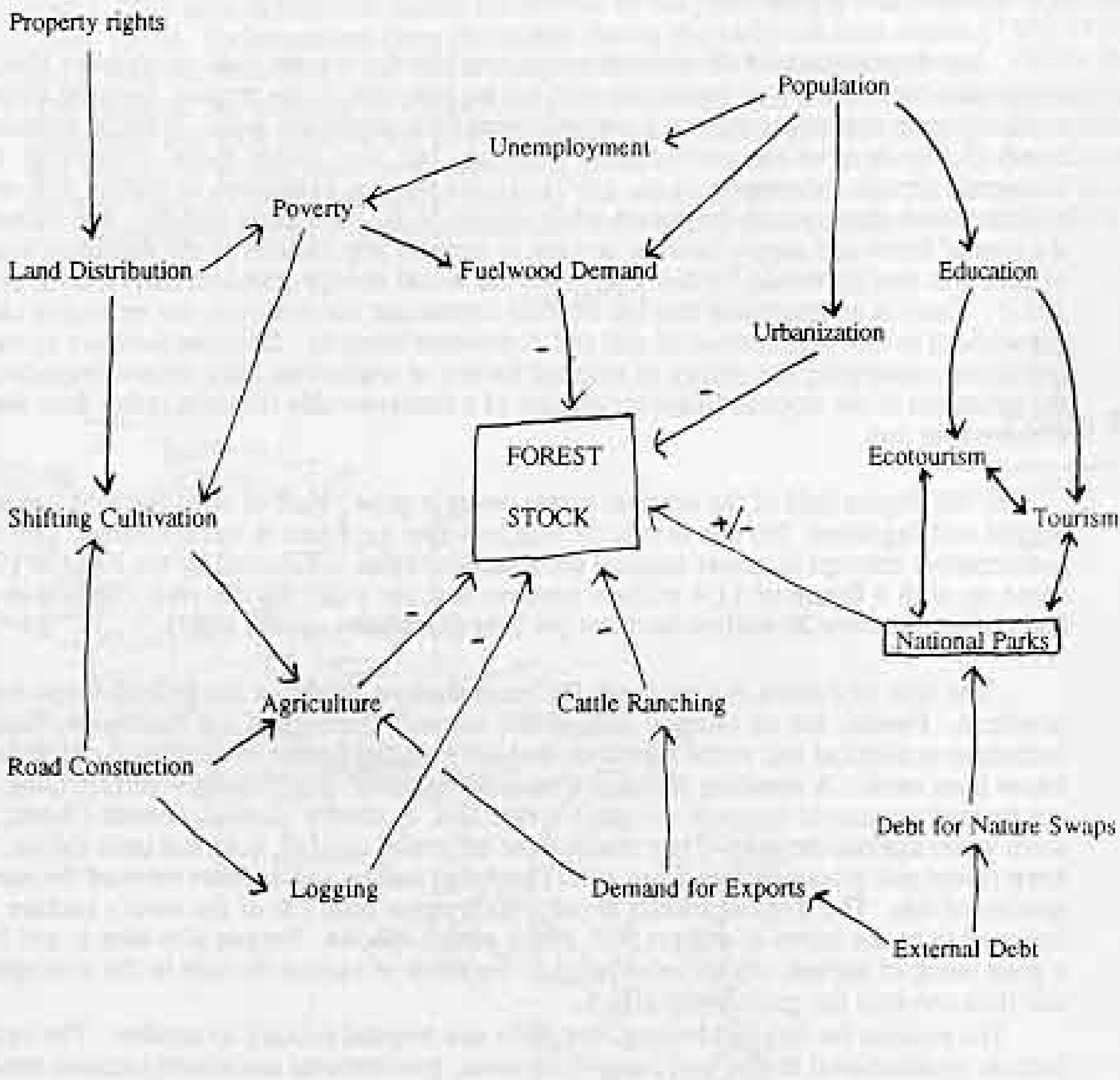
Chapter 2: Dawn M. Anderson

THE HISTORICAL TRANSITION OF FOREST STOCK DEPLETION IN COSTA RICA

Schematic Model

The following is the model that the paper is based upon with regard to loooking at the historical land use trends accounting for the depletion of the forest stock in Costa Rica.



Schematic Representation of Possible Pressures Accounting for the Depletion of the Forest Stock in Costa Rica

Introduction

Before humans invented agriculture there were 6 billion hectares of forest on Earth. Now there are 4 billion, only 1.5 billion of which are undisturbed primary forest. Half of that forest loss has occurred between 1950 and 1990.

The United States (excluding Alaska) has lost one-third of its forest cover and 85% of its primary forest. Europe has essentially no primary forest left. Its remaining forests are managed plantations of just a few commercial tree species. China has lost three-fourths of its forests. The remaining temperate forests are in Canada and Russia, where 1.4 billion hectares remain, half of them never harvested. Temperate-zone forests are now roughly stable in area, although many of them are declining in soil nutrients, species composition, wood quality and growth rate.

As degradation of the forests occur worldwide, we are able to observe that the temperate-zone history of forest use will not be repeated in the tropics, because tropical soils, climates, and ecosystems are very different from temperate ones. Tropical forests are much richer in species, much faster growing, but also much more vulnerable than temperate forests (Meadows, et al., 1992). In the tropics, extinction of forests will mean serious wood shortages in the future while demands are increasing rapidly. For instance, the loss of fuelwood supply sources so vital to tropical populations as the dominant source of fuel and energy would further aggravate the world energy problem (Srivastava, et al., 1982). There is no guarantee that the tropical forests can survive even one extensive clear-cut without severe degradation of soil and ecosystem integrity. Because there are so many questions concerning the ability of tropical forests to regenerate after severe degradation, the treatment of the tropical forest is now one of a nonrenewable resource rather than that of a renewable one.

In the tropics half of the original forest cover is gone. Half of what remains has been logged and degraded. No one is exactly sure how fast the forest is being cleared. The first authoritative attempt to assess tropical deforestation rates, conducted by the FAO in 1980, came up with a figure of 11.4 million hectares lost per year. By the mid-1980s that rate had climbed to over 20 million hectares per year (Meadows, et. al., 1992).

The loss of forests is a problem for more reasons than just the loss of forest-based products. Forests are an integral part of life support systems of the planet, performing numerous ecological and social functions that are essential for the continuation of life as we know it on earth. A standing forest is a resource in itself, performing vital functions that are beyond economic measure. Forests create soil, moderate climate, control floods, and store water against drought. They cushion the effects of rainfall, hold soil onto slopes, and keep rivers and seacoasts free from silt. They also harbor and support most of the earth's species of life. The tropical forests alone, which cover only 7% of the earth's surface, are believed to be the home of at least 50% of the earth's species. Forests also take in and hold a great stock of carbon, which helps balance the stock of carbon dioxide in the atmosphere and thus combats the greenhouse effect.

The reasons for forests clearing vary from one tropical country to another. The cutters include multinational timber and paper companies; governments anxious to increase exports and pay external debts; rich local landowners, ranchers, and farmers; and poor local people scrambling for firewood or a patch of land on which to grow food. In one way or another, all of these factors (not excluding demographic trends) have created an exploding demand for productive land. The problem is twofold. First, the velocity of exploitation and change has been so rapid that the ability of the forest, along with other resources, to recover naturally has been sharply curtailed. In the case of tropical forests, the soil nutrients are so poor that even with time they may never recover. Secondly, the economic returns produced to date from this stepped exploitation of a region's natural resources have been almost entirely generated by an increase in the consumption or destruction of the resources rather than an increase in the management of its systems on a sustainable basis. It is now that one must take action to determine what the future consequences are if widespread destruction of natural resources continues.

Overview of Deforestation in Costa Rica

Originally only 3.5 percent of the country of Costa Rica was non-forested (Sylvander, 1981). The area deforested before the arrival of the Spaniards is estimated at 2 percent (Tosi, 1974). Deforestation rates fluctuated during the early colonial period (1500-1750) and it was not until after 1750 that a sharp increase in deforestation occurred. Before the 20th century, the majority of Costa Rica's deforestation was associated with agricultural settlement and took place in the Central Valley where homesteaders had originally settled and where the coffee boom was centered. Much of this can be explained by population dynamics and colonial agricultural practices that were inappropriate for the climate. Figure 2.1 shows the topography and some characteristics of population settlement in Costa Rica.

Figure 2.1

Deforestation accelerated in the 20th century when migration away from the Central Valley began to increase markedly with the burgeoning population and the emergence of other export-agricultural activities alongside subsistence production. The Atlantic lowlands became dominated by the commercial production of bananas, and the Pacific northwest region was transformed mainly from forest to the production of subsistence crops and cattle ranching. The construction of the Pan-American Highway during World War II was a further cause of deforestation , as it provided access to otherwise isolated areas of the country, facilitating both settlement and marketing of goods. Thus, deforestation before World War II was a function of both population and agricultural growth.

Deforestation rates throughout history vary according to sources, and perhaps understandably so. Almost no written record exists of early forest types and even after 1940, when ariel photographs became more available, the coverage was not complete and/or frequent enough for precise calculations. Sader and Joyce (1988) estimate that the total primary forest remaining in 1940, 1950, 1961, 1977, and 1983 as 67, 56, 45, 32, and 17 percent respectively. Figure 2.2 below shows this trend.

Figure 2.2

Over half of the country's deforestation has occurred since 1950 (Steen and Tucker, 1992). Costa Rica's forest cover has been reduced from 29,650 sq. km. in 1960 to 25,670 sq. km. in 1970 to 18,300 sq. km. in 1980 (World Rainforest Movement, 1990). Throughout most of the 1980s, the average deforestation rate for the country of Costa Rica remained as high as 4% (World Resources Database, 1992). This prediction regarding the rate of deforestation in Costa Rica is contradictory. An official from the Dirección General Forestal noted that, since most of the remaining forested land is under park, refuge, or reserve status, and practically no deforestation is occurring in these areas, the forest conversion rate would have to be decreasing. Data used for the World Resource Institute's report were based on research conducted between 1977 and 1983 (Steen and Tucker, 1992). Thus, it would seem that the WRI's claim may have held true for 1985, but perhaps not for 1990.

Figure 2.3 shows that at the onset of the forestry transition a large percentage of a region is under forest cover. During the transition, rapid deforestation occurs and finally forest cover stabilizes at a lower level. This level is determined primarily by the local region's needs, which in Costa Rica is that of fuelwood and agricultural lands for poor peasants and farmers; the state of local and national economies, which in Costa Rica is one of tremendous external debts; and climate and soil characteristics, which is quickly becoming degraded through unsustainable land use practices in Costa Rica. In most settings this transition will end in a steady state equilibrium balancing growth and harvest (Drake, 1992). Figure 2.4 includes reforestation efforts in total forest cover. It may be that Costa Rica has completed its forestry transition and has reached a stable equilibrium of 1640 thousand hectares of forest.

Figure 2.3

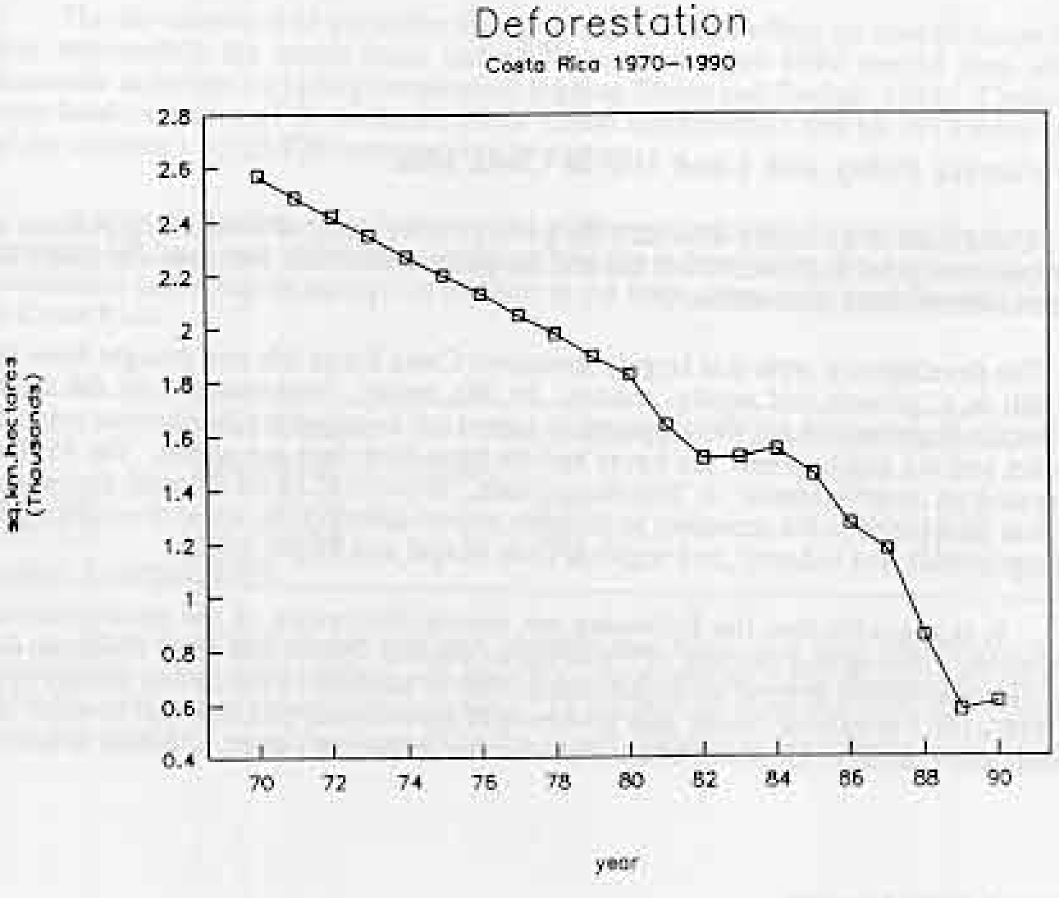
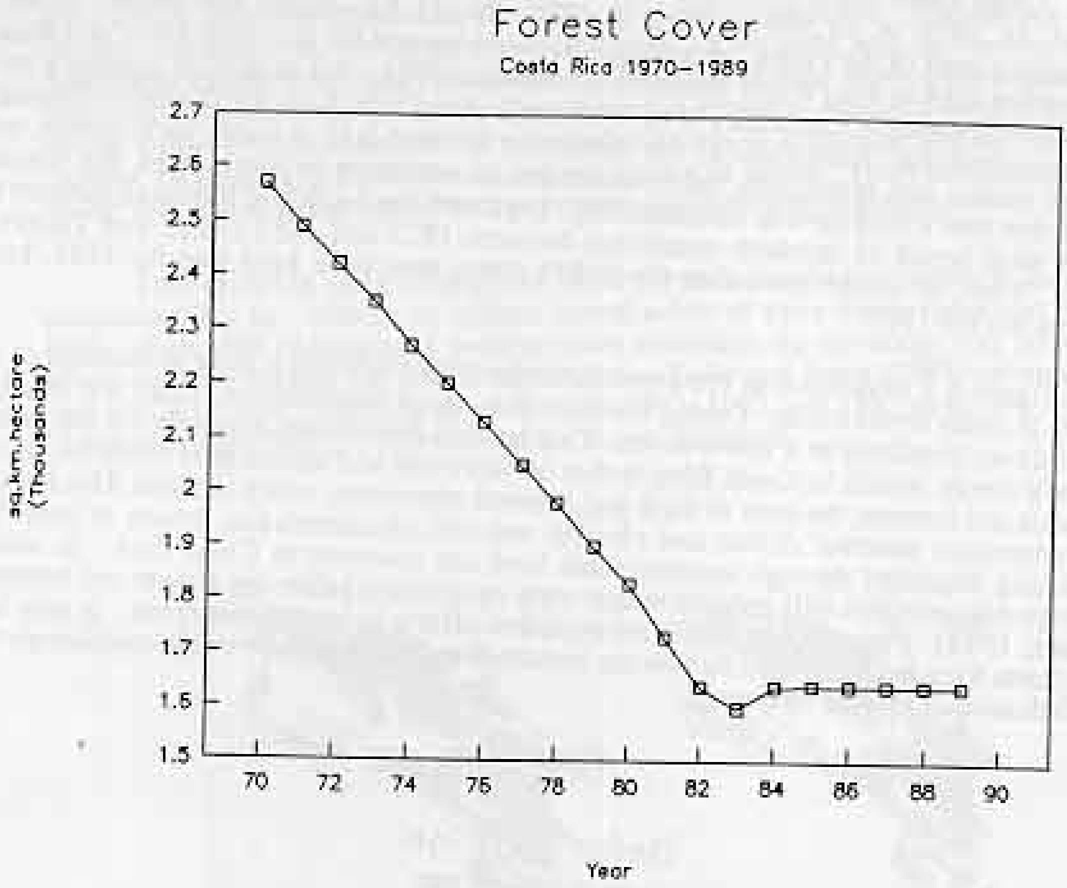


Figure 2.4



Government Policy and Land Use in Costa Rica

Costa Rica is a country in which the government's maze of conflicting policies and inadequate program implementation fail and the government itself becomes associated with severe environmental destruction.

The development style that largely structured Costa Rican life and thought from 1948 to 1980 is a 'growth and equity' model. In this model, implemented by the Partido Liberación Nacional (PLN), development is conceived as occurring if everyone materially benefits and the gap between the haves and the have-nots does not widen. The PLN also advocated an 'interventionist' or 'benefactor' state. In order to avoid external dependency, the state intervened in the economy to promote import substitution, some diversification in both agriculture and industry, and regional trade (Engel and Engel, 1990).

It is arguable that the following are among the causes of the environmentally devastating clearing and farming of Costa Rican tropical forests and steep mountain land: an unjust land tenure system; an unjust distribution of burdens on the lowest classes during the 1980-1982 economic crisis; and government agricultural policies that favored large farmers and ranchers. Deprived of environmentally respectful modes of access to land and credit, small and subsistence farmers are forced to farm in ways that contribute to Costa Rica's environmental crisis.

Cattle Ranching

In the 1950s-1960s, the government promoted export diversification in agriculture and import substitution in industry. The cattle industry was a major thrust of Costa Rica's agro-export diversification beginning in the 1950s. The Costa Rican government pumped both federal and international credits into the cattle industry in order to support this new sector of economic development (Steen and Tucker, 1992). In the early 1970s, about 1/2 of all agricultural credit was going to support the livestock industry.

In 1973, the Agriculture Census in Costa Rica found that 84 percent of the country's farmland was used for cattle pasture. Although much of it was used in combination with various crops, the Census still estimated that about 50 percent of the farmland was devoted exclusively to pasture at that time. Moreover, the Census showed that of the previously forested lands cleared for farming between 1950 and 1973, more than 70 percent had ended up exclusively used for pasture by 1973 (Leonard, 1987).

This conversion to pasture not only increased land values, it was the best way to secure land title because any unused land (ie. forest) is always a potential target for squatter invasions or for expropriation under government land reform programs. Unfortunately, ecological destruction caused by ranching programs is deemed to be long-term and irreversible. The land is rapidly depleted of nutrients and invaded by toxic weeds and within a few years, the land is so degraded that the operation must be abandoned (WRM, 1990).

The development of the cattle industry had a notable effect on overall forest loss. It was responsible for much more deforestation in the pre-1980 period than all other economic activities including commercial logging (Steen and Tucker, 1992). Cattle are the most land-extensive of Costa Rica's major export commodities and by 1973 more than 1/3 of the country's 5,135,900 hectares was in pasture.

Large disparities exist between the different agricultural pursuits in terms of the intensity of land use. The most striking feature is how little the beef cattle industry contributes to the export receipts in relation to the huge amounts of land devoted to pasture in Costa Rica.

Table 2.1

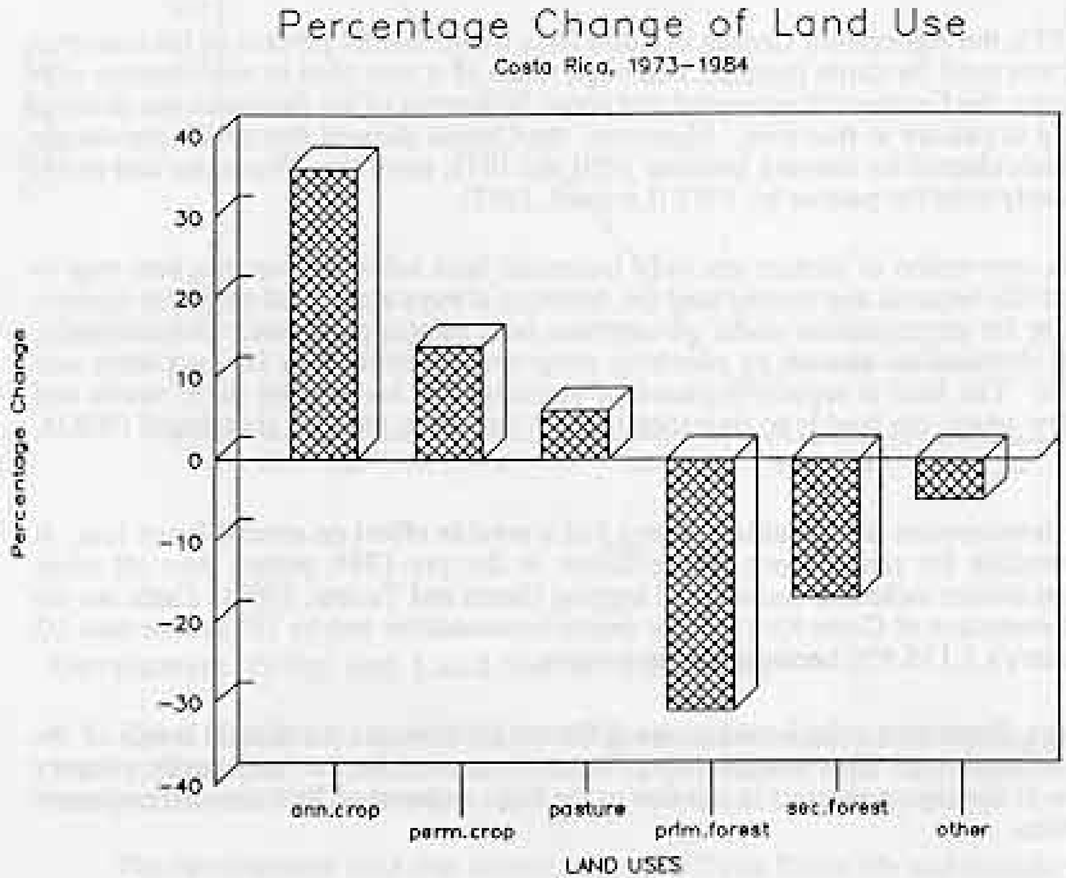
	Export Receipts ($millions)	Area Utilized (Km^2)	Export Receipts per Km^2 (US$)
COFFEE	252.0	810	3,111.11
CATTLE	65.0	480	41.72

Source: Leonard, 1987.

