in the peanut basin of Eastern Senegal. Its main crops are peanuts and millet. (see the SAM of table 2). Peanuts are the commercial, export crop. Millet is the non-traded, subsistence crop. The agricultural system is in a state of transition from grass-fallow to annual cultivation. Animal traction and hand hoes were the only implements used in farming. There was no manuring and purchased inputs consisted primarily of peanut seeds and pesticides.

The village is organized into compounds, consisting of one or more nuclear families. The compounds govern the economic life of their members. They allocate rights to fields among members, who act as field managers, and pool consumption. There were 22 compounds in the village with an average of 11 members per compound.

The main economic interactions among compounds took place on the input side: there was borrowing and lending of fields among compounds, and compounds used not only household and compound labor but also labor from other compounds ("village labor") and labor from other villages ("imported labor").

There was significant economic differentiation in the village. There were six large compounds, owning an average of 12 hectares of land per compound; nine medium compounds, with average holdings of 8.8 hectares; and seven small compounds, of whom two were landless, owning an average of 2.2 hectares per compound. The large compound owners were people of power and prestige. One large compound was owned by the county chief, one by the village chief, two by religious leaders, and two by commercial farmers. The income of large compounds was, on the average, six times that of small compounds. Eighteen percent of the cultivated land was borrowed from other compounds. The average cultivated land per compound member was .85 hectares and the average compound owned 7.7 hectares.

Tenurial rights were complex. A Law of National Domain had been passed in 1964,

[36] The use of SAMs to model village economies was first introduced in Adelman, Taylor and Vogel, 1989.

Table 2: Social Acconting Matrix (SAM) Keur Marie, Senegal.

	1.Peanuts	2.Millet	3.Other Crops	4.Animals	5.Service	6.Commerce	7.Manager Lab
1.Peanuts	223176.00	0.00	0.00	0.00	0.00	0.00	0.00
2.Millet	0.00	26669.00	0.00	0.00	0.00	0.00	0.00
3.Other Crops	0.00	0.00	3165.00	0.00	0.00	40000.00	0.00
4.Animals	218500.00	218000.00	22500.00	0.00	0.00	0.00	0.00
5.Service	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6.Commerce	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7.Manager Labor	105920.00	269875.00	28550.00	0.00	0.00	0.00	0.00
8.Household Labor	265142.50	455125.00	22937.50	0.00	0.00	0.00	0.00
9.Compound Labor	81875.00	79500.00	20500.00	0.00	0.00	0.00	0.00
10.Village Labor	31000.00	100875.00	3000.00	12000.00	0.00	0.00	0.00
11. Imported Labor	4875.00	11750.00	250.00	0.00	0.00	0.00	0.00
12.Non-Ag Labor	0.00	0.00	0.00	396750.00	124500.00	296750.00	0.00
13. Secure Fields	808612.50	1423700.00	31512.50	0.00	0.00	0.00	0.00
14.Moderately Sec	119875.00	32650.00	72300.00	0.00	0.00	0.00	0.00
15.Insecure Fields	346775.00	11500.00	63550.00	0.00	0.00	0.00	0.00
16.Borrowed Fields	292875.00	222300.00	-9150.00	0.00	0.00	0.00	0.00
17.Grazing Rights	0.00	0.00	0.00	50250.00	0.00	0.00	0.00
18.Large Compounds	19817.00	0.00	125.00	0.00	0.00	0.00	109000.00
19.Medium Compounds	19817.00	0.00	0.00	0.00	0.00	0.00	169232.50
20.Small Compounds	19817.00	0.00	0.00	0.00	0.00	0.00	126112.50
21.Capital/Savings	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23. ROW	383323.00	2506.00	5760.00	0.00	500.00	1922500.00	0.00
25. Totals	2941400.00	2854450.00	265000.00	459000.00	125000.00	2259250.00	404345.00

Source: Elise H. Golan (1990).

Table 2: Social Acconting Matrix (SAM) Keur Marie, Senegal.