From the chart above one can observe that there is a very inefficient level of productivity in the cattle industry, whether it be measured by cattle production/acre of land or by the real rate of return on investment. As it turns out, both are quite low. Therefore, with the ranching of cattle there exist the dual problems of economic inefficiency and environmental deterioration. Absolute inefficiency cannot be determined due to lack cost of production data with regards to both coffee and cattle.

In a comparison of Costa Rica's 1973 and 1984 Agricultural Censuses, percentage changes in different land uses on the national level facilitates an evaluation of agricultural trends. Land use categories include annual and permanent crops, pasture, primary and secondary forest, and "other" which includes portions of agricultural farms occupied by buildings, roads, waterways, or any other land use not explained by the other land use categories.

Figure 2.5

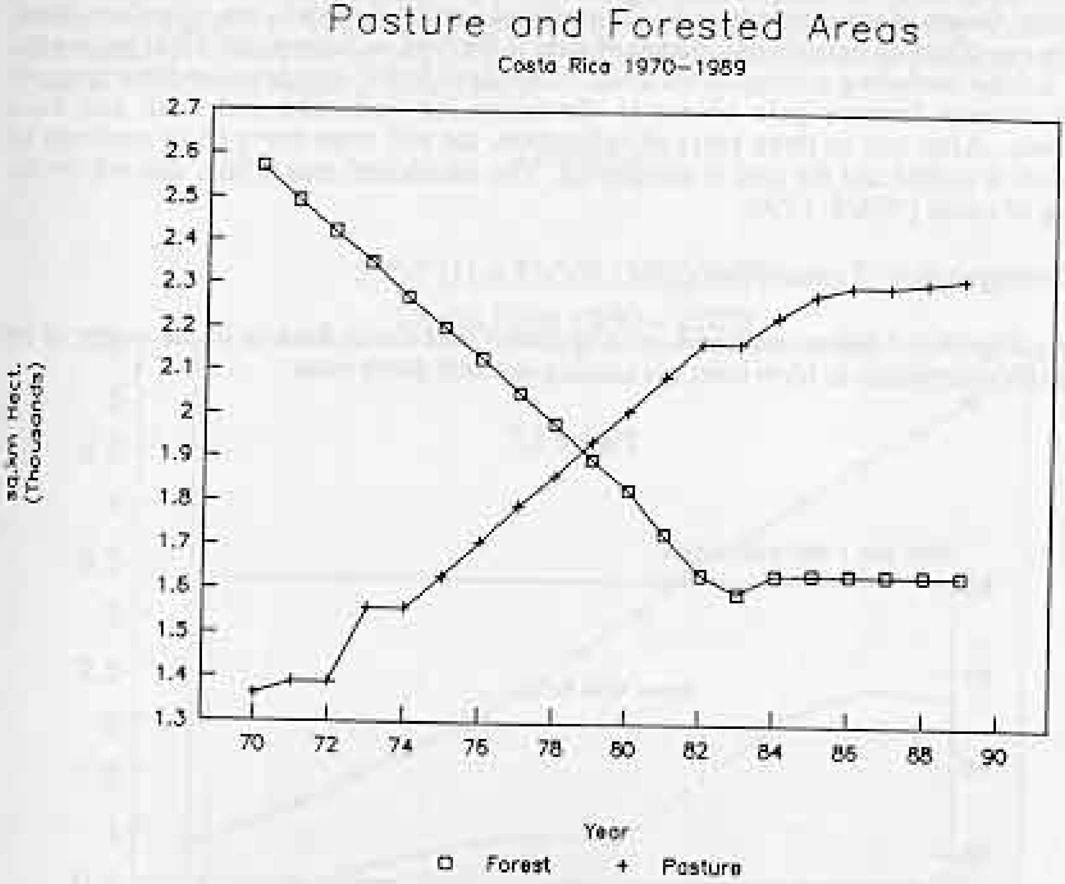


At the national level, these changes reflect minimal growth for pasture land, with a positive 6% change during the period 1973-1984, whereas annual crops show the highest positive change at 36%, followed by permanent crops at a positive 14% increase for the same period. The sharpest decreases in land-use were in primary and secondary forests, at a negative 31% and 17% respectively (Steen and Tucker, 1992). These figures seem to indicate that the conversion to pasture has not been the driving force behind deforestation in the 1973-1984 period, since pasture growtl. was minimal. However, it does seem to indicate that the cultivation of annual crops has played an increasing role in forest conversion.

The Agricultural Transition

Historically, the forestry transition has been largely the mirror image of the agricultural transition as land was cleared in order to extend cultivation. One can observe the mirror image of the agricultural and forestry transitions in Figure 2.6 below. But, in the case of Costa Rica, the agricultural lands were also used for the ranching of cattle which leads to some discrepancy when attempting to separate the two uses.

Figure 2.6



In this graph we can observe that both the agricultural and the forest transition are beginning to level off. Although the mirror image still exists, future increases in agriculture coming mainly from intensification rather than the extension of cultivated land may cause the association to become less apparent (Drake, 1992).

The Timber Industry

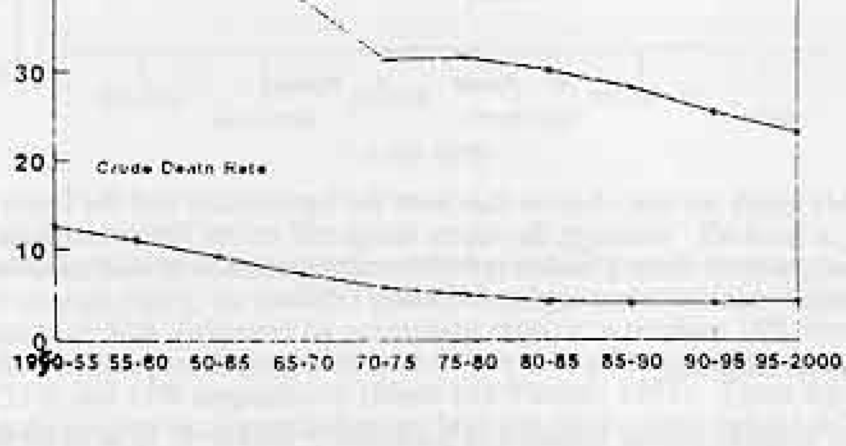
The tropical timber industry is particularly sensitive to accusations of causing deforestation, arguing that it is only responsible for some 10% of forest destruction worldwide. The timber industry is not a major force of deforestation despite very rapid consumption of forests in recent years. This is because much of the timber cut annually is not harvested for commercial purposes. Instead, large quantities of potentially commercial timber are burned in place or felled and not harvested.

In Costa Rica all tree cutting is supposed to be authorized by the Forest Service. In 1980, the Dirección General Forestal (DGF) gave permission for the cutting of 22,000 hectares, or only about 35 percent of the estimated deforestation in Costa Rica for that year (Leonard, 1987). These statistics are slightly misleading. Although the timber industry may not be a direct cause of massive deforestation, logging is often a precursor of deforestation by opening up of previously inaccessible areas to landless peasants (WRM, 1990). DGF estimates that at least 1/2 of this unpermitted forest cutting is attributable to squatters and colonists who fell and burn forests as the quickest means of establishing possession claims to unoccupied lands. Throughout Central America, not only Costa Rica, a person can claim ownership of a parcel of land if the land is "improved" by changing the natural habitat-including cutting down trees. From these forest openings, landless peasants and subsistence farmers gain access to the forest for fuelwood and slash and burn agriculture. After two or three years of cultivation, the soil loses many of its nutrients so cultivation is shifted and the area is abandoned. The abandoned area is later utilized for the ranching of cattle (WRM, 1990).

The Demographic Transition

As Figure 2.7 below indicates, it is apparent that Costa Rica is in the midst of its demographic transition as birth rates are tending towards death rates.

Figure 2.7

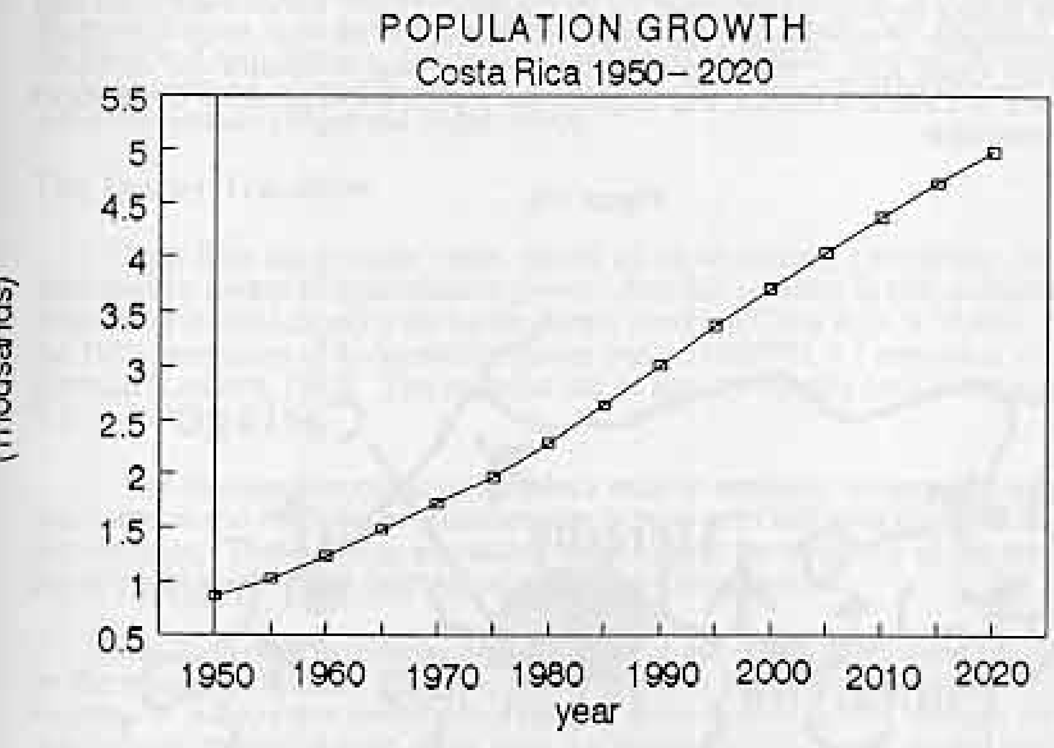


Source: Population Reference Bureau, June 1992.

Although Costa Rica falls into the category of more moderate growth in comparison to other Latin American countries because it has lowered overall fertility rates, the crude birth rate was 27 (per thousand) compared to a crude death rate of 4 (per thousand) in 1992. With this discrepancy, total population will continue to increase substantially, although there appears to be an equilibrium approaching which will allow for substantial increases in the quality of life and shows great promise for the future.

Although population growth rates are decreasing, Costa Rica will still experience a net growth in population. This is due primarily to population momentum, the time period in which the children born during the period of dramatic population growth go through the child-bearing years. Costa Rica's current population is 3,187,000 and as it completes its demographic transition, the population is projected to increase to nearly 5,500,000 by the year 2025 (United Nations, June 1992).

Figure 2.8



It's an axiom of the environmental movement that population growth is a big obstacle to preserving the environment: the more people there are, the greater demands on the Earth's resources. But few development experts consider that when the poor landless peasants' resources are taken away, the family is actually more likely to want more children in order to help with the increased workload in finding food, fodder, and fuel with decreasing resources available. This 'population trap' will compound the destruction of the local environment (Jacobson, 1992).

The Urbanization Transition

Population growth presses on the natural environment. Traditional technologies that were sustainable in the past, become destructive when used with larger and more densely settled populations. Rising population density in an area would inevitably lead to innovations that would increase the human carrying capacity of the land. Unfortunately, many farmers in tropical countries are just too poor to afford to invest in such practices. Indeed, their poverty is so dire that it severely constrains the sustainability of much less sophisticated practices and is just as important a cause of any land misuse and degradation as any overcrowding (Meadows, et al., 1992).

Costa Rica appears to have a moderate population density with approximately 55 persons per square kilometer. This figure may be somewhat illusionary because Costa Rica's population distribution is highly uneven. In 1987, two-thirds of all Costa Ricans lived in the fifteen-by-forty-mile Central Valley (Leonard, 1987). Unfortunately, this high urban concentration of the Central Valley is also the location of the most fertile agricultural lands within Costa Rica. The map on the following page illustrates the economic development in Central America, and displays the significant expanse of Costa Rica's urban concentration.

Figure 2.9

In Costa Rica, the migration off the land that has occurred by poor subsistence farmers has to date been overwhelmingly in the direction of the urban areas. Approximately 46 percent of the population of Costa Rica live in urban areas and urban growth, particularly in the capital cities, has been explosive since 1960. Growth in the secondary cities of Alajuela, Cartago, and Heredia has been equally intense. The percentage growth rates for urban areas in Costa Rica for 1960-1970, 1970-1980 and 1980-1985 are 52%, 43.8%, and 20.9% respectively. Consequently, the government of Costa Rica has sought to encourage more landless and near landless people to move into frontier areas as a sort of safety valve for relieving pressures in the heavily populated Central Valley. Migration of small landowners and landless peasants into frontier zones now exceed migration into urban areas (Leonard, 1987). Although this migration to newly developed lands is helping to reduce overall urban growth rates, dense forests with very thin or poor quality soils have been cleared for pasture and cultivation and thus has caused the environmental impacts to be enormous.

Along with the urbanization transition (or as in the case of Costa Rica, what looks to be a mode of reverse urbanization transition-the movement out of the cities into the countryside), the distribution of land and resources is grossly inequitable. In 1987, 36 percent of all land in Costa Rica was in the form of large farms of 500 hectares or more. By establishing a more just system of land tenure, pricing, credit, and technical assistance for small and poor farmers, deforestation and environmentally unsound farming practices could be reduced, as well as become a source of basic needs satisfaction and communal self-determination (Engel and Engel, 1990).

The Energy Transition

Costa Rica can proudly boast, that of all of the country's electricity, 99 percent is generated by means of hydroelectric power. And this resource is still underutilized. The estimated potential capacity for hydroelectric power in Costa Rica is 37,898 GWH while the 1980 generation of hydroelectric power was 1,780GWH, 4.7 percent of the estimated potential (Leonard, 1987). This potential can be seen by refering back to the map in Figure 2.1.

The hydropower capacity that does exist is seriously endangered by watershed deterioration and consequent sedimentation in reservoirs and river channels as a result of deforestation. These effects are raising doubts about the longevity of the reservoirs and power plants along with a decrease or a potential loss in revenue.

There is no need to reiterate the discussion of the effects of poor and landless farmers on the energy transition. This discussion has been incorporated into the various other sectors. It is apparent that a great deal of deforestation occurs through the land use practices and through the use of the more traditional fuels (ie. wood, animal and vegetative biomass, etc.) which will further aggravate the need for alternative sources of energy in the future.

Debt Crisis and A "Natural" Mistake

The experience of Costa Rica shows how a failure to account for natural resource assets can lead to economic disaster. To many naturalists, the country is renowned as the Western Hemisphere's conservation leader. It has set aside almost a fifth of its land for national parks and is the site of pioneering programs in nature tourism and restoration ecology. Yet during the past 20 years, Costa Rica has suffered devastating deterioration of its natural resources.

One of the hemisphere's highest rates of deforestation had lead to the loss of 30 percent of the country's forests in the past 20 years. Furthermore, most of the forest was simply burned to clear land for relatively unproductive pastures and hill farms, sacrificing both valuable timber and myriad plant, animal and insect species. Because most of the area converted from forest was unsuitable for agriculture, its soil eroded in torrents.

Because forests, along with fisheries, farming and mining directly account for 17% of Costa Rica's national income, 25% of its employment and 55% of its export earnings, this destruction caused severe economic losses. The year 1989 saw the destruction of 3.2 million cubic meters of commercial timber worth more than $400 million caused by slash and burn agriculture. This amount, $69 for each person in Costa Rica exceeded payments on the foreign debt by 36 percent (Repetto, 1992). Losses in the areas of agriculture, fisheries and livestock were also observed, yet nothing in Costa Rica's national economic accounts recorded these asset losses.

When Costa Rica ran into economic difficulties in the early 1980's, economists diagnosed the problem as a debt crisis. Foreign liabilities had increased, and servicing the debt became even more problematic. The International Monetary Fund (IMF) brought in programs in order to stabilize the monetary base, but no one spoke of stabilizing the natural resource base even though the loss in domestic assets had been much greater than the increase in external liabilities and had deprived the country of export income from which debt-servicing payments could have been made. The difference is that the buildup in foreign liabilities had been recorded and scrutinized; the depreciation in natural resource assets had been obscured and ignored. And despite a declining rate of deforestation in recent years, asset depreciation has increased dramatically because the hardwoods being destroyed have become more valuable. The forestry sector generated substantially negative levels of net national income throughout the 1980's: the value of forest capital destroyed greatly outweighed the value of forest products generated (Repetto, 1992).

Government Policy Revisited

The first signs of alarm at the rapidly growing conversion of tropical forests in Costa Rica appeared in the mid-1970s. During the Oduber Administration (1974-1978) "a more systematic and rational strategy was adopted for the country's forests" (Steen and Tucker, 1992). These initiatives included financial support and physical expansion of the National Parks Service and important additions to the Forestry Law of 1973, all of which contrast markedly with the "cattle" policy under the same administration.

Oduber also assigned 5 new areas to the National Parks Service and incorporated 8 additional forest reserves. In addition, 6 existing protected zones were enlarged and the first wildlife refuge was created. In all, the Oduber administration's contribution to the country's protected areas totalled 42.2% of all current parks and reserves.

By the mid-1980's, concerns over Costa Rica's loss of forest ecosystems, coupled with the debt crisis, led to 2 new approaches to combat both problems: these were "debt-for-nature" swaps and "ecotourism".

Debt-for-nature swaps were first proposed in 1984. In a swap, a nongovernmental organization (NGO) purchases part of a developing country's debt from the lending bank. The NGO would then offer to forgive the debt, or donate the "debt-instrument" to that country's central bank, in exchange for certain environmentally beneficial actions to be taken in that country. Costa Rica had implemented the largest and most varied swap program, but the more than $50 million in debt swapped still represented only 3-4% of the country's $1.5 billion debt in 1990 (Patterson, 1990).

Ecotourism is another new market which was given priority by the government in the last half of the 1980s to help spark economic recovery. This specialized market has been a means for Costa Rica to expand its tourism industry. Tourism replaced beef as the number 3 export earner as early as 1980 and has since moved to number 2 behind coffee exports. Likewise, ecotourism is dependent upon continued efforts to protect forest ecosystems through such mechanisms as debt-for-nature swaps.

The case of Guanacaste National Park is perhaps the first example of pasture-to-forest conversion, marking a reversal of the forest conversion trend. The park was established in the 1980s on lands that were purchased from former cattle ranchers. Scientists are attempting to restore this deforested land to its previous life zone status as dry tropical forest (Steen and Tucker, 1992). The park has a rather symbiotic relationship with nature swaps and ecotourism, as it will benefit from the input of nature swaps and the interest generated by ecotourism while the swaps and ecotourism function as a result of such innovative parks as Guanacaste.

Since 1970, Costa Rica has been one of Latin America's most conservation-minded countries. It has set nearly 25% of its land for parks and reserves-more than any other nation in the tropics. In 1987, President Arias signed the Forestry Emergency Decree designed to halt the current deforestation in Costa Rica as well as establish a national forest and land use policy (Engel and Engel, 1990).

The Costa Rican government is now boosting efforts at reforestation by means of fiscal incentives under the Forestry Law, including tax breaks and subsidies. A total of 43,498 hectares were reforested between 1967 and 1990, of which 42,898 were reforested in the years 1980-1990 alone (Steen and Tucker, 1992). Figure 2.10 on the following page re-emphasizes the nearly exponential growth in reforested areas per year in the last few years.

Although reforestation has not completely outpaced deforestation, as observed in Figure 2.11 on the following page, it is nonetheless possible that timber is not being supplied solely from primary forest and/or the reforestation rate may some day offset the deforestation rate.

Figure 2.10

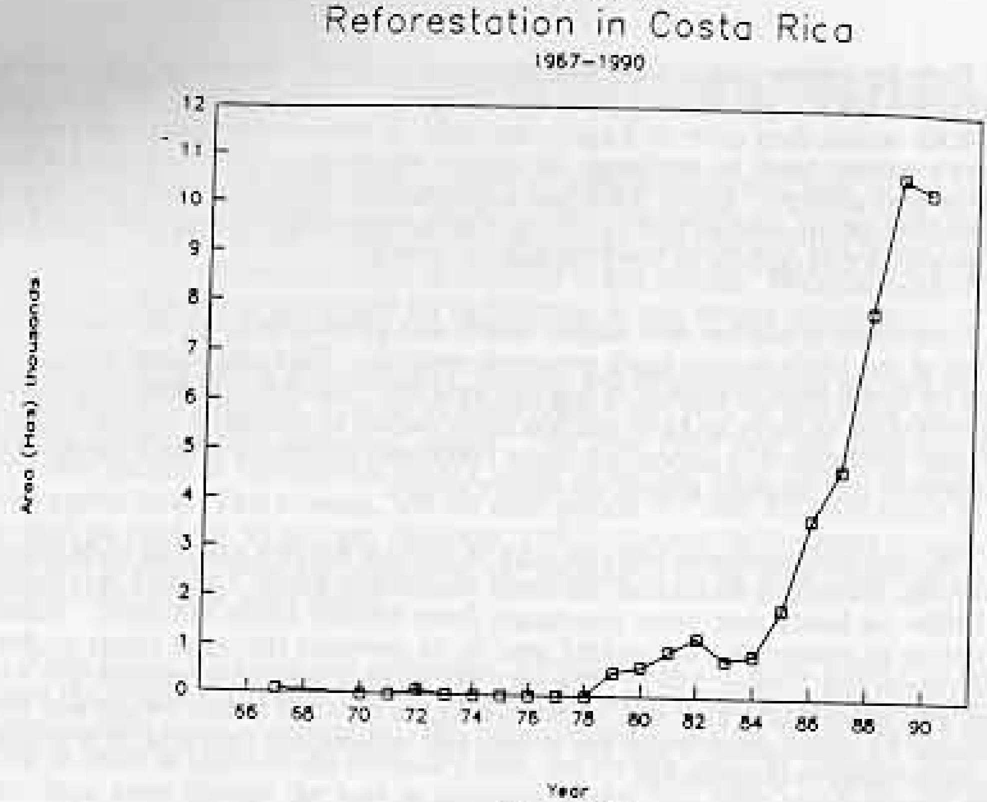
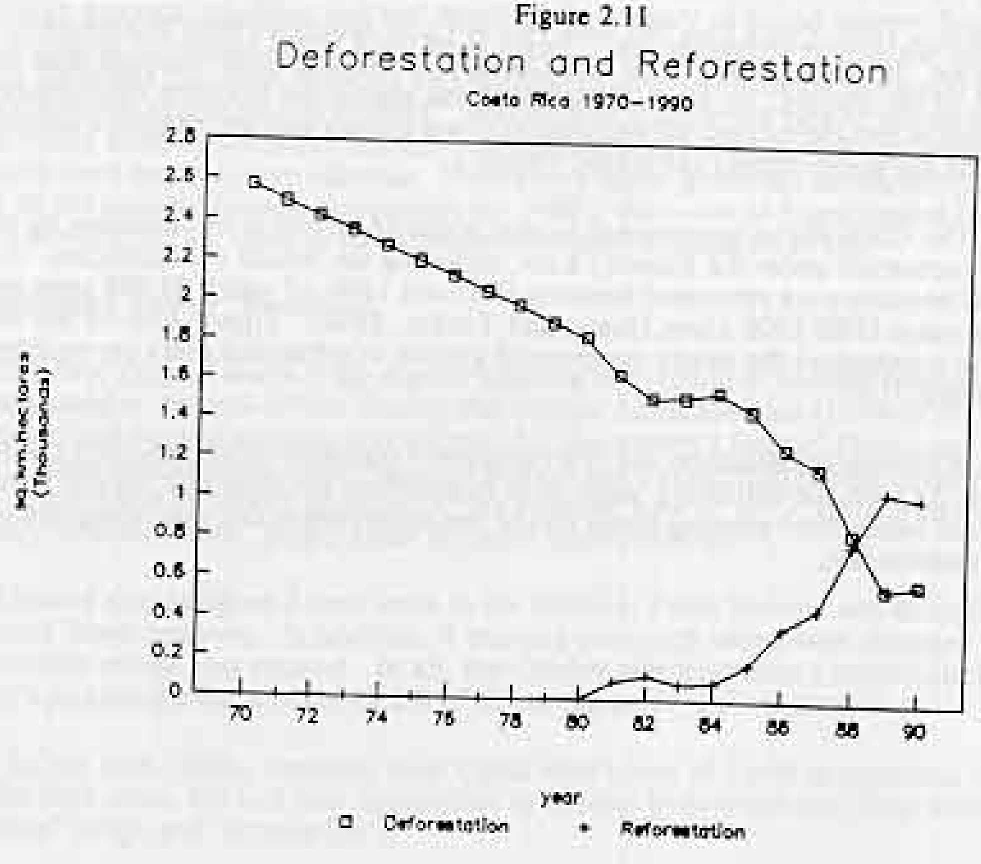
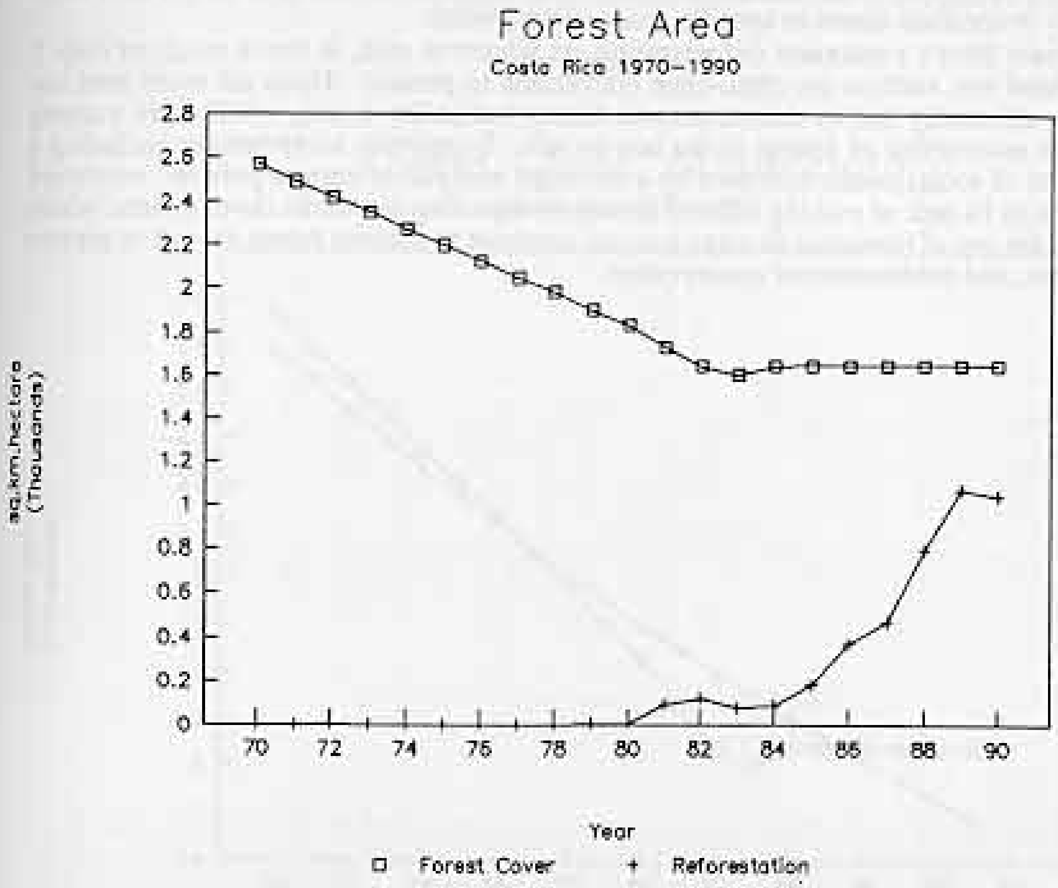


Figure 2.11



In order to observe if reforestation was having an effect on the rate of deforestation, a graph was created that incorporated both the reforestation and deforestation data to show total forest cover. This can be seen in Figure 2.12 below. This graph indeed shows that the reforestation efforts have had a positive effect on the stabilization of total forest cover.

Figure 2.12



Under the new Forestry Law passed in 1990, incentives for natural forest management were provided, and should have been implemented in 1991 in order to stimulate maintenance of the remaining privately owned forests. Also, under the present Calderón administration, the reforestation goal is set at between 80,000 and 100,000 hectares by the year 1995 (Steen and Tucker).

Recommendations and Conclusions

The first step in lending proof to the argument that expansions in agriculture, road systems and urbanization, and commercial logging are just as pervasive as cattle ranching in the conversion of forests would be to generate more accurate correlations of deforested areas to specific land uses. Also, there must be continued monitoring of forest clearing using satellite change detection techniques and quantitative estimates of change in order to allow one to assert with more reliability the nature of the forest cover loss, and then more accurately to correlate losses to specific economic activities.

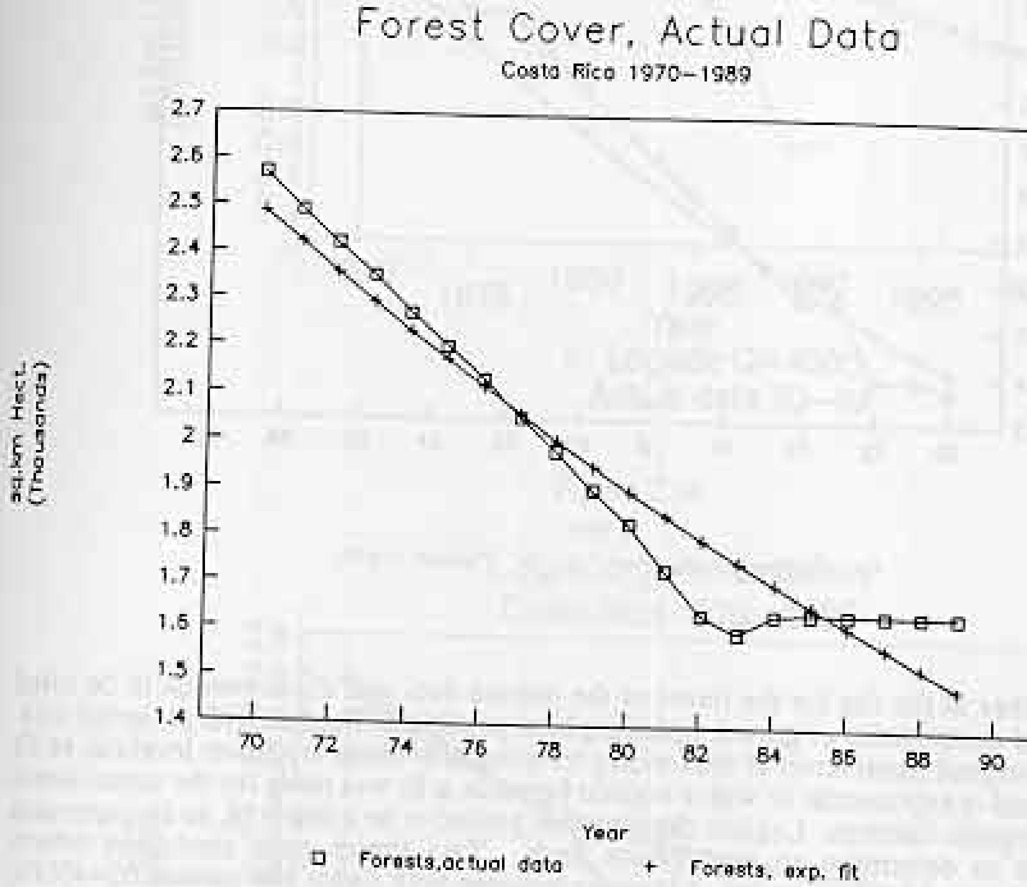
Costa Rica's continued deforestation, at whatever rate, is not a result of only 1 specific land use, such as the often-cited conversion to pasture. There are many land use activities, ultimately tied to socioeconomic forces and policy issues, which have a strong bearing on conversion of forests in the last decade. Systematic investigation, including a recognition of social needs, followed by a thorough analysis of current policies, would aid Costa Rica in its task of making rational decisions regarding economic development, which promotes the use of resources in ways that can continue to support future as well as present generations, and environmental conservation.

Dynamic Modeling

In deforestation, the models presently estimating the loss of forest cover are relatively crude and are unable to accurately predict change. Another feature which increases this complexity is the explicit recognition given to the interconnectedness among sectors and across scales (Drake, 1992).

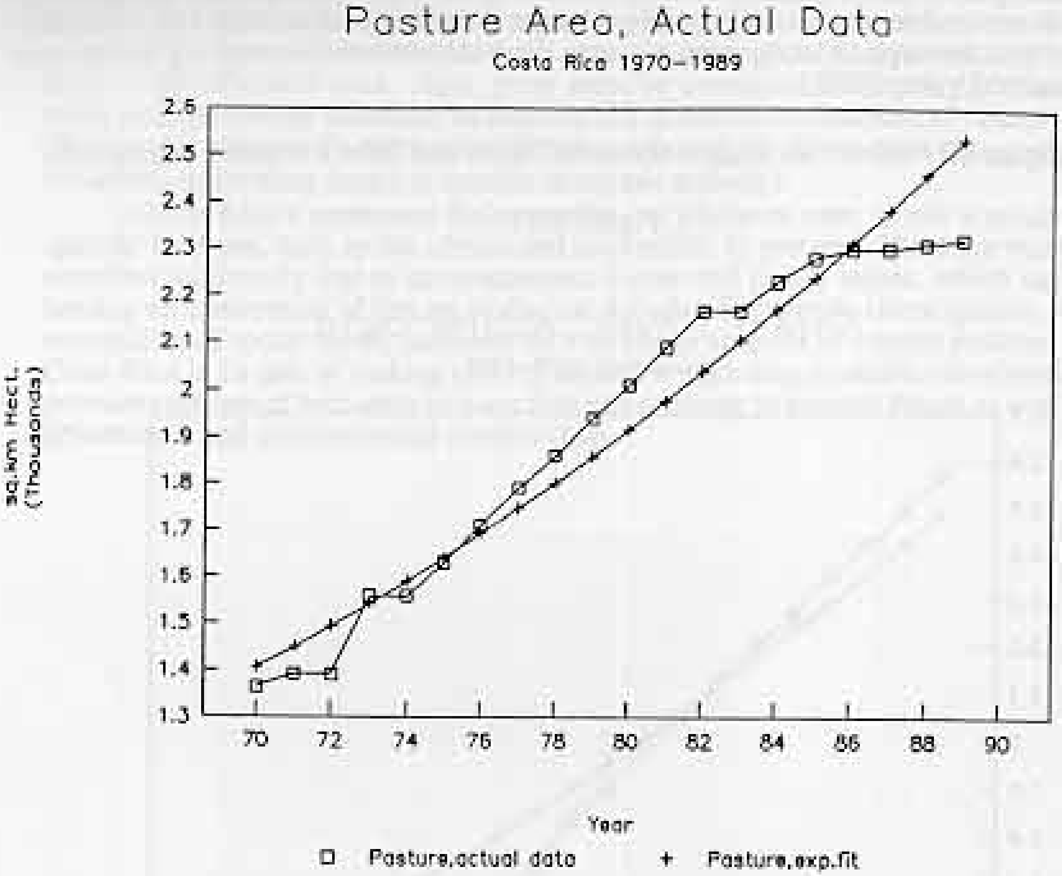
In Figure 2.13 below, we observe the actual forest data fit to a negative exponential.

Figure 2.13



As a source of comparison, the actual pasture data was also fit to an exponential. This can be seen on the following page.

Figure 2.14



Neither of the fits for the forest or the pasture data was close enough to be ruled exponential deterioration or growth which explains possible difficulties with projected data. Since the original forest cover of the forestry transition that drops to a lower level can be fit with a negative exponential or with a logistic function, a fit was made for the actual forest data to a logistic function. Logistic deterioration proved to be a better fit, so an expansion was made to determine an appropriate limit. Two limits were used, one which corresponded to the total number of hectares between both forest and pasture (Q=4000), which seemed to be rather constant, and one which corresponded to the amount of land currently under protection (Q=1270). This was done for both the deforestation data and the total forest cover which includes reforestation. These can be found on the next two pages.

Figure 2.13

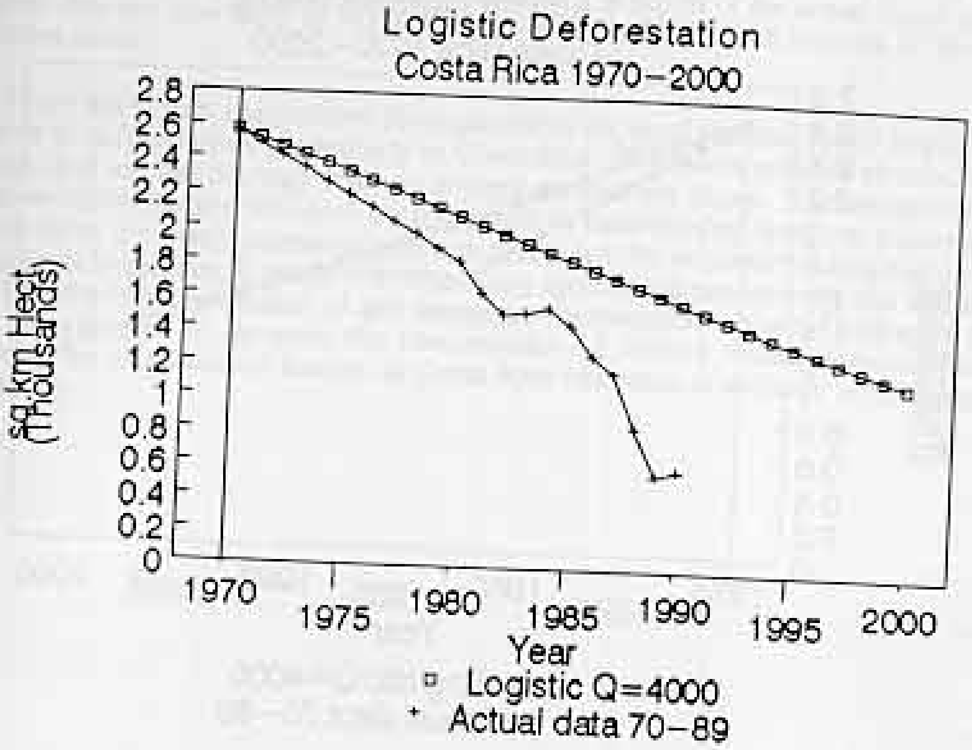
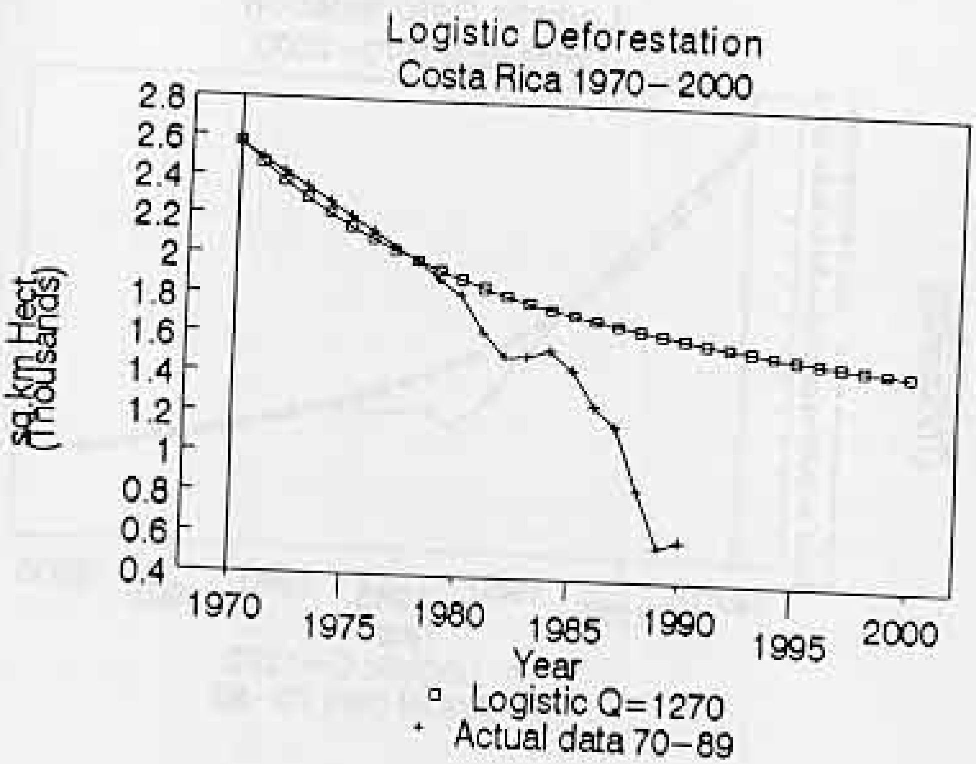