	8.Household Lab	9.Compound Lab	10.Village Lab	11.Imported Lab	12.Non-Ag Lab	13.Sec Fields
1.Peanuts	0.00	0.00	0.00	0.00	0.00	0.00
2.Millet	0.00	0.00	0.00	0.00	0.00	0.00
3.Other Crops	0.00	0.00	0.00	0.00	0.00	0.00
4.Animals	0.00	0.00	0.00	0.00	0.00	0.00
5.Service	0.00	0.00	0.00	0.00	0.00	0.00
6.Commerce	0.00	0.00	0.00	0.00	0.00	0.00
7.Manager Labor	0.00	0.00	0.00	0.00	0.00	0.00
8.Household Labor	0.00	0.00	0.00	0.00	0.00	0.00
9.Compound Labor	0.00	0.00	0.00	0.00	0.00	0.00
10.Village Labor	0.00	0.00	0.00	0.00	0.00	0.00
11. Imported Labor	0.00	0.00	0.00	0.00	0.00	0.00
12.Non-Ag Labor	0.00	0.00	0.00	0.00	0.00	0.00
13. Secure Fields	0.00	0.00	0.00	0.00	0.00	0.00
14.Moderately Sec	0.00	0.00	0.00	0.00	0.00	0.00
15.Insecure Fields	0.00	0.00	0.00	0.00	0.00	0.00
16.Borrowed Fields	0.00	0.00	0.00	0.00	0.00	0.00
17.Grazing Rights	0.00	0.00	0.00	0.00	0.00	0.00
18.Large Compounds	338875.00	54750.00	46500.00	0.00	186500.00	999575.00
19.Medium Compounds	224392.50	125625.00	56375.00	0.00	447750.00	1051500.00
20.Small Compounds	179937.50	1500.00	44000.00	0.00	183750.00	212750.00
21.Capital/Savings	0.00	0.00	0.00	0.00	0.00	0.00
23. ROW	0.00	0.00	0.00	16875.00	0.00	0.00
25. Totals	743205.00	181875.00	146875.00	16875.00	818000.00	2263825.00

Source: Elise H. Golan (1990).

Table 2: Social Acconting Matrix (SAM) Keur Marie, Senegal.

	14.Moderately Sec	15.Insec Fields	16.Borrowed Fields	17.Grazing Rights	18.Large Comp
1.Peanuts	0.00	0.00	0.00	0.00	109313.00
2.Millet	0.00	0.00	0.00	0.00	1079073.00
3.Other Crops	0.00	0.00	0.00	0.00	79920.00
4.Animals	0.00	0.00	0.00	0.00	0.00
5.Service	0.00	0.00	0.00	0.00	68750.00
6.Commerce	0.00	0.00	0.00	0.00	159088.00
7.Manager Labor	0.00	0.00	0.00	0.00	0.00
8.Household Labor	0.00	0.00	0.00	0.00	0.00
9.Compound Labor	0.00	0.00	0.00	0.00	0.00
10.Village Labor	0.00	0.00	0.00	0.00	0.00
11. Imported Labor	0.00	0.00	0.00	0.00	0.00
12.Non-Ag Labor	0.00	0.00	0.00	0.00	0.00
13. Secure Fields	0.00	0.00	0.00	0.00	0.00
14.Moderately Sec	0.00	0.00	0.00	0.00	0.00
15.Insecure Fields	0.00	0.00	0.00	0.00	0.00
16.Borrowed Fields	0.00	0.00	0.00	0.00	0.00
17.Grazing Rights	0.00	0.00	0.00	0.00	0.00
18.Large Compounds	176225.00	114175.00	248850.00	25125.00	0.00
19.Medium Compounds	48600.00	307650.00	91500.00	17587.00	0.00
20.Small Compounds	0.00	0.00	165675.00	7538.00	0.00
21.Capital/Savings	0.00	0.00	0.00	0.00	194015.00
23. ROW	0.00	0.00	0.00	0.00	2990058.00
25. Totals	224825.00	421825.00	506025.00	50250.00	4680217.00

Source: Elise H. Golan (1990).