Figure 2.14



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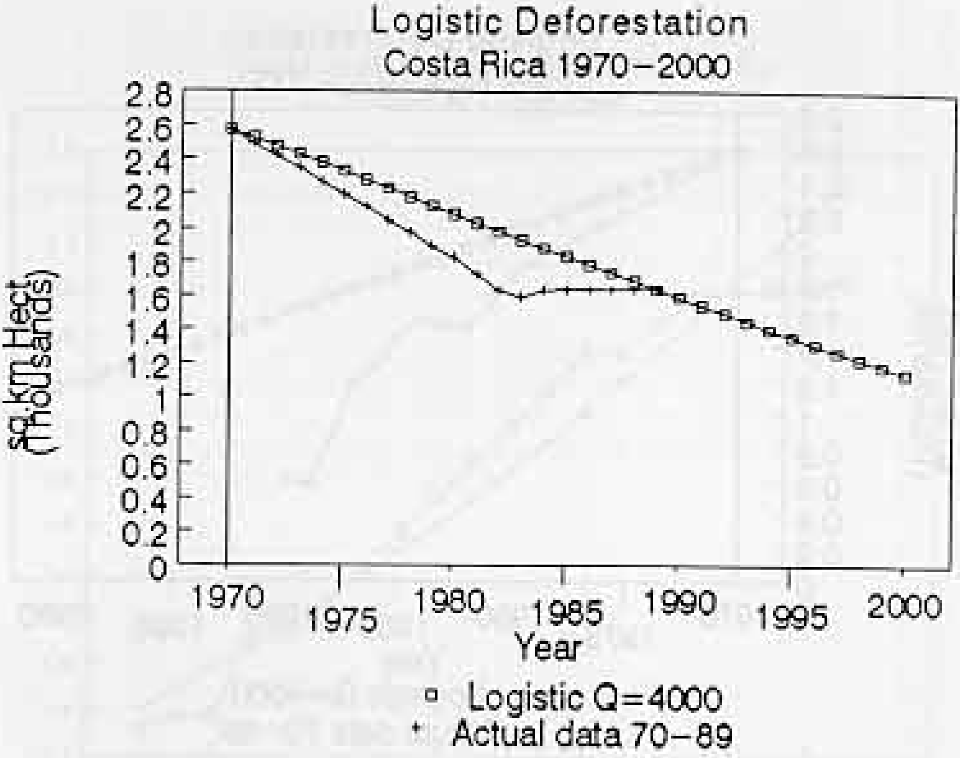
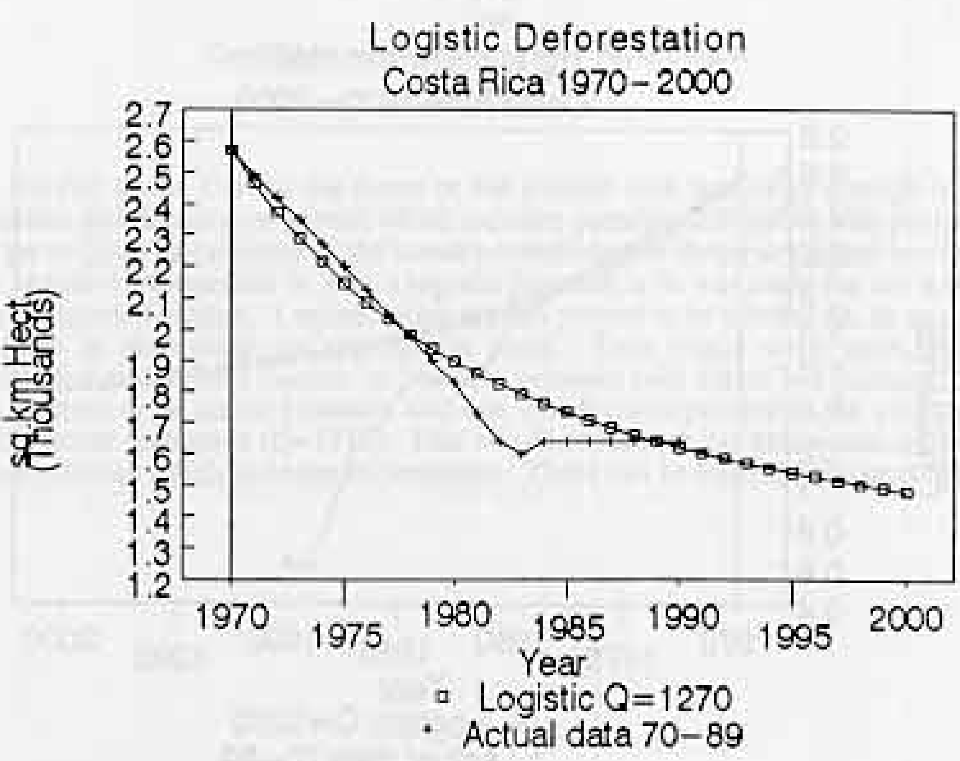


Figure 2.16



Because both the forest and pasture trends seem to be stabilizing, one would assume that the best logistic fit would be that of the limit of Q=4000. Surprisingly, this is not the case. The logistic with a limit of Q=1270 took on a better fit of the actual forest data. This suggests that the true limit of deforestation in Costa Rica is the amount of lands under protective status.

There have been suggestions throughout this paper of various policy implications to the issue of deforestation, particularly in Costa Rica. The move towards an equilibrium in national land use morphology will not depend on land use alone. Socioeconomic factors and government policy will also be important in determining land use patterns. Also, because there are many interacting factors that drive the expansion of agricultural lands leading to deforestation, it seems that improving agricultural productivity and sustainability should be the key ingredients of any integrated deforestation control strategy. Relying solely on attempts to increase the conservation of forests within national parks and improving the protection of forests, as Costa Rica has done, is unlikely to be successful in the long run.

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Chapter 3: Katharine A. Duderstadt

THE ENERGY SECTOR OF POPULATION-ENVIRONMENT DYNAMICS IN CHINA

Introduction

If population and capital growth continue to rise as they have in recent history, the world energy demand will increase 75% by 2020.[1] Nonrenewable fossil fuels will persist as the major energy sources during this time. Though the world foresees shortages of oil and gas in the near future, sources of coal will remain relatively abundant -- especially in China, India, and the former Soviet states.

The problems arising from producing energy by burning coal include local air particle pollution causing respiratory disease, regional sulfur dioxide pollution resulting in acid rain, and global increases in atmospheric carbon dioxide levels relevant to the controversial issue of global climate warming. As populations increase and economies expand, the demand for more energy could lead to further coal use and further pollution. However, new technologies and economic reforms directed toward energy efficiency combined with implementation of alternative energy sources may allow countries to increase their energy output while maintaining or decreasing the current level of environmental impact.

Recent events in Eastern Europe and China have allowed Western countries a glimpse into the successes and failures of centrally planned economies to orchestrate industrialization and energy production while controlling environmental impact. Although the monster factories of Eastern Europe can be awe-inspiring, their economic and environmental consequences appear admittedly grim. One reason for this contrast to the relatively cleaner industry of Western market economies lies in energy intensity. Energy intensity measures the amount of energy needed to produce a specific amount of output -- for example, the amount of Gigajoules required to burn one ton of coal. With all other variables equal, higher energy intensity corresponds to lower energy efficiency. Data suggest a correlation between central planning and energy intensity. The nations of the former Soviet Union, Central Europe, and China support one third of the world's population, consume one third of world energy, yet produce only one fifth of the world's economic output.[2]

How can these countries reduce their energy intensity while still satisfying increasing needs in production? Technology to allow higher efficiency in energy

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[1] Donella H. Meadows, Dennis L. Meadows, and Jorgen Randers., *Beyond the Limits*, (Chelsea Green Publishing Company, Post Mills, Vermont, 1992), 66

[2] William U. Chandler, Alexei A. Markarov, Zhou Dadi, "Energy for the Soviet Union, Eastern Europe and China," *Scientific American*, (Scientific American, Inc., New York, Sept 1990. Vol 263 n3), 121

production will clearly be a dominant factor. Improvements in end-use technology will also play a major role by reducing energy consumption requirements.[3] In this situation, end-use refers to the products which use energy to perform services -- such as ovens, lighting, heating, etc. Price reform, dematerialization, energy alternatives, economic reform, and government policy will mediate between the various energy sectors.

Scholars often lump China, the Soviet Union, and Central Europe together in addressing issues of energy intensity. Central and Eastern Europe serve as ideal starting points because of their current transition from planned to market economies and their active efforts to address existing environmental problems resulting from inefficient use of fossil fuels. Contrasting energy trends in socialist countries with those in capitalist countries such as the United States and Japan allow postulations of the effect of economic and governmental ideals, organization, and policy on energy related issues. The United States is of further interest as it remains the largest energy user in the world, as well as the greatest contributor of carbon dioxide to the atmosphere. Japan, on the other hand, leads the world in energy efficiency and has surprisingly low rates of CO_2 emissions.

The study of the scale of China's energy use deserves high priority in the realm of global climate change. A report from the National Academy of Sciences projected that if coal use and economic output continue to increase at their current rate in China, the country's contribution to global CO_2 emissions will quadruple in under 40 years, passing that of the United States.[4] Suggestions that China drastically curb its use of coal before this time is impractical, given the amount of reserve that the country boasts and energy pressures resulting from the country's increasing population. Energy efficiency, therefore, seems to be the best focus for the short term. Shifting to other energy sources will indeed become necessary in the future -- but remains a long term goal because of the slow implementation time of technology and policy.

The technology necessary to lower the energy intensity of China exists. However, knowledge about the social changes necessary to procure and implement this technology effectively remains scarce. Factors involved in such an analysis include studies of centralized government environmental and economic structure, environmental policies and the implementation of these policies, price control, cost comparisons, the needs and wants of communities , basic individual values concerning material and service needs, and cultural respect for the environment.

Transition Theory

In studying the energy sector of population-environment dynamics, I would like to use transition theory as a framework. William Drake provides a good overview of

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[3] Amulya K.N. Reddy and Jose Goldemberg, "Energy for the Developing World," *Scientific American,* (Scientific American, Inc. New York, Sept 1990. Vol 263 n.3), 112

[4] Paul C. Stern and others, *Global Environmental Change -- Understanding the Human Dimensions,* (National Academy Press, Washington, D.C., 1992), 64

transition theory as applied to population-environment dynamics by discussing a "family of transitions." [5] Most time-dependent sectors involved in population and environment can be described by a transition. A transition begins at a point of relative equilibrium and then enters a period of dramatic change. Eventually it either succeeds in re-stabilizing, overshoots, or collapses. Transitions entering the scope of this paper include the demographic transition, energy transition, urbanization transition, industrial transition, and toxicity transition. Through describing each transition in China, graphing with fitted curves, and providing a theoretical model relating all transitions, I hope to provide greater insight into the future of China's energy sector. It is particularly important to remember that these transitions are dynamic, that is they depend on time. The relation of how they depend on time is of great importance when relating one to another. The starting points and rates of change determine how one transition has or will influence the success of the others. The timing of transitions in relation to one another can determine whether stability, overshoot, or collapse occur.

In studying energy, the energy transition appears as the most obvious starting point. The energy transitions in China and Eastern Europe differ from other industrialized countries. The United States and Western European countries went through a time where energy from fossil fuels increased alongside rapid industrialization and consumption. Though economic growth continued after this initial leap, productive output became less energy intensive because of more efficient technology and a shift from heavy industry to service sectors. Industrialization began in China and Eastern Europe with a similar upswing. However, their governments continued to invest in heavy industry and outmoded technology -- to the point where production became so inefficient that the governments had to subsidize the factories and utilities to continue to provide necessary services. The natural progression toward efficiency and lower cost did not occur in the centrally planned countries, perhaps because of lack of natural incentives brought about by a market economy. Stability has not yet been reached at the end of the energy transition in China because of the inability to modernize existing hardware and implement government policy.

The increase in industrial production brought with it an increase in toxic by-products -- the start of the toxicity transition. In a typical transition, toxic substances continue to accumulate and pollute until the public demands a cleaner, healthier environment. Eastern Europe and China have reached this stage, gaining attention not only from their citizens but also from the world as a whole. Unfortunately both countries stand at an economic low, increasing their vulnerability towards continuing the upward slope of production and pollution. Furthermore, environmental policies prove difficult to implement and enforce.

Another type of transition is now occurring in Eastern Europe and China. The need to improve material well-being in the socialist countries has led to a desire for a political transition towards democracy. Such a transition is underway in Eastern Europe and dramatic economic reforms in China suggest this country will soon follow. It is

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[5] William D. Drake, "Towards Building Theory of Population-Environment Dynamics: A Family of Transitions," 301-349

interesting to note that socialism was initially seen as the inevitable outgrowth of capitalism. Marx and Engels argued that a capitalist society generates problems that can only be solved by a transition to socialism. Evidently, many countries in Central and Eastern Europe never succeeded in a stable transition to socialism. Instead, their transitions resulted not in equilibrium but rather in collapse. Now a reverse transition toward capitalism is occurring. In Eastern Europe these changes have grown to a transition from centrally planned economies to market economies. China may follow this path as well, and it would therefore be wise to trace the current socio-economic and environmental problem-solving techniques in Eastern Europe, as China may soon encounter a similar necessity to address such crises.

Public Policy

The problem with using public policy to limit pollution and energy intensity deals with yet another transition mentioned in the chapter: the bureaucratic transition. Common among all centrally planned economies is a bureaucratic structure that sets environmental policies from the top down. The policies must pass through various tiers in order to reach the local level, by which time they are often distorted and weakened. For example, the multi-tiered system of prices in China allows mines to sell coal that exceeds planned quotas to other enterprises that manufacture "out of plan" goods which are then sold for the profit of employees.[6] The former Soviet Union, as another example, had one of the strictest governmental environmental policies in the world -- but lacked the incentives and management structure to enforce it.[7] Western democracies, on the other hand, rely on competition between independent enterprises to naturally curb costly waste of environmental resources.

China has developed policies to reduce coal use, but not to improve energy efficiency. The goal is the reduction of urban air pollution, freeing rail cars for non-coal cargo, and the reduction of sulfur oxide emissions. It is difficult to imagine Chinese families using less energy -- and thus less coal. A Chinese household consumes 36 times less energy than an American household.[8] As the economy improves, no doubt individuals will want to use more energy. Public policy concerning energy efficiency will prove more productive than directly limiting the quantity of coal consumption.

William Drake stresses: "Whether a society passes through the transition into a satisfactory state is determined by many factors, largely defined, and often remediable by human intervention. It should be the purpose of public policy to formulate, develop and implement these positive interventions."[9] Indeed, the transition toward more efficient energy use will depend greatly on public policy as well as social interventions. Not only

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[6] Chandler, 123
[7] Charles E. Ziegler, *Environmental Policy in the USSR,* (The University of Massachusetts Press, Amherst, 1987), 102
[8] Chandler, 121
[9] Drake, 303

will top-down policy enforcement from the central government become necessary, but also participatory management programs at the local level will be needed.

Participatory management programs approach problems from within the community as opposed to from the outside. In participatory management, people coming from outside the community serve as valuable resources -- experts who can answer questions, provide examples of other successful projects, warn people of the negative side effects of newly created policies, and facilitate projects initiated by the community. These efforts are commonly referred to as a grass-roots projects. Although grass-roots environmental organizations are making their way into Eastern Europe, it is still doubtful when environmentalists in China will have enough democratic power to organize and have an impact on governmental policy. Environmentalists clearly need more freedom in China.[10]

Limits

The idea of limits to throughput in Beyond the Limits is particularly relevant to energy efficiency. The limits to energy growth include limits from sources of fossil fuels, limits in technology, limits in funding available for alternative energy sources, and limits to the sinks for the pollution produced by burning fossil fuels. This book addresses the limits of coal in particular as being limits to the sinks in carbon dioxide. Optimistically, the authors write, "Technical changes and efficiencies are possible and available, which can help maintain production of final goods and services while reducing greatly the burden on the planet." [11] The problem then becomes one of the limits to efficiency rather than quantity.

Beyond the Limits also gives optimistic scenarios of improving energy efficiency worldwide, rising to the efficiency levels of Western Europe and Japan: "Efficiency of that magnitude would make it possible to supply most or all of the world's energy from solar-based renewable sources--sun, wind, hydropower, and biomass such as wood, corn, or sugarcane." [12] It is improbable that the need for world energy will decrease, especially with an increase in population. Thus, the answer to air pollution seems to come from cleaner energy production and more energy efficiency. Indeed, the book describes limits as "speed limits, not space limits, limits to flow rates, not limits to the number of people on the amount of capital." [13] Certainly, after the next few decades the reality of global climate change may force the world to dramatically slash fossil fuel use. However, at this point Draconian reductions seem severe, and energy efficiency appears more practical and attainable.

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[10] Stern, 66
[11] Meadows, 8
[12] Ibid., 76
[13] Ibid., 99

Overview of Paper

I have divided this paper into two basic sections. The first section covers transition theory, discussing a variety of transitions relating to energy, population, and environment. The data used in this section come primarily from the World Resource Database.[14] This section includes a description of the transitions in relation to China, graphs of the data, and curve fits of various parameters with discussions of the implications of these fits.

The second section concerns dynamic modeling, referring to the work of Dennis Meadows et al. in Beyond the Limits. This portion of the paper concerns the relationships among the various transitions. I have chosen to use Stella software to form a dynamic model of energy-population-environment relations in China.[15]

The Demographic Transition

The demographic transition models time changes in total population. At the starting point of the demographic transition birth and death rates remain in relative equilibrium. A dramatic drop in death rates initiates the transition. Usually death rates fall because of improving health conditions of the population, but they could also depend on solving political conflicts and wars or improving sanitation or agricultural technology. When gradual decreases in death rates are accompanied by decreases in birth, the total population increase becomes manageable. Problems arise when the death rate plunges rapidly without time for a corresponding decrease in birth rate, bringing about an unmanageable population explosion.

The final stage of the demographic transition requires reductions in birth rates. In areas such as the United States, birth rates dropped naturally because of a need for fewer children as infant mortality decreased and technology took the place of human labor. However, nations facing this stage of the transition today do not have the time for natural decreases in birth rates. Public policy and education have become critical to overcome this lack of time. China, for example, has dramatically decreased birth rates over recent decades because of its implementation of family planning policies.

In assessing China's demographic transition, it appears instructive to compare it to transitions of other highly populated and industrialized nations. I will take Japan, the USSR, and the USA as countries for comparison. The People's Republic of China contains the largest national population on earth, currently comprising one-fifth of the total world population. Current figures place China's population at 1.165 billion of the world's 5.4 billion. The Population Crisis Committee forcasts that China's population

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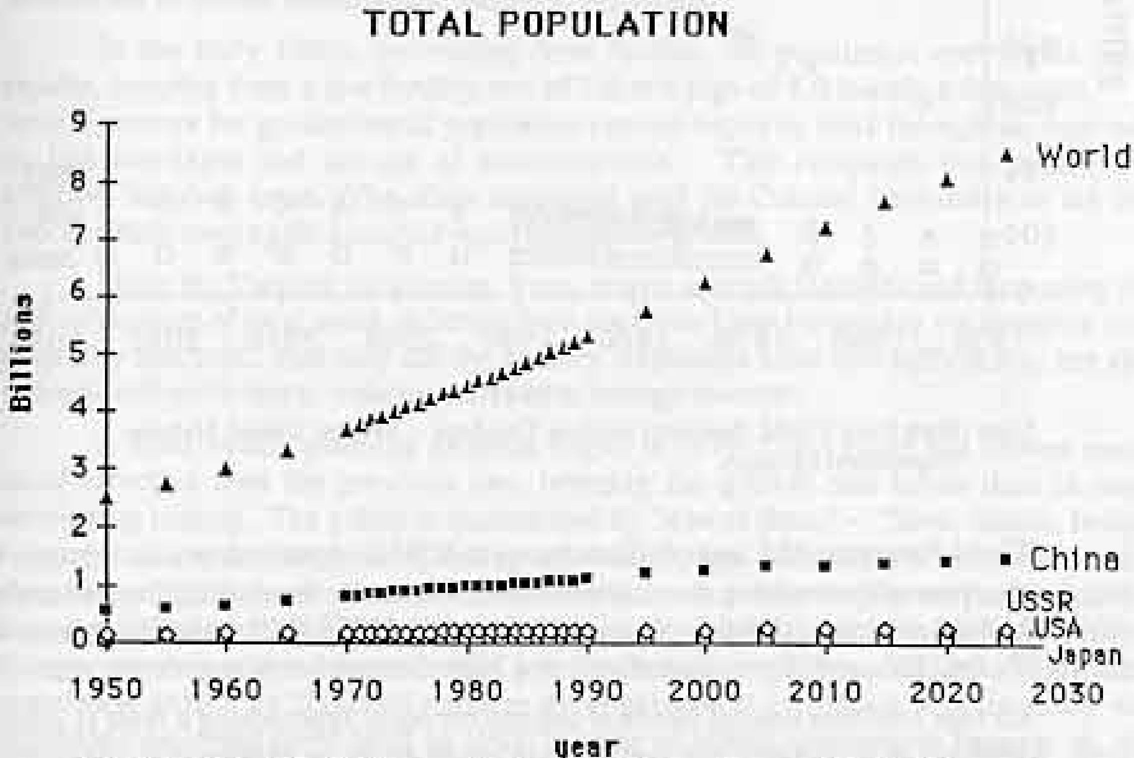
[14] World Resource Data Base (Oxford University Press, New York, 1992)

will stabilize at 1.5 billion.[15] This figure is actually optimisitic when one compares it to India, whose population is expected to surpass that of China by 2035 and may level off at 2 billion.[16] However, a levelling of population growth in China at 1.5 will in itself place extreme stress upon not only the natural resources of China but the environment as well. Until recently, the economic troubles have overshadowed environmental concerns. However, the future fate of China may depend more on how it treats environmental degredation than on socio-political concerns.[17]

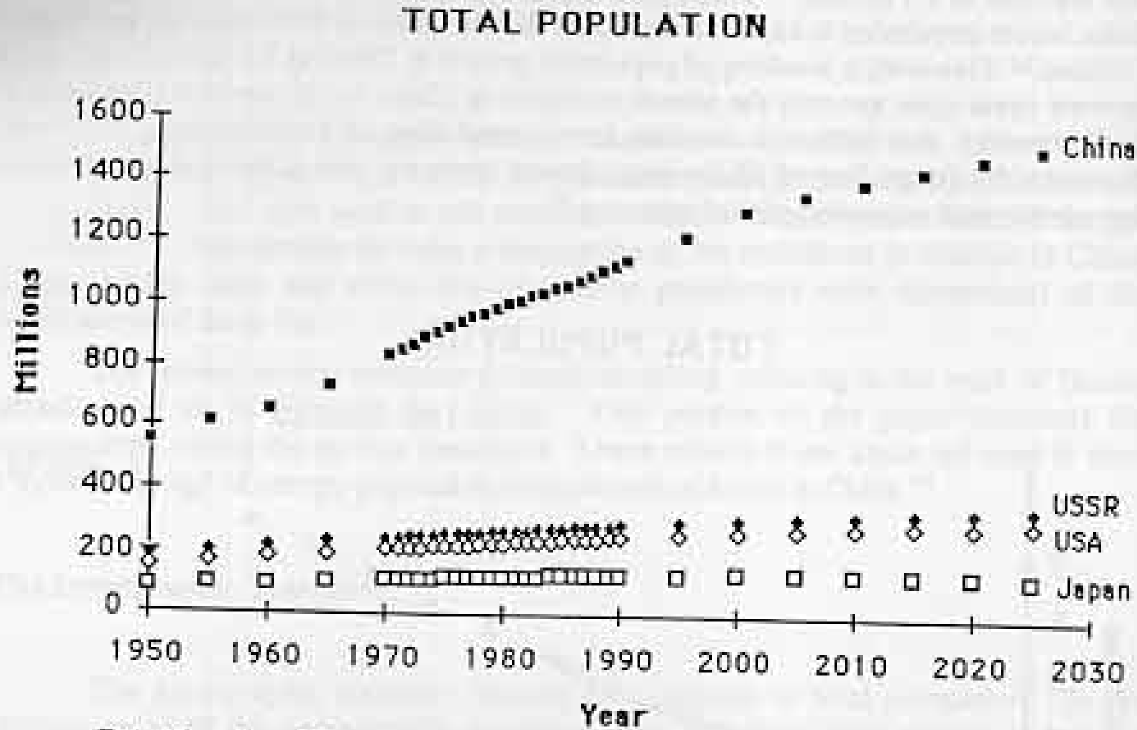


Data taken from World Resource Institute Database – Source: United Nations Population Division

[15]Barbara Crossette, "Population Policy in Asia in Faulted," *The New York Times*, (New York, Sept 15, 1992)

[16]Ibid.

[17]Vaclav Smil, "China's Environmental Morass," *Current History*, (Sept 1989, v88 n539), 277



Data taken from World Resource Insitute Database – Source: United Nations Population Division

World Resource data and predictions up to 2025 suggest a dramatic increase in population, primarily resulting from population increase in the developing nations of Africa, Latin America, and Asia. Comparing graphs of China's population to those of the USSR, the USA, and Japan, we indeed see a large discrepancy in population rates.

All four countries exhibit trends of logistic curves -- approaching a limit at infinite time. Meadows et al. suggest that these curves could either be exponential, logarithmic with a limit, or curves which rise and then fall.[18] Japan has already exhibited a definite decline in population growth rate, and World Resource predictions expect a decline in total population around 2010. The population trends of the USSR are difficult to predict, perhaps because of the current political and economic turmoil. World Resources assumes close to an approximate straight line projection for population growth. The USA is also approaching a limit in population, yet at a slower rate than Japan. It appears that population will level off at 300,000,000. This will not occur, however, until well into the next century.

It is helpful to briefly summarize the recent historical demographic trends of China. In the 1950s, sanitation and medical care improved, causing death rates to decline and an ensuing period of rapid population growth, beginning the critical phase of its demographic transition. China realized the threat of exponential growth and

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[18]Meadows, 123

developed a campaign for birth control. It made abortions more available, ordered health agencies to assist in promoting contraception, and used officials and scholars to argue for birth control. The Great Leap Forward in 1958 began a movement emphasizing a shift to small "backyard" production units, using local resources and labour -- a reaction to the 1953 Five Year Plan which emphasized the development of heavy industry. By 1960, however, it became apparent that this shift actually produced lower quality products at higher expense, as well as took people away from agriculture. The country faced an agricultural crisis, famine, and a rise in death rates. The country tried to counter the crisis by focusing resources once again on agriculture. Irritating this crisis was the concurrent withdrawal of Soviet financial and technical assistance.

In the early 1960s, recovering from famine, the population once again grew rapidly, jumping from a low fertility rate of 3.0 to a high of 8.0 in only a few years.[19] A second attempt for governmental population control began in 1962 through an emphasis on late marriages and the use of contraceptives. This campaign was particularly effective in urban areas. The effort continued until the Cultural Revolution in the late 1960s, which once again launched rapid population growth.

Since the Cultural Revolution, focus turned to small factories and increasing the self-sufficiency of local areas, differing from the Great Leap Forward in the attention paid to quality and cost. Not only did the country emphasize local self-sufficiency, but also national self-sufficiency, isolating itself from foreign markets.

A third family planning program began in 1970. This effort has proved much more effective than the previous two, bringing the growth rate lower than in most developing nations. The policy is summarized by "wan xi shao," -- "later, farther, fewer" -- marry later, space the children, and have fewer of them. The policy's success showed a drop in total fertility rate (average number of children a woman will have) from 4.8 to 2.4 between 1970 and 1980.[20] National birth control policies gained strength in 1979 when the government adopted a one child per family policy. The goal was to reach zero population growth by 2000 and stabilize the population at 1.2 billion.[21] This policy was rigorously enforced from 1979 to 1983, in spite of public disapproval because of the natural human desire for more children and traditional pressure of a family to have at least one son. In the cities, this policy proved quite successful. In rural areas, however, the government met great resistance. In 1984, the government allowed modifications of the policy to occur at local levels, allowing a second child in "difficult rural circumstances." [22]

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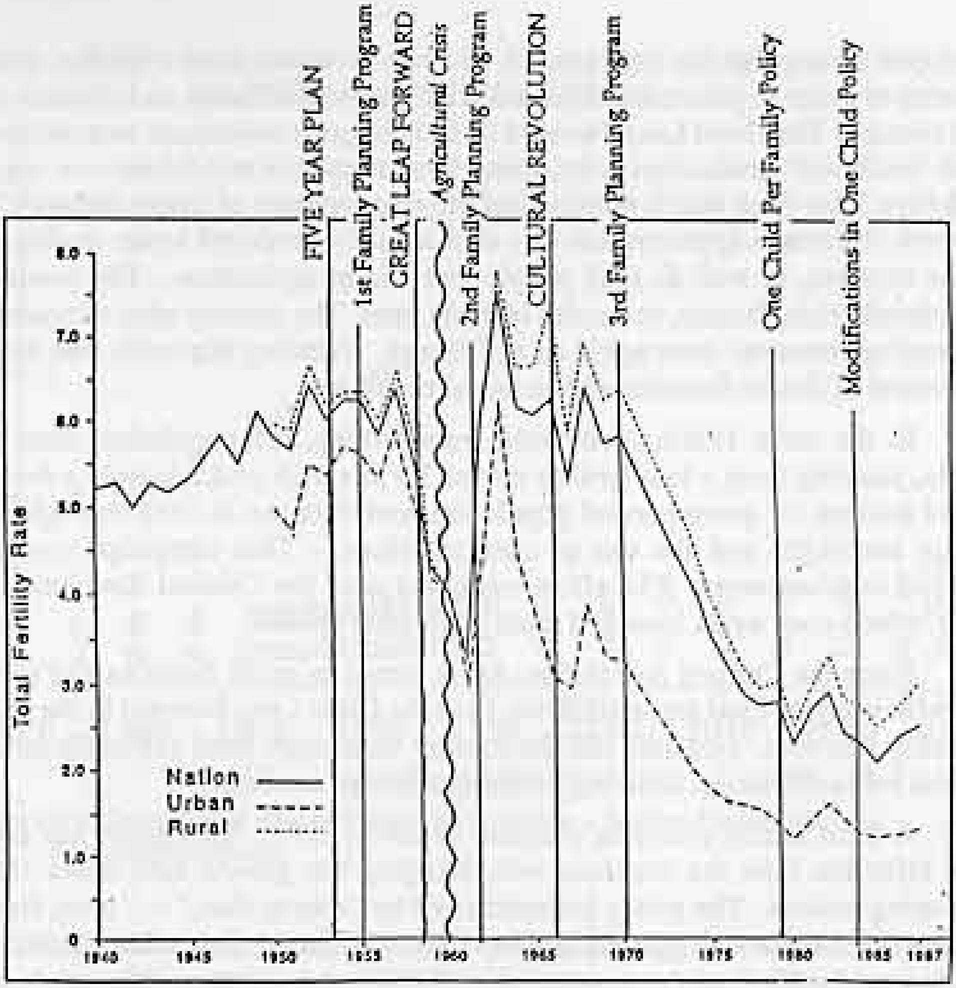
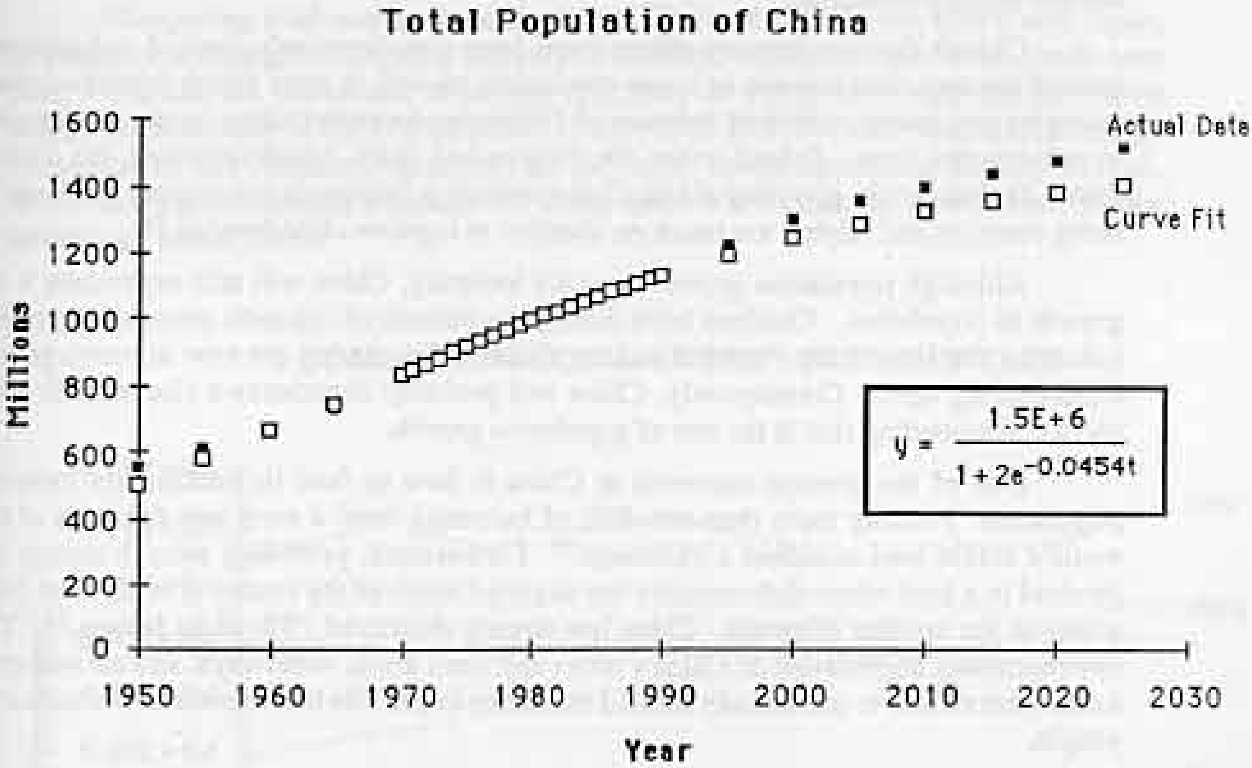
[19]Mei-Ling Hsu, "Population of China: Large is not Beautiful," Focus, (The American Geographical Society, Spring 1992, vol. 42 n.1), 14
[20]Ibid., 14
[21]Ibid., 15
[22]Ibid., 15



Base graph taken from Mei-Ling Hsu, "Population of China: Large is not Beautiful," *Focus*, (The American Geographical Society, Spring 1992, vol.24 n.1), p.14
University of Minnesota Cartography Lab

The graph representing fertility rates follows the expectations of historical population planning policies, allowing a lag time for policy implementation. The first family planning program in the 1950s instigated a decline in fertility rate. The second family planning program began during a rise in birth rates. Fertility rates dropped again after this program. The third family planning program in 1970 dramatically intensified the drop in fertility rates. The 1979 program was followed by a small increase (perhaps because of the child-bearing age of women born in the population boom of the 1950s) and then decrease in fertility rates. Modifications in 1984 correspond with a rise in fertility rate, especially in rural areas. Consequently, we see a strong correlation between policy and population control. It is interesting to note the difference between urban and rural fertility rates. Even after the one child per family policy of 1979, rural women continued to have more than one child, the lowest fertility rate being approximately 2.5. Only in urban areas did the fertility rate approach one.



The 1979 goal of a stable population of 1.2 billion by the year 2000 appears over-optimistic. The population in 1990 was 1.14 billion. This gives only ten years to stabilize the population, at a time when population increases are around 1.4 percent, or over 15 million people per year.[23] According to World Resource predictions, even the Population Crisis Committee's forcast of stability at 1.5 billion appears over-optimistic, when considering a logisitic curve fit aimed to stabilize at this value.

Today, economic concerns overshadow family planning in local rural areas. Each year there are a large number a births exceding town quotas and it is common for towns to under-report births and falsify birth-control records. New efforts will be required to keep China's fertility rate under control. Perhaps the most promising method would be to provide more education and opportunities for China's women. Female illiteracy comprises 70 percent of all illiteracy in China. [24] Increasing literacy among women would give them more opportunities outside of family responsibility.

However, these efforts will require a substantial break from traditional custom. Another hopeful prospect in slowing population growth suggests that as China becomes more urban, values will change, and couples will have fewer children.[25] Unfortunately,

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[23]Smil, 1989, 277
[24]Hsu, 16
[25]Ibid., 16

China already cannot provide basic needs, employment, and a clean environment for its current urban populations.

China's family planning efforts have been simultaneously praised and critized: praised for statistical success in lower population growth, at rates which few developing countries can boast; criticized because of Draconian measures taken by the government to achieve this drop. Indeed under the Reagan and Bush Administrations, the United States denied family planning aid to China, accusing its population control methods of being coercive and relying too much on abortion to regulate child-bearing.[26]

Although population growth rates are lowering, China will still experience a net growth in population. Children born during the periods of dramatic population growth following the Great Leap Forward and the Cultural Revolution are now at marriage and child-bearing age . Consequently, China will probably experience a rise in birth rates and a corresponding rise in the rate of population growth.

One of the greatest concerns in China is how to feed its continually growing population. Feeding more than one-fifth of humanity from a mere one-fifteenth of the world's arable land is indeed a challange.[27] Furthermore, providing enough energy for survival in a land where deforestation has depleted much of the source of traditional fuels arises as yet another dilemma. China has already destroyed 75% of its forests.[28] The environmental degredation of China's urban and rural areas, waterways, and air will only exacerbate efforts to use already limited resources to provide basic needs to the country's people.

The Energy Transition

In the typical energy transition, a country begins to transfer traditional fuel use and human work for basic needs to the use of other energy sources -- primarily fossil fuels such as coal, oil, and natural gas. The increase of energy production at first appears free. In this case, energy use is blind to the notion of limited fossil fuel resources and pollution effects.

Once a country attains the capability to meet the basic needs of the people, it continues to increase energy production to meet luxury desires. This trend could continue indefinitely if lack of resources and pollution effects did not make themselves apparent. However, once these costs are realized, the country adopts more efficient technology and develops alternative sustainable energy sources. Energy efficiency requires that equivalent amounts of resources produce more energy at lower pollution costs. Adoption of such efficient technology as well as alternative sources (e.g. hydropower, wind generation, biomass, solar photo voltaic cells, and nuclear power)

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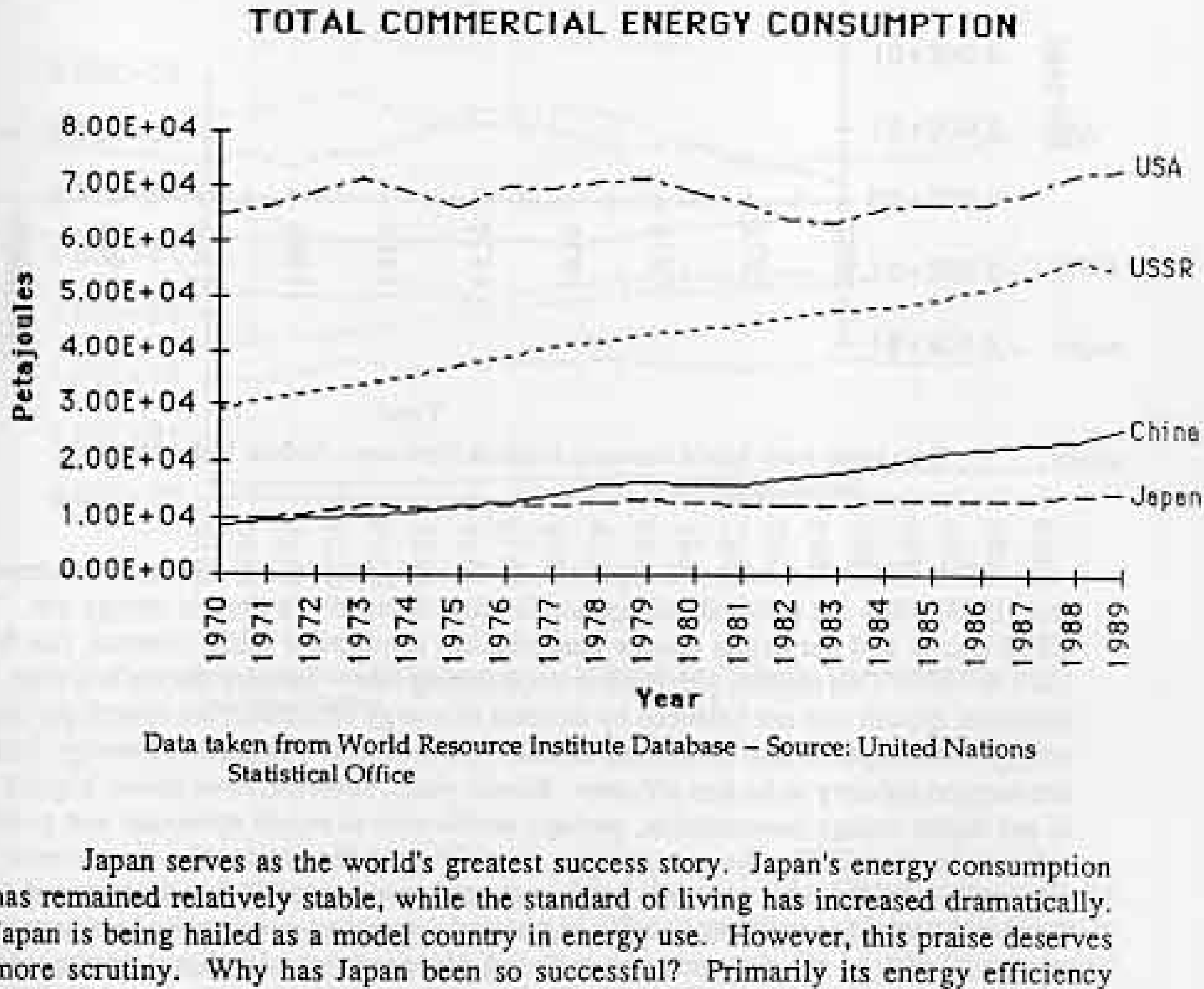
[26]Crossette
[27]Smil, 1989, 278
[28]Meadows, 57

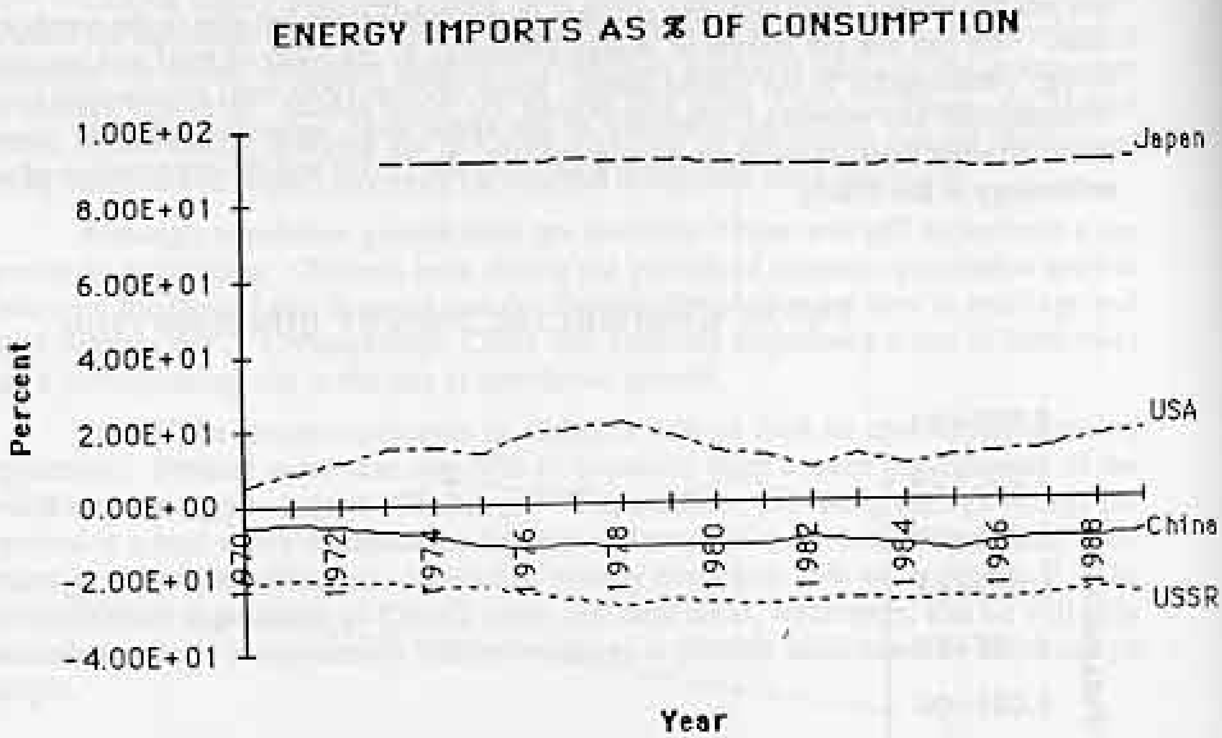
becomes a necessity. Energy consumption decreases as a result of efficiency, while the end-products of energy use remain stable.