Table 2: Social Acconting Matrix (SAM) Keur Marie, Senegal.

	19.Medium Comp	20.Small Comp	21.Investment	22. ROW	25. Totals
1.Peanuts	78811.00	3480.00	113407.00	2413213.00	2941400.00
2.Millet	1093983.00	654725.00	0.00	0.00	2854450.00
3.Other Crops	29680.00	25835.00	0.00	86400.00	265000.00
4.Animals	0.00	0.00	0.00	0.00	459000.00
5.Service	42500.00	13750.00	0.00	0.00	125000.00
6.Commerce	98345.00	31817.00	0.00	1970000.00	2259250.00
7.Manager Labor	0.00	0.00	0.00	0.00	404345.00
8.Household Labor	0.00	0.00	0.00	0.00	743205.00
9.Compound Labor	0.00	0.00	0.00	0.00	181875.00
10.Village Labor	0.00	0.00	0.00	0.00	146875.00
11. Imported Labor	0.00	0.00	0.00	0.00	16875.00
12.Non-Ag Labor	0.00	0.00	0.00	0.00	818000.00
13. Secure Fields	0.00	0.00	0.00	0.00	2263825.00
14.Moderately Sec	0.00	0.00	0.00	0.00	224825.00
15.Insecure Fields	0.00	0.00	0.00	0.00	421825.00
16.Borrowed Fields	0.00	0.00	0.00	0.00	506025.00
17.Grazing Rights	0.00	0.00	0.00	0.00	50250.00
18.Large Compounds	0.00	0.00	0.00	2360700.00	4680217.00
19.Medium Compounds	0.00	0.00	0.00	303820.00	2863849.00
20.Small Compounds	0.00	0.00	0.00	5000.00	946080.00
21.Capital/Savings	113416.00	13476.00	0.00	0.00	320907.00
23. ROW	1407114.00	202997.00	207500.00	0.00	7139133.00
25. Totals	2863849.00	946080.00	320907.00	7139133.00	0.00

Source: Elise H. Golan (1990).

which granted rights in previously unregistered land to the state. Only 11 parcels out of 226 had been registered prior to 1964. Ownership rights in a parcel were acquired through land having been cleared by someone in the compound head's lineage. Two thirds of the parcels had been obtained by inheritance; 11% had been granted rights by the village elders.

Security of tenure varied both among compounds and among members of a single compound. Tenure rights to 72% of the acreage farmed and 55% of the fields were secure, in the sense that field managers felt that no one could take the fields away from them, that their children would manage these fields, and that they had the right to determine what crops were planted, the amount of seed used and the amount of pesticide applied. Tenure rights to 5% of the land and 11% of the fields were only moderately secure in that while field managers felt no one could take their land away, they were not sure they would cultivate the land next year and they did not have the exclusive right to determine land use. Insecure tenancy rights characterized 33% of the fields and 5% of the acreage.

As of the time of the survey on which the SAM is based, the ability of farmers in Keur Marie to support themselves had become increasingly precarious. Due to the combination of drought with increased animal and population pressures, the quality of the land, marginal to begin with, has been deteriorating rapidly. Satellite pictures indicate that since 1977 vegetation has receded by 200 kilometers. Droughts have recently been frequent and during the last two decades the level of rainfall has fallen to half of what was previously considered normal. These reductions in rainfall may themselves be the result of environmental changes, primarily deforestation[37]. Each succeeding drought has generated further environmental degradation: water tables have dropped, streams have dried up and salinization has occurred.