Comparing total energy consumption in China, the USA, the USSR and Japan, one readily notes a great disparity not only in absolute values but also in the trends over time. We can see the effects of energy efficiency in the plots of total and per capita energy consumption in the United States. From 1970 to 1990, total commercial energy consumption has remained relatively at the same level, increasing slightly overall, demonstrating fluctuations from the Oil Crisis in the 1970's and the introduction of new technology in the 1980's.



Data taken from World Resource Institute Database – Source: United Nations Statistical Office

Japan serves as the world's greatest success story. Japan's energy consumption has remained relatively stable, while the standard of living has increased dramatically. Japan is being hailed as a model country in energy use. However, this praise deserves more scrutiny. Why has Japan been so successful? Primarily its energy efficiency derives from development of nuclear power in the 1980s. Japan's low pollution levels also stem from reliance on nuclear power ,as well as dependence on imports. Studying the energy imports as a percent of energy consumption, one plainly notices Japan's lack of self-sufficiency concerning resources. We must therefore be careful in trying to apply Japan's model of success to other nations.

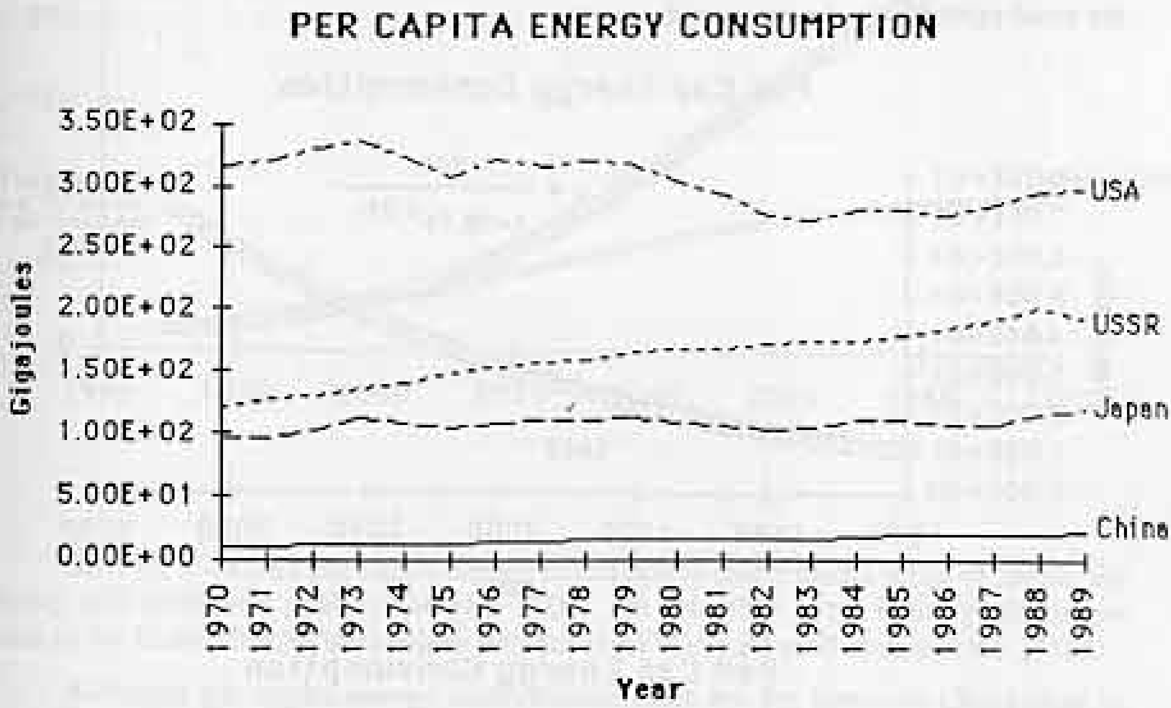


Data taken from World Resource Institute Database -- Source: United Nations Statistical Office

The USSR has followed a pattern of dramatic increase in energy consumption until 1988, when the political and economic crisis demanded a drop in energy use. The USSR's total and per capita energy consumption exhibited a fairly constant rise from 1970 to 1990. This country persisted in emphasizing heavy industry during this time. As industrial growth was not balanced by increase of energy efficiency, the overall per capita energy consumption rate continued to rise. Government subsidies of energy further encouraged industry to be less efficient. Recent years, however, have shown a quick fall in per capita energy consumption, perhaps attributable to recent economic and political reforms in the USSR. As an example, over the past few years, the government has removed subsidies and the cost of energy and transportation have increased. As electricity becomes more expensive and electricity meters are installed, industry and residents will be forced to account for their energy use, and per capita energy consumption will probably decrease. Worldwide concern over environmental effects of inefficient energy production in the USSR portends a continued drop in energy consumption in the near future, as the country adopts more energy efficient practices. The USSR is consequently in the phase of the transition where it must shift to higher efficiency and alternative energy sources.

China appears to be following a rise similar to that of the USSR. However, unlike trends in the USSR, the upward slope of energy consumption appears to be increasing with no signs of leveling in the recent future. Increasing worldwide concern over global pollution and dwindling resources coupled with China's recent openness to world politics and markets will shortly place China in the same category as the USSR.

Public concern over the energy consumption and ensuing pollution in China is indeed justified. However, per capita consumption is far below that of the United States, the USSR, and Japan -- as well as most industrialized nations.

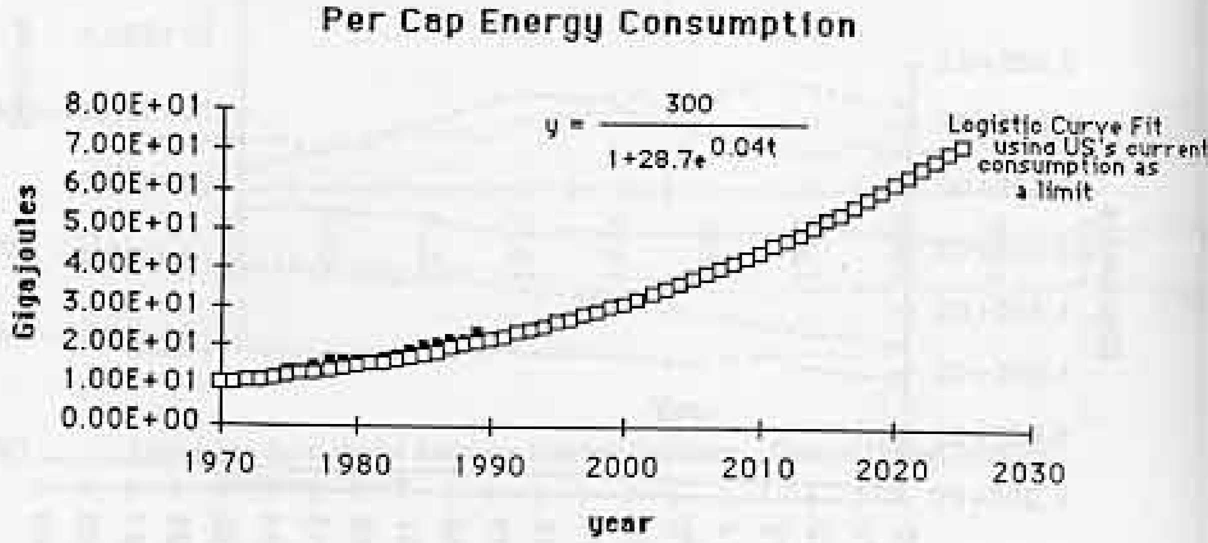


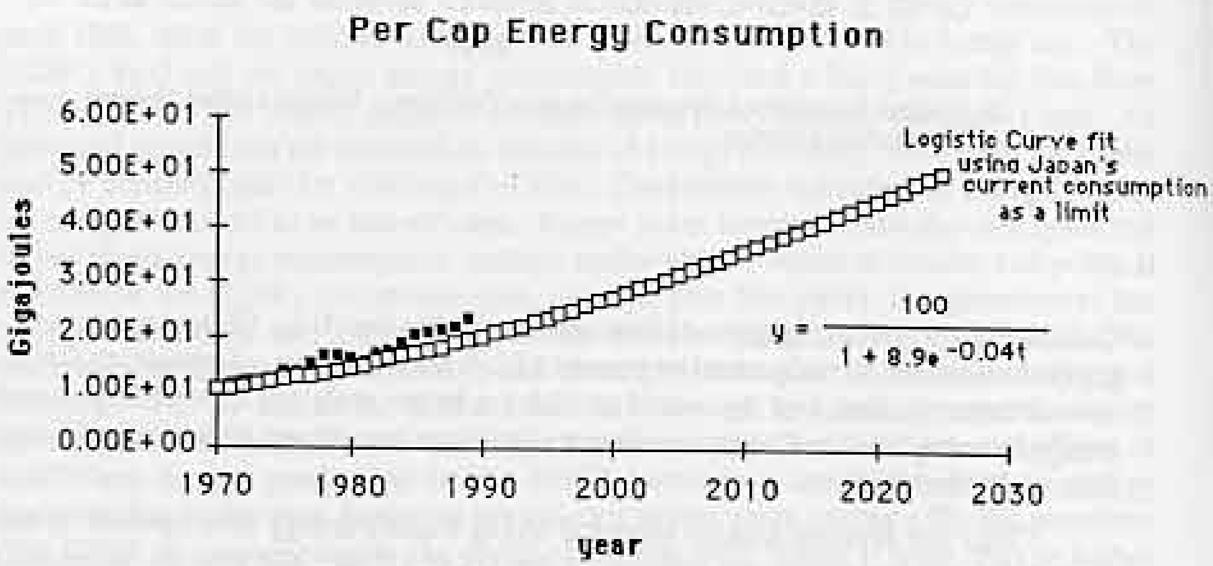
Data taken from World Resource Institute Database -- Source: United Nations Statistical Office

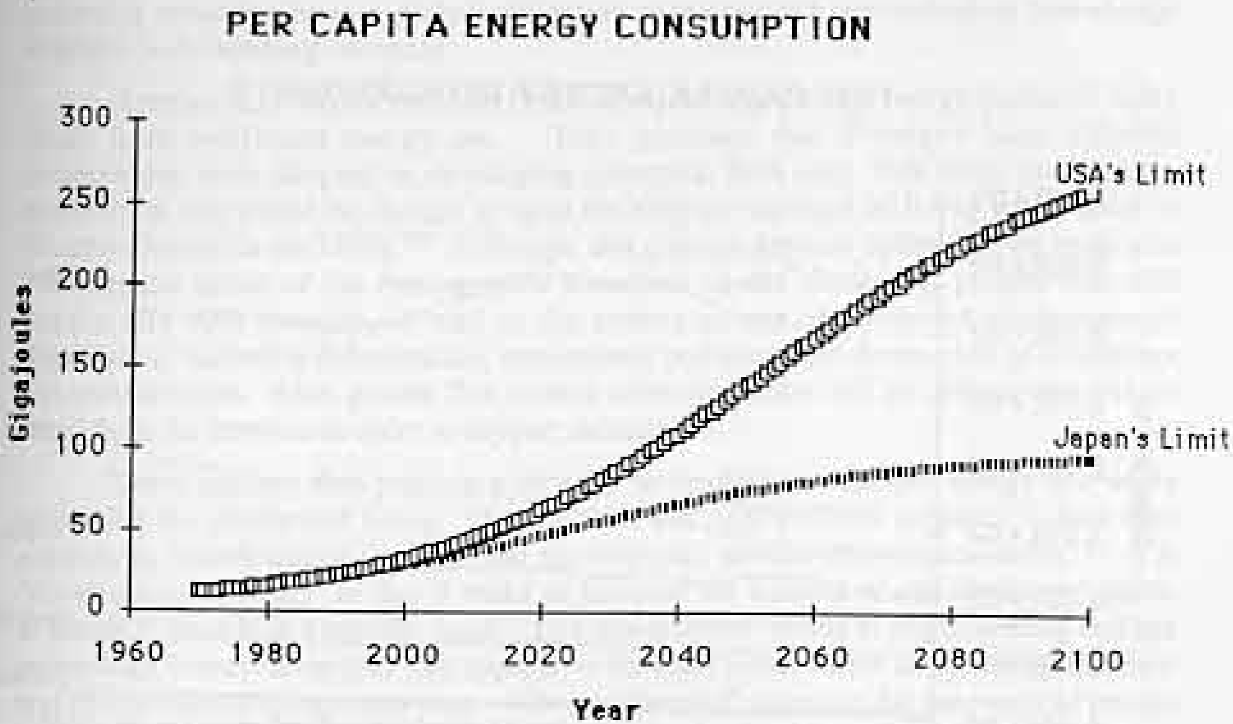
Compared to 300 gigajoules/person used in the US, China consumes 24 gigajoules/person, or only twelve percent of US consumption. Comparing China to several other countries of the world provides a better scale for how little per capital energy is being used in China, and how a significant percentage of this use still comes from traditional fuels.

This fact presents another barrier to aiding China's energy development. It seems absurd for the industrialized nations of the USA, USSR, and Europe to demand a reduction in resource exploitation in China, when a majority of the country lives barely above the subsistence level, using dramatically less energy per capita. In many respects, China is just beginning its energy transition.

If we fit existing data to a logistic curve, we note that the energy transition in China has yet to cross the inflection point of the curve, that is the limits of energy use have not seriously dampened exponential growth. If per capita energy consumption is set at limiting at the current level of per capita consumption in the United States (300 gigajoules), the graph of consumption over time will rise rapidly. On the other hand, if the level were set to Japan's current energy consumption (100 gigajoules) we would see the trend exhibited in the next graph.







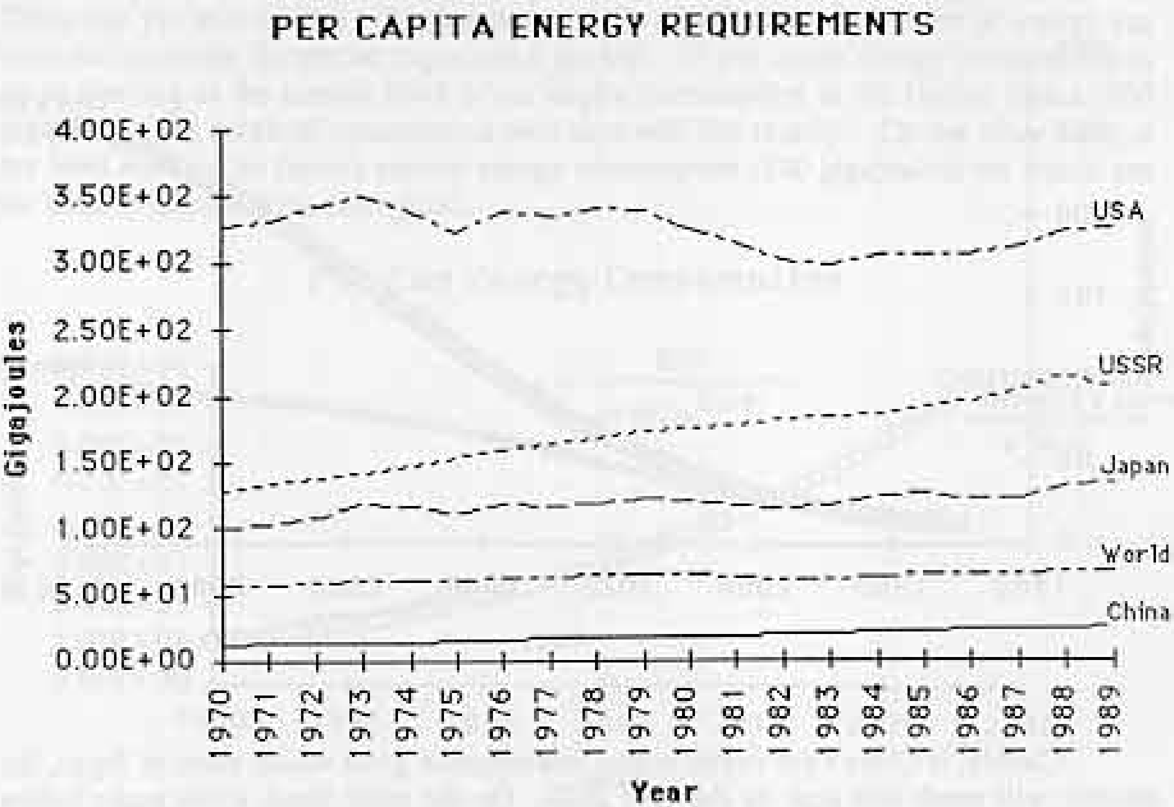
Clearly, if China's per capita energy consumption goals model those of Japan, the country will reach this goal by the year 2100. On the other hand, if the goals follow trends in the United States, the country will not reach this goal until well into the 2100s.

Although per capita energy consumption rates are far lower in China than in developed countries, energy production in China combined with population increases forecast rapid increases in the production of greenhouse gases. Therefore, China's contribution to global energy use will become a world concern. The goal must be to decrease pollution and resource depletion while at the same time allowing increases in services and basic needs. This goal will be met only with development and implementation of more efficient end-use technology.

Specifically end-use refers to the services derived from energy consumption -- from basic needs such as fuel for cooking and heating homes, to conveniences such as transportation and communications. Because of the threats of global environmental change, China faces vastly different constraints in development than the USA, the USSR, or Japan. China must first address basic needs before it can address issues wealthier countries encountered in their own industrial and energy transitions.

When we look at per capita energy requirements, we notice that China remains low, even compared to the world average. A reason for this level is that many people in

China still rely on tradition fuels -- especially in rural areas. Indeed, a great number of people do not even have the necessary energy to maintain subsistence requirements.



Data taken from World Resource Institute Database -- Source: United Nations Statistical Office

China must raise its energy per capita production, find a way to distribute this energy throughout the population and maintain the level of minimum subsistence energy requirements, turning to nonrenewable resources to expand energy production and allow services beyond subsistence requirements. Above all, current energy requirements in the United States should not serve as a goal in other countries. The United States must work to strongly decrease its own energy requirements.

Fortunately, the United States, Japan, the USSR and other industrialized countries have developed technology to make China's transition slightly less painful. The basic problem is how to transfer and implement this technology -- physically, politically, and socio-economically. "When Western Europe and North America were undergoing industrialization, their energy consumption had to grow faster than their GDP's to build infrastructures: roads, bridges, houses and heavy industry. Because of the revolutions in materials science that has taken place during the past half-century, however, materials can now be produced with less energy, and smaller quantities of modern materials can replace larger amounts of older ones. Consequently, developing nations can achieve comparable levels of industrialization with a lower ratio of consumed energy to GDP growth." [29] The industrial countries have a global obligation to make such technological knowledge available to developing countries.

Amulya K.N. Reddy and Jose Goldemberg declare that the energy problems today result from inefficient energy use. They postulate that if today's most efficient technologies were adopted in developing countries, then only 10% more energy than currently in use would be enough to raise the average standard of living to the level of Western Europe in the 1970s.[30] Although, this concept appears optimistic, we must also consider the effect of the demographic transition on the number of people who will require this 10% increase, as well as the serious effects of continued environmental degradation, including deforestation, atmospheric pollution, and destruction of waterways and coastal zones. Also, greater flux toward urban migration will put greater demand on fossil fuels for services in order to support subsistence.

These authors also propose a strategy to implement efficient energy use while increasing the standard of living. They dub this the "DEFENDUS scenario." This term expands to "development-focused, end use-oriented, service-directed scenarios."[31] It is "development-focused" in that it seeks to increase the amount of electricity and goods available to people in a specific local. "End use-oriented" refers to implementing end use technology (material capital) that appeals to the local needs in the most energy efficient and environmentally harmless way. "Service-directed" accounts for the needs of people not in terms of energy, or material capital, but rather in reference to the services they require -- primarily subsistence requirements. The authors point to the fact that survival has become a problem of such urgency to poverty-stricken regions that environmental expense loses its significance. Once people receive basic needs, they will be more open to topics of environmental conservation. The poverty-environment relationship appears to be circular -- poverty feeds environmental degradation, which in turn increases poverty, etc. -- a positive feedback situation. However, policy makers must realize that the most environmentally conservative policies are often also the most beneficial to humanity.

It is interesting to compare China's energy inefficiency to that of the former USSR and Eastern Europe. Both countries have followed a socialist government, a command economy, top-down administration, and a focus on heavy industry, leading to massive environmental degradation, economic collapse, and a reduced standard of living. However, we must also keep in mind the differences in need level in both areas. A great deal of attention has focused on, for example, the exorbitant costs of heating apartments in Eastern Europe and the USSR due to inefficiency. We must realize that much of China's rural population is not even to the level of heating their houses -- many even unable to obtain enough fuel to cook meals. The problems facing both countries are similar, but the scale is dramatically different.