There was evidence of soil mining in the village: 17% of parcels had not been rotated in two or more years; only 24% of parcels (and 22% of land surface) were left fallow and only 6% were left fallow "to give the land a rest". Land improvement investments were very low, and consisted mostly of trees. In 54% of parcels no improvements had been made during the last six months; in 48% of parcels, one or more trees or scrubby bushes had been either

[37] Brown and Woolf, 1985 pg 28 argue that the rainfall reduction characteristic of sub Saharan Africa is due to deforestation.

planted or left standing. No manure was used.

Our simulations of the potential results of land degradation induced by land intensification are summarized in table 3. These are intended to be illustrative. They are derived by computing the multiplier matrix associated with the SAM of table 2 and applying it to the vector of changes in total row-sums assumed for the particular experiment. Note that since the underlying model is linear, the results of any particular simulation can be easily scaled up or down by the reader to reflect assumptions he deems more appropriate. All comparisons in table 3 are to the pre-change base.

Our general perspective in the simulations is to imagine what is likely to happen in the village five years down the road. We start the cycle by assuming that during the next five years a 15% increase in the population of the village would occur. This rate of population growth is about average for sub-Saharan Africa. In the base experiment we further assume that this increase in population has led to a shortening of the average length of the fallow period and that this shortening has, in turn, led to a decrease in yields[38]. Specifically, in the simulation presented in the second row of table 3, we assume that the intensification in land-use has led to a 15% drop in crop yields across the board. (Estimates of the yield effects of land degradation in Sub Saharan Africa range from an average of 25 to 30% decreases; regressions quoted in Pingali, Bigot and Binswanger 1987, based on experimental studies with land intensification carried out worldwide, suggest an elasticity of yields per hectare with respect to intensification of -.38. Our assumed values thus imply a 40% intensification in cropping).

Our calculations, based on the SAM multiplier model, indicate that the assumed decline in yields results in a 9.69% decrease in village income compared to the base, with large compounds suffering the least (-7.19%) and small compounds the most (-13.7%). Compound and village incomes decline less than the value of output, because remittance income from migrants is already significant in the village (see the cell entries in the "rest of the world" column and the "compound" rows of the SAM of table 2). The distribution of

[38] The assumed population increase is the equivalent of five years' population growth, at the African rates of about 3%.

remittances among compounds is responsible for the regressive impact of soil degradation on compound incomes. There was one school-teacher migrant remitting large sums to a large compound. But, even without him, the distribution of migration income in Keur Marie was regressive. On a per capita basis, the simulation suggests that the combined impact of population growth and induced land degradation on incomes can be expected to be dramatic since the compound income must now be shared among 15% more members. The calculated declines in per capita income range from 22% in large compounds to almost 30% in small compounds. The small compounds were already at the margin of subsistence before the drop in yields.

The subsequent rows of table 3 are intended to illustrate the effects of potential village efforts to reduce the impact of this income catastrophe. The simulations are cummulative, and include both technological and institutional adaptations. We start with changes in technology. The first simulation, presented in the third row of table 3, summarizes the effects of a technological response: the introduction of manuring, better seed and chemical pesticides, reflected in the experiment by a thirty percent increase in purchased inputs other than peanut seeds; and increased use of animal traction reflected in a 20% increase in payments for animal services[39] and in payments for grazing rights . To perform this experiment with technological change, the SAM of table 2 is recalibrated to reflect the assumed changes in technology and a new multiplier matrix is calculated. We further assume that the technical changes introduced cut in half the declines in yields assumed in the previous experiment[40] uniformly across all crops. This assumption appears reasonable, but there is a fair amount of uncertainty in the specific numerical magnitudes assumed.

Our calculations indicate that the assumed halving of declines in yields implies that

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[39] Data on net revenue per hectare with and without animal traction in six sub-Saharan African countries quoted in Pingali et al 1987 pg 111 indicates an average increase of 14% in net revenue per hectare. But there are two instances of 10% decrease in the data.

[40] The average rate of growth of agricultural yields in Senegal was 1.28% annually between 1950 and 1982. In our simulation, we deduct five years' growth at 1.3% (or about 7.5%) from the assumed 15% decrease in yields. Our simulation thus assumes that, in the absence of land degradation, the assumed technology improvements would have increased yields in the village at the average rates of yield increase of post-independence Senegal up to 1982. This may or may not be optimistic.