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[29] Reddy, 112
[30] Ibid., 111
[31] Ibid., 113

China is working toward economic modernization. This will require substantial increase of energy consumption. Vaclav Smil argues that achieving a satisfactory quality of life will require energy consumption of at least 40 gigajoules per year -- twice the current Chinese rate of energy consumption.[32] Increasing per capita energy consumption will lead to an increase in coal combustion, in turn contributing more carbon dioxide emissions to the atmosphere. Recent studies indicate that carbon dioxide increases are probably affecting the global climate. If China continues to rely on coal (currently providing 70% of China's energy consumption) as its primary energy source, without necessary pollution controls on combustion plants, and if population continues to rise, a national crisis will spread to a global crisis.

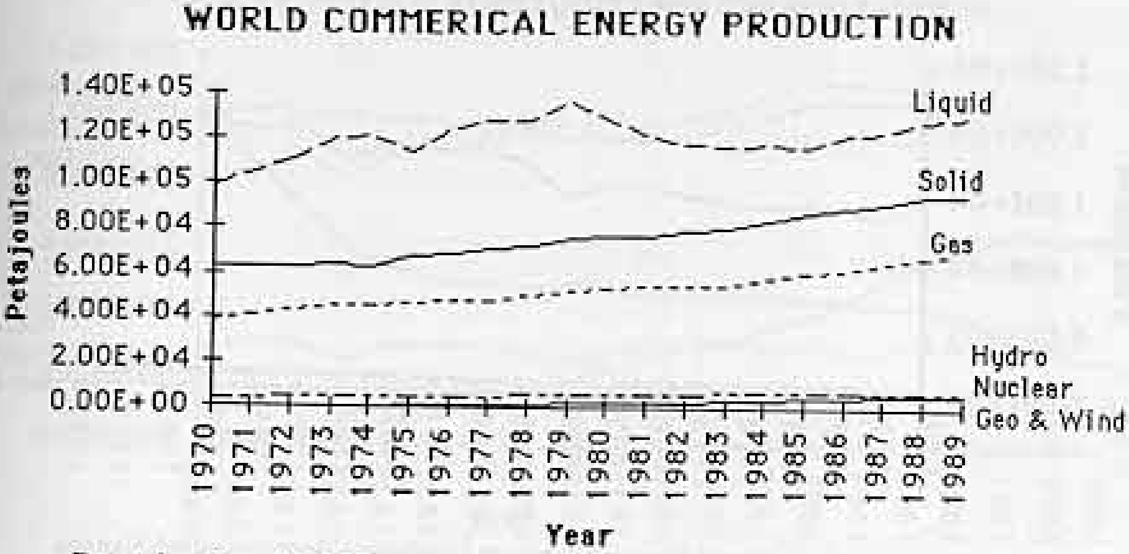
Energy Alternatives

China has the third largest reserve of coal in the world -- second only to the former USSR and the United States. Coal supplies 70% of the industrial energy production of the country. Furthermore, much of the coal is of extremely high quality and easy to mine. Problems with coal use however include inefficiency, lack of transportation (mines are scattered around the country and coal must be transported, usually by train to areas of need), and pollution.

World data on commercial energy production places liquid fuel (oil) at the top, solid fuel (coal) second, and natural gas third -- with renewable resources such as hydropower, geothermal power, and wind power as well as nuclear power relatively insignificant. Worldwide coal use is decreasing in terms of percentage of total energy use. In 1920 it accounted for 70% of the energy supply. Although this percentage remains in China, the figure has dropped to 26% of worldwide energy use.[33]

[32]Smil, 1989, 278

[33]Ged R. Davis, "Energy for Planet Earth," *Scientific American*, (Scientific American, Inc., New York, Sept. 1990, Vol 263 n3), 56

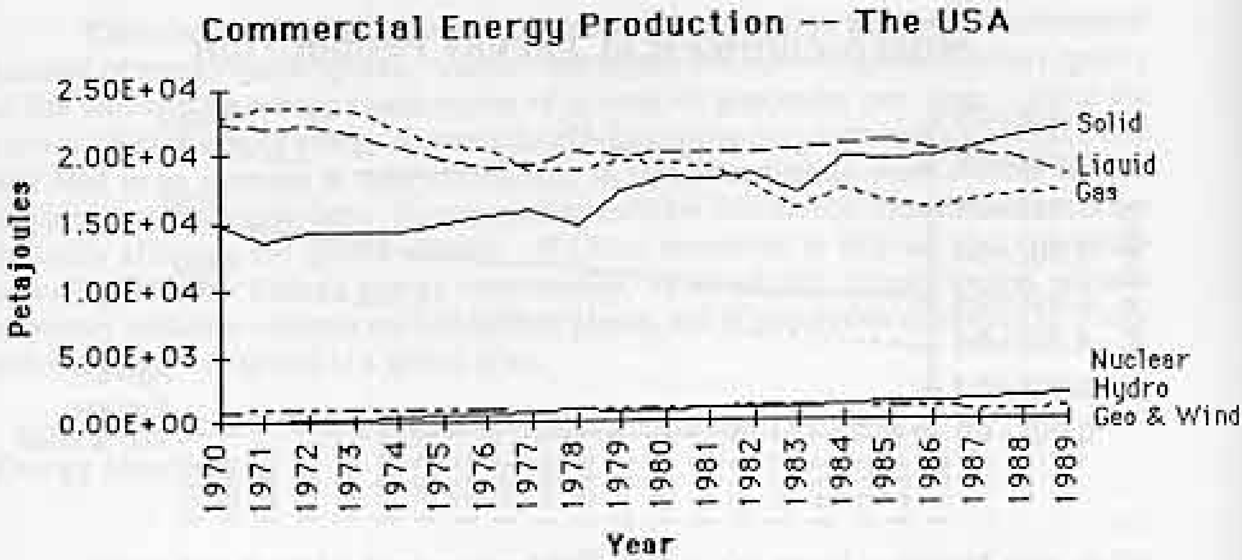


Data taken from World Resource Institue Database -- Source: United Nations Statistical Office

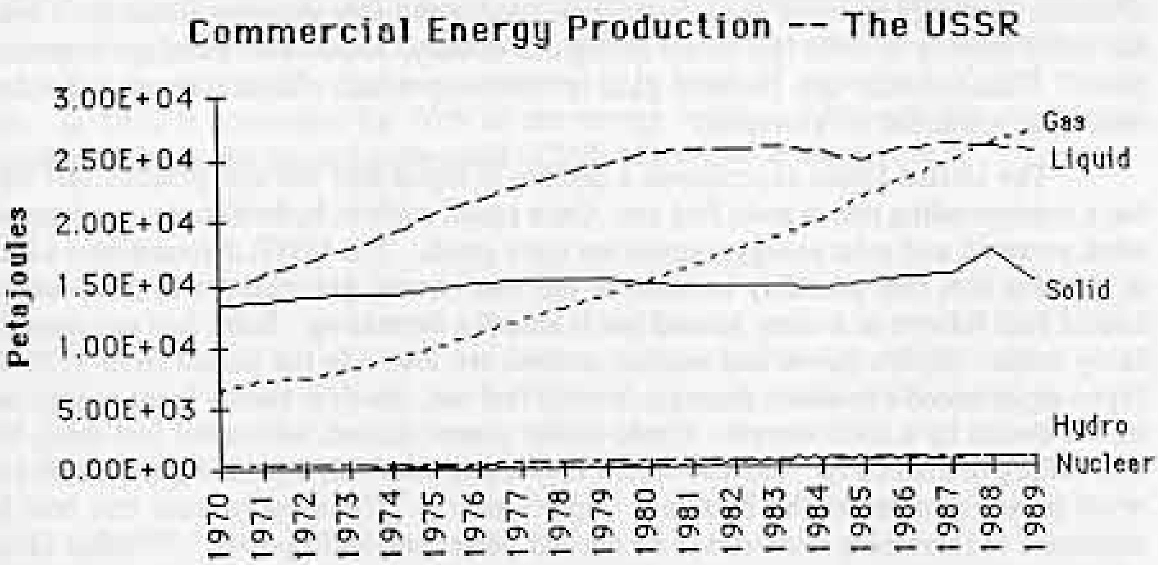
The previous section discussed the low per capita energy requirements of China. Each person requires little energy to satisfy their needs. The question of where this energy will come from should be addressed in conjunction with the analysis of the divisions of energy resource use in energy production throughout recent decades. China has relied heavily on solid fuel (coal) during this century. Liquid fuel (oil) lags in second place. Gaseous fuel use (natural gas) is relatively small. Hydropower and other renewable resources are also small.

The United States experienced a decline in liquid fuel use and gaseous fuel use, but a corresponding rise in solid fuel use. Once again, nuclear, hydroelectric, geothermal, wind powered and solar energy sources are quite small. The USSR demonstrates a lead in gaseous fuel use, probably because of the vast natural gas reserves in the country. Liquid fuel follows at a close second but is actually decreasing. Solid fuel use remains fairly stable. Hydro-power and nuclear sources are low. In the period from 1970-90 Japan experienced a dramatic decrease in solid fuel use. Nuclear energy leads energy use in this nation by a wide margin. Hyrdo-power places second, with solid fuel third, but still falling dramatically. Gas and liquid fuel use is relatively low and geothermal and wind power remains at the bottom. Japan's energy efficiency success can best be attributed to increasing dependence on nuclear power and hydropower. Whether either of these alternatives is compatible for world proliferation is a topic of great debate because of the problems associated with nuclear waste and the environmental threats of building dams.

China persists in its reliance on solid fuel, and no doubt will continue to do so, as reserves remain in great abundance.



Data taken from World Resource Institute Database – Source: United Nations Statistical Office



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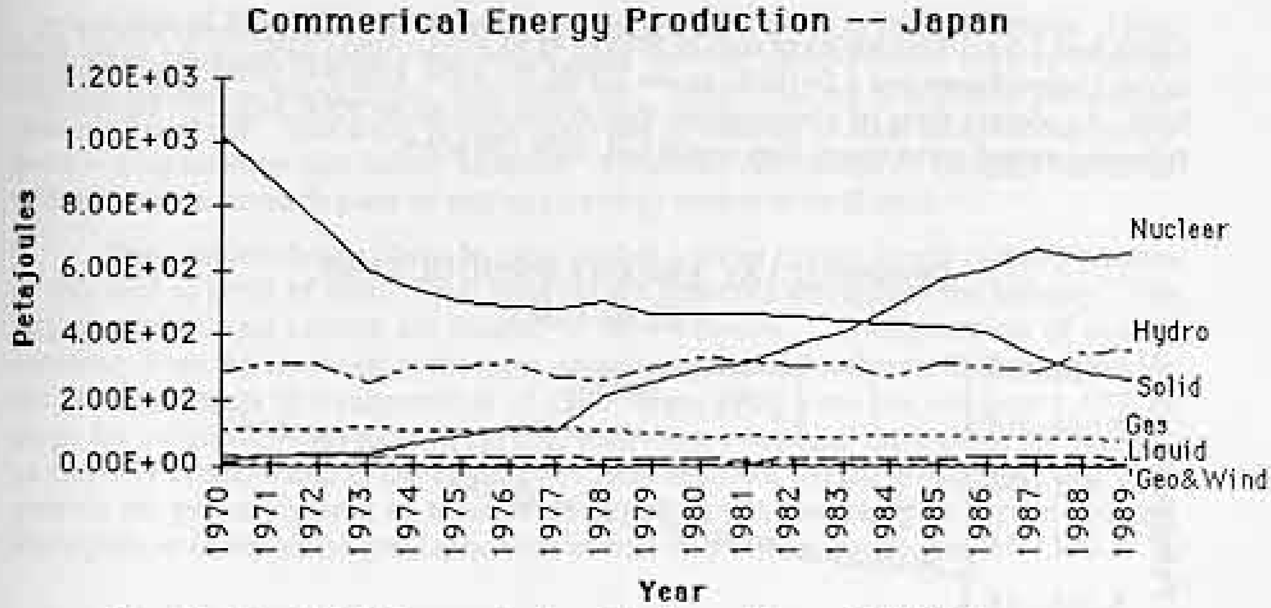

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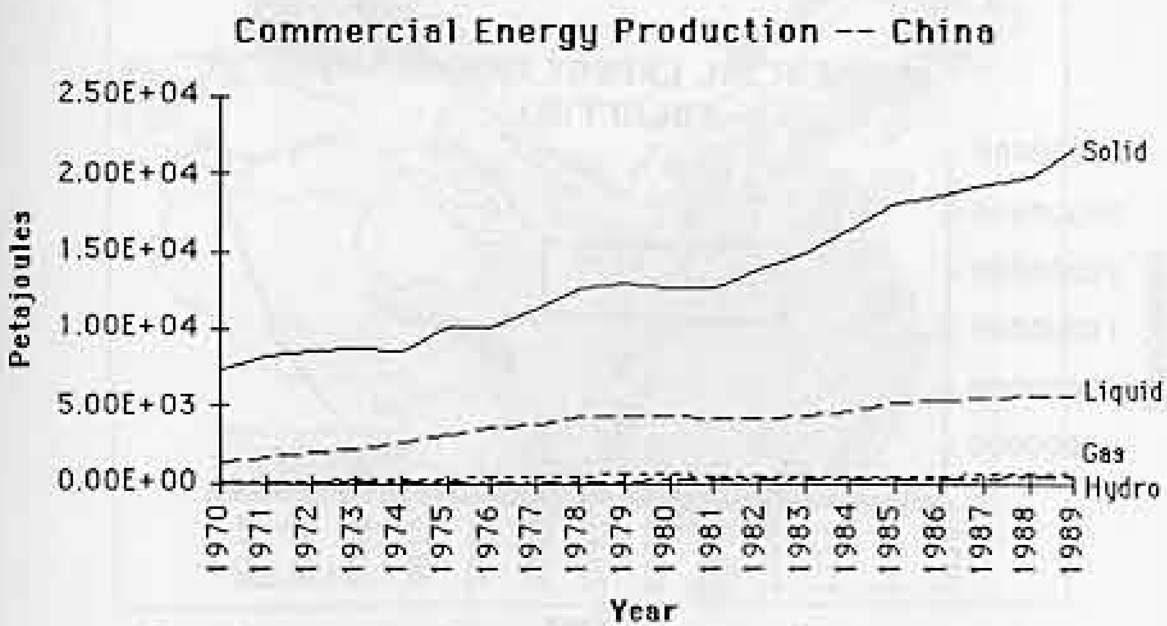
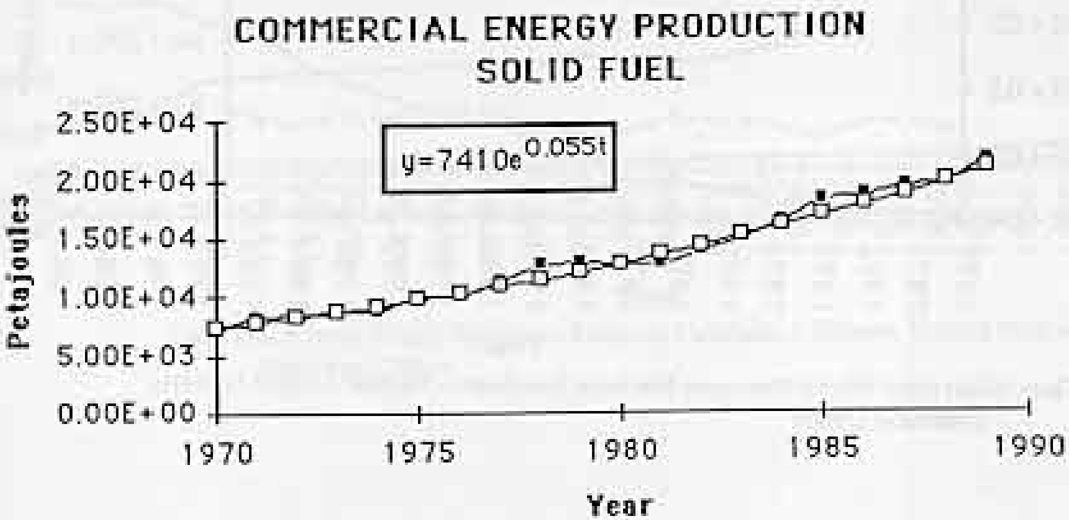
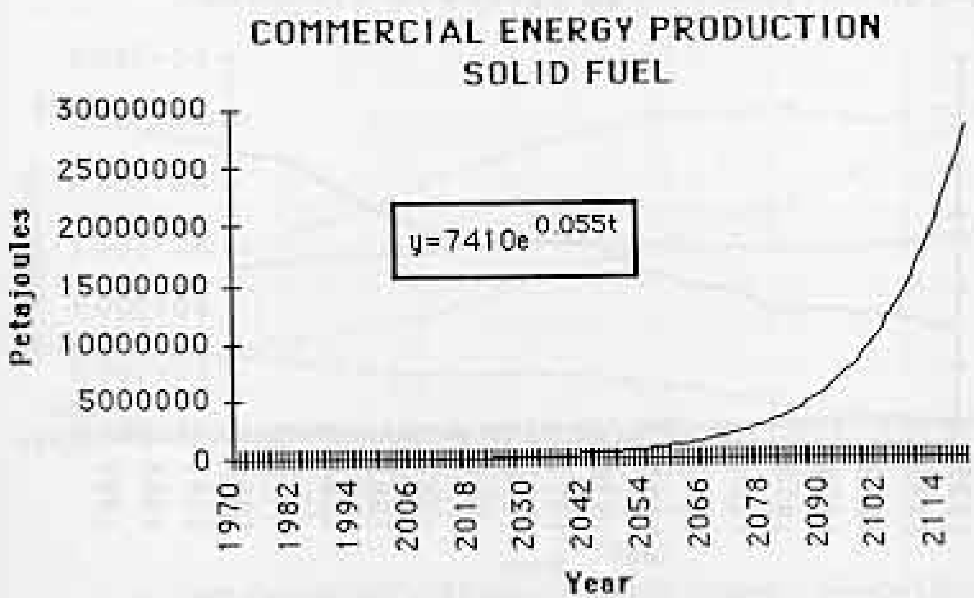


Data taken from World Resource Institute Database -- Source: United Nations Statistical Office

China had 2.5 x 10^21 joules of coal in reserve as of 1985. This compares to 5.5x10^21 in the United States and 4.0x10^21 in the USSR.[34] How long will these coal reserves last? At present rates of consumption they could last up to 1000 years.[35] However, following recent curve trends they would last only 130 years.

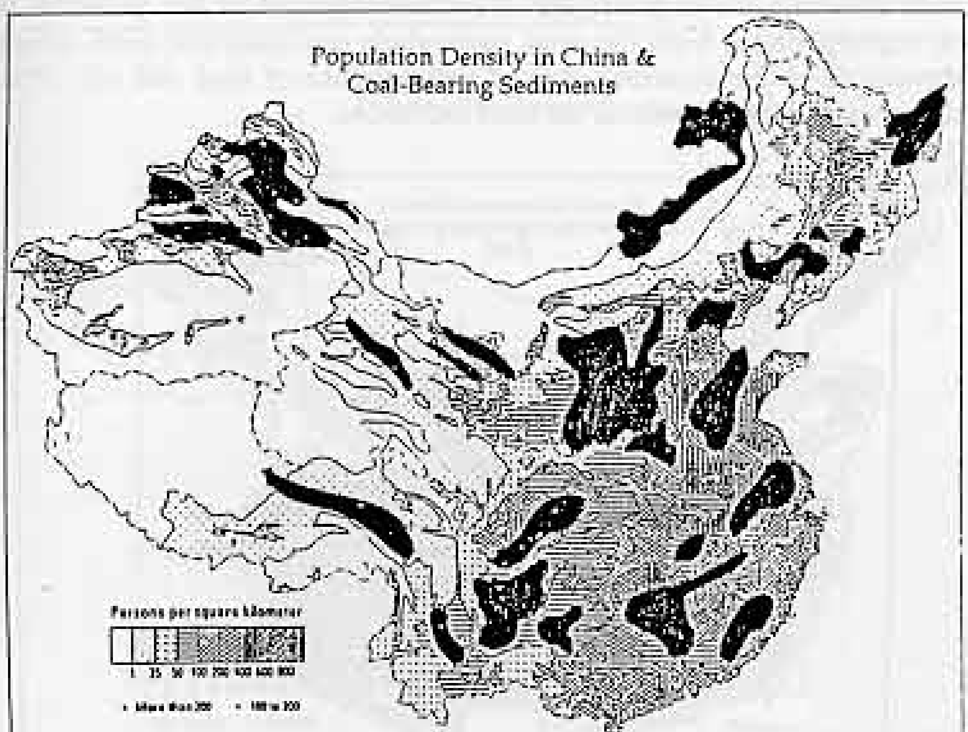




[34] Vaclav Smil, *Energy in China's Modernization*, (M.E. Sharpe, Inc., New York, 1988), 8
[35] Chandler, 126

Little of this fuel is used for residential concerns such as heating houses. Most rural areas continue to satisfy residential need through tradition fuels such as burning biomass material -- wood, straw, cow dung, etc. Urban coal use is higher in percentage than rural coal use. This trend is once again due to reliance of rural areas on traditional fuels -- crop residues and woody biomass. However, destruction of biomass resources will necessitate increasing use of coal as an energy source in rural areas.

One problem facing China in using coal as a major energy source is transportation of this coal to areas of need. Coal reserves are scattered throughout the country. The largest coal-mining centers are located in the Northeast. Transportation of coal is necessary from the Northeast to the more densely-populated Southeast. Railways provide the primary means of transportation of coal. Since 1960, coal has comprised 40% of cargo for railroads.[22] As most of the coal reserves are scattered throughout the country, particularly concentrated in the North away from southern coastal urban areas, rail lines provide the primary means of transportation. However, the transport system remains inadequate to transport the great quantities of coal over such a vast country.