Table 3: Experiments with Land Degradation, Keur Marie, Senegal.

	Income per Compound				Income per Compound, per Capita			
	Large	Medium	Small	Total Income	Large	Medium	Small	Per Capita
Base Income[1]	2342	961	390	25492	213	87	35	105
Change in %								
1) Output Decline[2]	-7.19	-12.47	-13.75	-9.69	-22.19	-17.47	-28.75	-24.69
2) + Technology Change[3]	-3.5	-6.11	-6.9	-4.75	-18.50	-21.33	-21.90	-19.70
+Land Tenure Change								
3) No Borrowed Fields	+.28	5.66	-11.03	+.82	-14.72	-9.34	-26.03	-14.18
4) No Insecure Fields[4]	+4.10	+12.12	-10.66	+5.15	-10.90	-2.88	-25.66	-9.85
+ Labor Market Change								
5) + No Imported Labor[5]	+4.31	+12.52	-10.00	+5.48	-10.69	-2.48	-25.00	-9.52
6) + Reduced Use of Village Labor[6]	+4.12	+12.01	-11.16	+9.94	-10.88	-2.99	-25.16	-5.06
7) + Increase Outmigration[7]	+16.48	+18.82	-6.44	+15.50	+4.78	+7.12	-18.14	+3.80

1. In 1987 dollars, converted from CFA at a rate of 333 CFA per dollar.

2. Assume 15% increase in population and 15% decline in crop yields.

3. Computed by recalibrating the SAM to reflect the use of: 30% more chemical inputs in peanut production; introduce the use of 70% as much chemical inputs in millet as in peanut production; increase the use of chemical inputs in other crops correspondingly; increase the use of draft animals in all crops by 20%; and reduce the loss in yields by one half.

4. Computed by recalibrating the previous SAM. The insecure fields were eliminated and their value added reallocated to the moderately secure and secure fields. These fields then distributed the income increase to compounds in the same proportions as in the base SAM. The increases in income of compounds were then allocated to increases in consumption and investment as in the base SAM.

5. Computed by recalibrating the SAM. The institution of "imported labor" was eliminated from the SAM. Its income was reallocated to "village labor" and the increase in income of village labor was then redistributed among compounds in the proportions of the base SAM. The increases in income of compounds were then allocated to increases in consumption and investment as in the base SAM.

6. Computed by changing the final demand vector in the previous SAM. The use of village labor was decreased by 20% and household and compound labor were increased to compensate.

7. Computed by changing the final demand vector in the previous SAM. It was assumed that the redundant village labor migrates to the city and migrant remittances are increased by 20%. The remittances are distributed to compounds in the same proportion as in the base SAM.

the declines in compound incomes are also cut in half; but the declines in per capita income are, on the average, only 20% less than they were in the base since the income reductions must still be shared among 15% more compound members.

We now turn to simulations summarizing the likely impact of institutional responses to land degradation in factor markets. With respect to land tenure, the effect of land degradation is that more land needs to be farmed by each compound to maintain incomes. With land becoming scarcer, one can anticipate pressures to reduce or abolish the lending of land among compounds and pressures to increase security of tenure. We simulate the effects of these changes on compound incomes in rows four and five of table 3. In row four, we eliminate the institution of "borrowed land" from the SAM of table 2 and assume that the land is now farmed by the compounds originally owning the land. This means that, for each crop, the output from borrowed fields is reallocated among the other fields; that the income from borrowed fields is reallocated to the original compounds together with the increased income from other land categories; and that the compounds change their consumption and savings patterns accordingly. The new SAM matrix is then used to calculate a new inverse, which, together with the changes in row-totals implied by the new SAM, is used to calculate the consequent changes in compound incomes indicated in the fourth row of table 3.

Abolishing borrowed fields shifts the incidence of land degradation among compounds dramatically. The large compounds succeed in recouping their income losses (they gain 3.78% from the abolition of borrowed fields, winding up gaining .28% rather than losing 3.5% compared to the base). The medium compounds actually gain 5.6% in income over the base; they are the large gainers from the abolition of the practice of lending fields since their total gain due to abolishing this practice is 11.77%. And the small compounds are the big losers; their loss from abolishing borrowing of fields is 4.13% and their cummulative income loss relative to the base becomes 11%. Thus, this institutional change injures the land-and-income poor small compounds significantly.

By contrast, the abolition of insecure fields (row 5 of table 3) appears to be Pareto optimal, on the average[41]. But the distribution of gains is less favorable to small compounds than it is to larger compounds. Again, the calculations were performed by removing the institution of insecure fields from the previous SAM and recalibrating it in a manner analogous to the recalibration performed to remove the institution of borrowed fields. The abolition of insecure tenure increases the incomes of large compounds by 3.8%, of medium compounds by 6.46%, and of small compounds by only .38%.

The distribution of incidence of costs of land degradation is widened by the changes in land tenure. Before the changes in land tenure, the range of incidence of per capita per compound income declines is from -18.5% for large compounds to -21.9% for small ones; after the abolition of both borrowed and insecure fields, the range of incidence is from a decline of 2.88% for per capita incomes of medium compounds to a decline of 25.66% for the per capita incomes of small ones.

The next set of institutional changes modelled in table 3 takes place in the labor market. It is assumed that greater poverty leads compound members to substitute own labor for purchased labor. The first to suffer are laborers from other villages. In the experiment summarized in the sixth row of table 3, imported labor is eliminated and village labor is substituted for it. The SAM is again modified to reflect this change. Since non-village labor accounts for only 1% of total labor inputs, the impact is small. But the elimination of labor hired from outside the village reduces the income losses of all compounds within the village, especially the small ones.

The next labor-market change is to substitute increased use of compound labor for labor hired from outside the compound. In this experiment the use of "village labor" is decreased by 30%, and the use of household and compound labor is increased to compensate, in proportion to the use of each type of labor in the previous SAM. This move reduces the incomes of all compounds, by from .19% for large compounds to 1.16% for small ones. It is not a worthwhile move in itself, but is a necessary prelude for the next experiment--

[41] The concept of Pareto optimality used in this sentence is a "class" concept rather than as an individual-welfare concept. While all classes of compounds gain from strengthening tenure rights, there may be individual compounds that loose. There is also strong reason to expect that field managers with insecure tenure rights within compounds (e.g. women with insecure tenancies) loose from strengthening tenure rights.

outmigration.

In the migration experiment, it is assumed that the village labor made redundant in the previous experiment emigrates from the village. Its outmigration has two effects over and above the previous experiment: it decreases the number of mouths to feed (by 3.3% of the population, which is the equivalent of 30% of village laborers that are assumed to migrate) and increases remittance income by 30%. The increased remittances are distributed to compounds in the same proportion as the original remittances. With these assumptions, the effects of migration on compound incomes are very positive. Under the assumed distribution of migrant remittances, large compounds benefit most from migration (+12.36%); medium compounds benefit by 6.81%; and small compounds by 4.72%. Outmigration raises village income by 5.56%, and average per capita income by 8.86%.

Our simulations of the effects of land degradation on the economy of the village indicate that, for the village as a whole, the cummulative effects of the assumed technological, institutional and socio-demographic changes can turn a decline of almost 25% in village per capita income to an increase of 3.8%. However, at the end of the day, the poor still continue to experience an almost 20% decline in their per capita incomes despite all adaptation mechanisms to land degradation. The changes in technology actually benefit the poor proportionately more than they do the rich. But the institutional changes in land tenure succeed in shifting the incidence of land degradation plus population increase and onto the land-poor households. The major culprit is the abolition of lending of fields among compounds. By the end of our experimental chain only the poor suffer, in income terms. The other compounds actually succeed in increasing their per capita incomes, but at the wrenching cost of migration.

Of the changes considered, some are "one shot" affairs. This is true of the tenurial reforms and of the expulsion of non-village labor. Thus, the range of instruments available for adaptation to continual land degradation is considerably narrower than that reflected in our instruments. Barring reductions in population growth, adaptation to further environmental degradation in the future will be limited to changes in technology and emigration.

Among changes in technology that have some potential for reversing the land degradation cycle in sub-Saharan Africa are[42]:(1) agroforestry, the practice of combining tree crops with cultivated food crops;the use of this technology can reduce soil erosion, increase the recycling of soil nutrients, and increase the resistance to drought.(2) changes in cultivation patterns, which combine restraining production on marginal and steep terrain and increasing the productivity of more suitable land; this would decrease runoff, siltation on low-elevation adjacent lands and loss of topsoil; (3) mulching (4) replanting trees; and (5) terracing and bunding. Some of these soil conservation measures have short run private cost-benefit ratios which are less than unity[43]. Most others may be very hard to engineer. By far the best solution would be to adopt soil conserving agricultural practices in the first place.

VI. CONCLUSION

Our review of types of environmental damage in developing countries led us to conclude that the major economic sources of environmental damage in developing countries lie in energy consumption and in agricultural systems. With respect to the former, our analysis in the previous sections indicated the existence of systematic links between energy consumption, on the one hand, and industrialization-cum-trade development strategies on the other. We found these links to be significant, but not very large, and capable of being overshadowed by other factors and governmental policies.

Our simulation model of the likely consequences of environmental degradation for an African village served as a cautionary tale, which indicated the severity and pervasiveness of its deleterious effects on the poor in a village economy. Likely institutional changes in land tenure converted a village-wide economic disaster into a disaster that touches the poor only. Our simulation thus suggested that land degradation and its likely concommitants are likely to succeed in propelling the poor in the village from conditions of marginal survival to poverty to poverty levels so severe that their very survival is threatened. While the larger compounds succeeded in adapting to the land degradation, our simulation also suggested that

[42] Brown and Woolf, 1985 .

[43] Some studies of erosion indicate that planning horizons of farmers would have to exceed 50 years and discount rates would have to be very low for soil conservation practices to pay off.Douglass, 1984.

the pattern of adaptation would destroy the fabric of the village society and, eventually, the village itself.

The moral of the cautionary tale is the critical need to embed sustainability concerns into the design of patterns of agricultural development before it is too late. This requires bringing new perspectives to bear on agricultural system design. Up to now, short run increases in agricultural yields have been the major object of agricultural development. Frequently, the current techniques used to increase yields in the short run decrease soil productivity and arable land surface in the medium run. The goals of agricultural development must be refocussed to include soil conservation practices in the broad sense. This means a change in focus for agricultural research establishments, agricultural extension, agricultural investment patterns and patterns of rural development.

This is not an easy task, since the criterion of sustainability in agriculture cannot be a static one. In view of population growth rates already embedded in the current demographics of developing country populations, sustaining per capita food supplies will require a 40% increase in food production by the year 2000. The challenge of agricultural sustainability therefore is to increase yields more than twice as rapidly as the worldwide average of 1.6% annually achieved during the last decade while maintaining soil quality and arable land surface. This is a daunting task, whose feasibility is unclear, but whose critical urgency is apparent. Furthermore, agricultural development strategies must include social development, since it is patently obvious that family limitation must be part and parcel of agricultural sustainability. Sustainable agriculture requires us to return once more to the now unfashionable concept of rural, rather than merely agricultural, development. Fostering family limitation, soil conservation and reforestation must be critical elements in the design of sustainable rural development strategies. This implies substantial reshaping of agricultural research, extension and agricultural investment projects and a refocussing of agricultural foreign assistance programs.

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Contingent calculations