Base graph taken from Mei-Ling Hsu, "Population of China: Large is not Beautiful," *Focus*. [Source: University of Minnesota Cartography Lab] Information for overlay taken from Smil, *Energy in China's Modernization*

[36]China, *Encyclopedia Britannica*, (Encyclopedia Britannica, Inc., Chicago, 1992 Vol 4), 58

Oil comprises nearly half the world's annual use of industrial energy forms, including traditional fuels. However, if consumption of oil and gas continue to double ever 15-20 years as following current trends, the stock will be 80% depleted in another 30 or 40 years.[23] China has limited amounts of oil (with further unquantifiable potential in offshore drilling) and less amounts of natural gas. As a comparison, China has about 1/3 the amount of oil reserve potential and the USSR. Gas reserves are on the order of 1/100 that of the US and 1/1000 that of the USSR. Most oil reserves are located in the northeast -- requiring transportation to the southeast which is the area of greatest energy demand and population concentration. Potential for natural gas exists also from offshore possibilities as well as importing from the former Soviet states to the north. These resources, however, remain overshadowed by the abundance of coal. Clearly, according to national reserves, oil and natural gas seem improbable alternatives to coal consumption.

Perhaps the most optimistic scenario of supplying energy for subsistence needs lies in the generation of hydropower. China is well-endowed with rivers and mountainous regions, providing ample potential for hydropower. Most of the hydroelectric potential lies in the Southwest. While China has rich overall energy potential, most of it remains undeveloped. Furthermore, most of this potential lies in geographical regions distant from the need, particularly the industrial need, which was originally developed in the Northeast due to rich supplies of coal and oil. Potential hydroelectric potential also depends on seasonal monsoons.

Base graph taken from Mei-Ling Hsu, "Population of China: Large is not Beautiful," *Focus*. [Source: University of Minnesota Cartography Lab]. Information for overlay taken from Smil: *Energy in China's Modernization* [Source: Shell *Focus*, 1983]

[37]John P. Holdren, "Energy in Transition," *Scientific American*, (Scientific American, Inc., New York, Sept. 1990, Vol 263 n3), 158

As of 1985, only 7 percent of the hydroelectric potential in China had been tapped, compared to 40% in the United States.[24] Of course, barriers to hydroenergy include current environmental concerns over building dams and diverting the natural flow of waterways. Most of the current hydroelectric stations are in areas of moderate to high population density. Few of them are on the coast, however, where population densities remain the greatest. China possesses great hydorgeneration capacity, and this form of energy will remain a valuable alternative to nonrenewable fuel use.

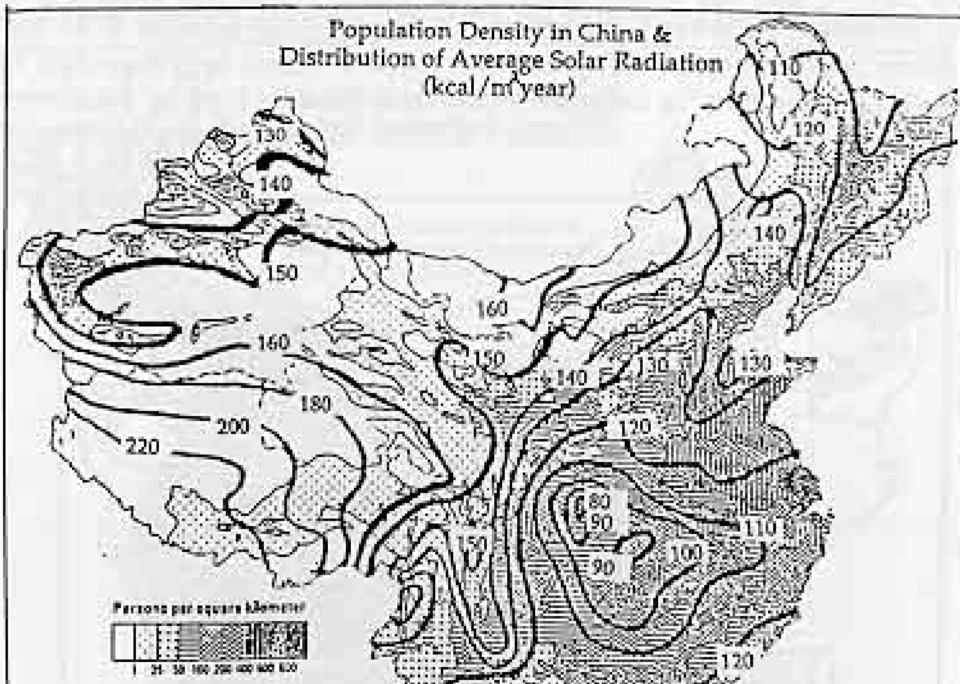
China's most impressive renewable resource lies in the potential for geothermal energy. Influenced by the movements of the Pacific plate and the Indian plate, China experiences not only devastating tectonic movements (earthquakes, for example) but also the potential to harness this energy for human use. The distribution of hot springs presents a valuable indicator of geothermal potential. The annual heat discharge of China's hot springs amount to the thermal equivalent of 3.8 million tons of standard coal.[25] The heat flow harnessible for direct thermal uses, 2,613 GW would provide four times the total of China's primary energy production in the mid 1980's.[26] Today, geothermal energy is used in China primarily for heating greenhouses and fishing pools, hot water for washing and dyeing in the textile industry, and space heating and public bathing. Areas of highest potential in the Southwest have not yet been tapped.

Base graph taken from Mei-Ling Hsu, "Population of China: Large is not Beautiful," Focus. [Source: University of Minnesota Cartography Lab]. Information for overlay taken from Smil, *Energy in China's Modernization*. [Source: State Geological Bureau 1979]

[38]Smil, 28
[39]Ibid., 15
[40]Ibid., 17

Yet another alternative renewable energy source is the direct conversion of solar energy through solar collectors. Although solar energy has been used in China in the sunnier North to heat water for several bathhouses, hotels, and hospitals, solar energy has remained expensive and impractical for most homes and businesses in China. By 1983 only 5,000 small household solar energy water heating units were in use.[27] This number is insignificant compared to the more than 200 million families in China. The reasons for the unpopularity of solar energy is both the expense and the lack of stable sunshine across the country. Smil points out that even if the total collector area increased 100 fold over 1983 levels, nationwide fuel saving would only amount to 1% of the coal consumption.[28]

Furthermore comparing the distribution of solar radiation to population density, we notice a complete mismatch. Areas with the greatest population density have the lowest annual solar radiation. The densely settled farmlands and cities of the coastal and interior South receive an amount of solar energy equivalent to the Pacific Northwest or Maine, whereas the virtually uninhabited regions of the western plateau experience more solar energy than Arizona or New Mexico.[29] Urban areas also block a great deal of sunshine through air pollution and natural dust.



Base graph taken from Mei-Ling Hsu, "Population of China: Large is not Beautiful," Focus, [Source: University of Minnesota Cartography Lab]. Information for overlay taken from Smil, *Energy in China's Modernization* [Source: Wang, Anang, and Li (1980)].

[41]Ibid., 13
[42]Ibid., 13
[43]Ibid., 10

Similarly, wind power potential remains low. The highest potential once again lies in the least populated areas. The most promising region is the Nei Monggol area where wind faster than 3 meters per second occur for more than 200 days a year.[44] China is working on developing this potential. Indeed by 1985 there were 3,000 small wind-powered generators across Nei Monggol and other regions. However, future plans remain uncertain, and the contribution of wind power to China's energy production will probably remain small in the near future.

Yet another possibility arises with the construction of nuclear power plants. Until recently China has not adopted nuclear energy for commercial use. However, three plants are now under construction.[45] Nuclear energy on the surface appears to be a panacea to environmental problems -- particularly the threat of global warming and local air pollution. However, controversy remains over the danger of the operation of nuclear power and the problems of radioactive waste disposal. Nuclear power also stands economically above other means of energy production. However, until nuclear power can be regulated safely, and the people can be assured of its controllability, it remains for many a dangerous option.

The Urbanization Transition

Urban migration usually occurs when rural communities lose their means of sustenance either because of desertification of farmland, deforestation, or a change in governmental policy on land use or ownership. People then move to the urban areas hoping to find employment in industry or services. This transition is particularly interesting in China. In recent decades the urban population has increased exponentially, with a dramatic increase after 1980.

Comparing the recent trends and future projections of urbanization collected and projected in the World Resource Database for China, the USSR, the USA, and Japan, we note frightening difference in urban population growth. Compared to world urban population growths, China remains at one-fifth the population increase.

One explanation of the difference in urbanization rates depends on the urbanization transition. The US, USSR and Japan are at the end of their urbanization transitions, foreseeing a slowing rate of increase in urban populations. China, however, joins other developing nations in beginning the urbanization transition. Although China boasts some of the most highly populated cities in the world, compared to its total population and population density, the most dynamic part of the logistic growth curve is yet to come.

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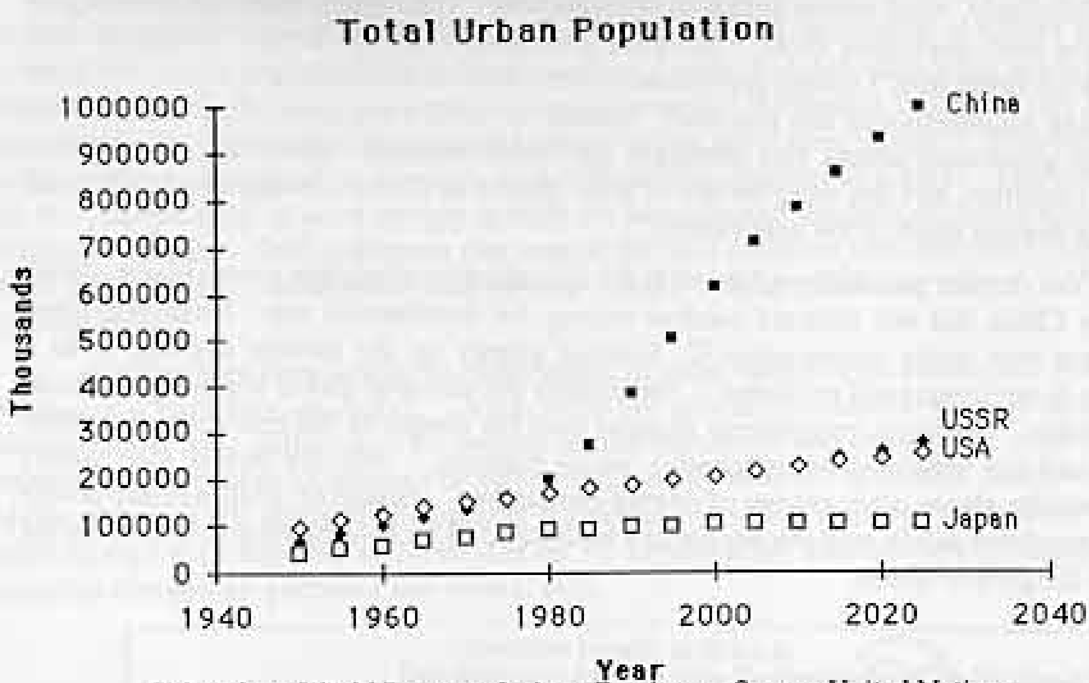
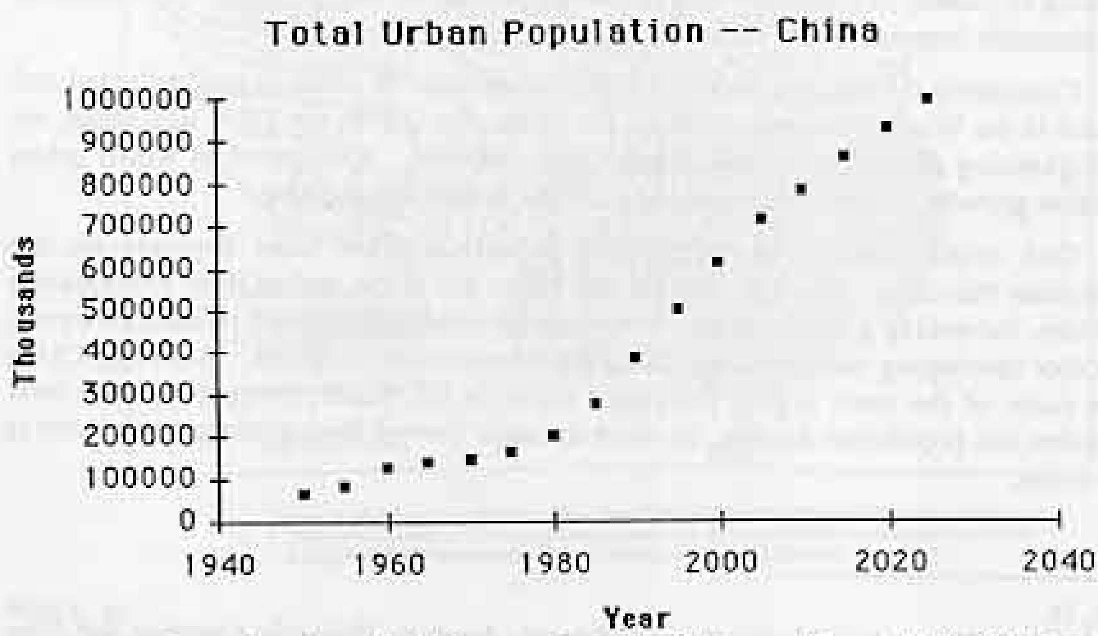
[44]Ibid., 14

[45]Wolf Hafele, "Energy from Nuclear Power," *Scientific American*, (Scientific American, Inc., New York, Sept. 1990, Vol 263 n3), 138

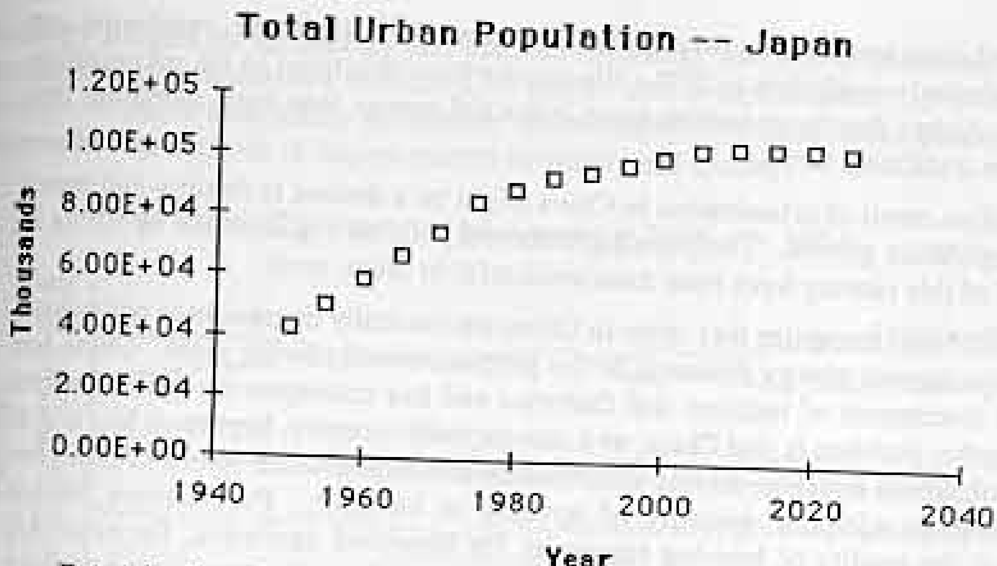


Taken from World Resource Insitute Database -- Source: United Nations Population Division, United Nations Center for Human Settlements

The graph of total urban population in China shows that the inflection point (change in acceleration of population growth rate) will occur around the turn of the century. In Japan, as a comparison, this turning point occurred around 1970.

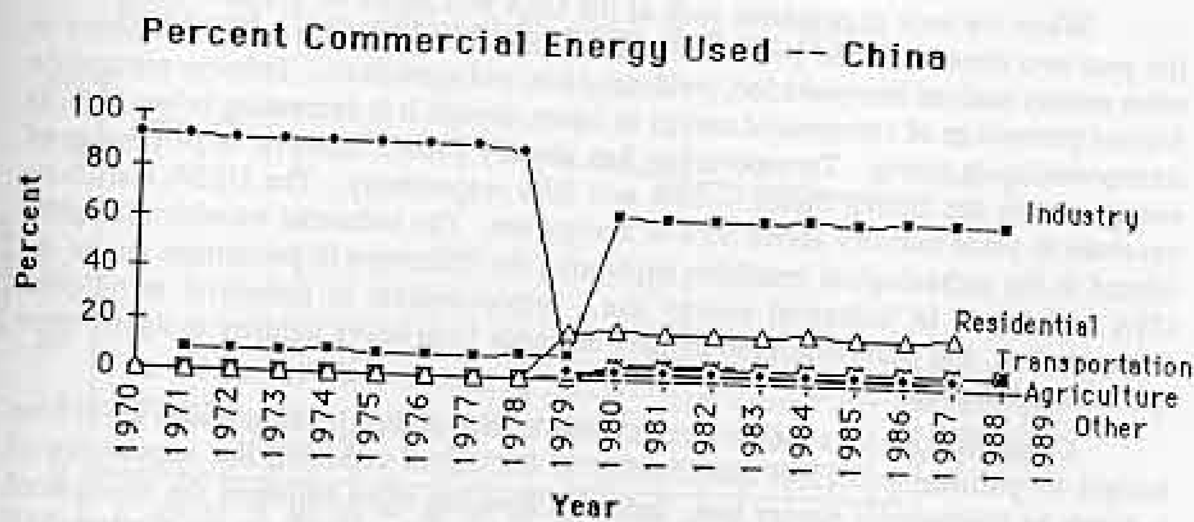


Data taken from World Resource Institute Database -- Source: United Nations Statistical Office



Data taken from World Resource Institute Database – Source: United Nations Statistical Office

Comparing the percent of commercial energy use in China as divided among the sectors of industry, residential use, transport, agriculture, and commercial, we see a puzzling shift in 1979.



Taken from World Resource Institute Database – Source: United Nations Statisical Office

Commercial energy use drops from around 90% to 2%. Perhaps this drop can be explained by post Mao rural economic reforms in 1979, breaking up collectively tilled fields into land contracted out to private families to work.[46] However, residential use jumps from relatively negligible to 20%. We can attribute this trend to the urbanization of the 1980's. Urban dwellings require more industrial energy than rural dwellings that rely heavily on traditional fuels.

A positive result of urbanization in China might be a decline in fertility and thus a slowing of population growth. The population control policies implemented by China in the latter half of this century have been most successful in urban areas.

We must also recognize that cities in China are currently overpolluted and cannot satisfy the housing and energy demands of the people currently living there. China has concentrated investment of industry and factories and has consequently ignored urban housing. Another problem is that China, as a non-capitalist country, kept rents low and at times even subsidizes housing, driving construction and maintenance prices even higher and preventing an adequate quantity of housing to be built. Furthermore, recent restrictions of the quality of housing (necessity for improved sanitation, for example) have discouraged further housing construction. Consequently, projections for near future housing shortages are high, foreseeing a growth in slums and homelessness for those people migrating from rural to urban areas.

The Industrial Transition

When we look at countries such as the USA and Japan we notice a decline over the past two decades in the percent of commercial energy use for industry relative to other sectors such as transportation, residential use, and agriculture. Industry sustains the highest percentage of commercial energy in Japan, though it is decreasing below 50%, as transportation is rising. Transportation has already passed industry in percentage of energy use in the United States -- 35% and 30% respectively. The USSR and China continue to place industry above 50% of energy use. The industrial transition is tightly related to the technological transition explaining the difference in percentage rate of the USA and Japan in industrial energy use. Improvements in industrial techniques, transportation, and communication transfer demands from heavy industry to lighter more specialized industry.

Comparing China's industrial transition to that of the USSR provides us with an insight to political processes contributing to the lag of reducing the importance of industry in commercial energy use. Indeed, China has often followed the example of communist Soviet states and has accepted the aid of the USSR in developing their industrial infrastructure.

Industrial output has been growing at a rate of about 10% per year.[47] China's industrial workforce exceeds that of all other developing nations combined. Most

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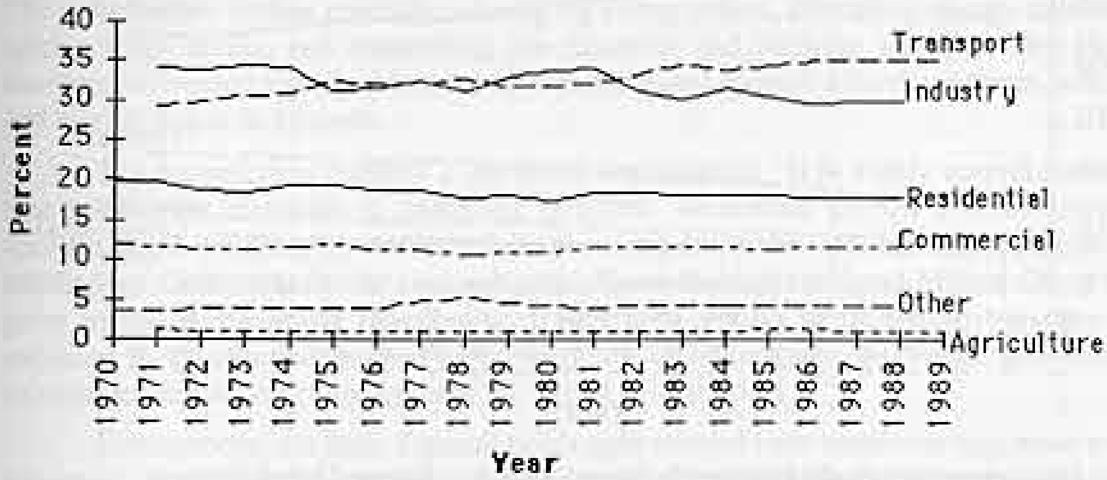
[46]Enc. Brit., 53
[47]Enc. Brit., 55

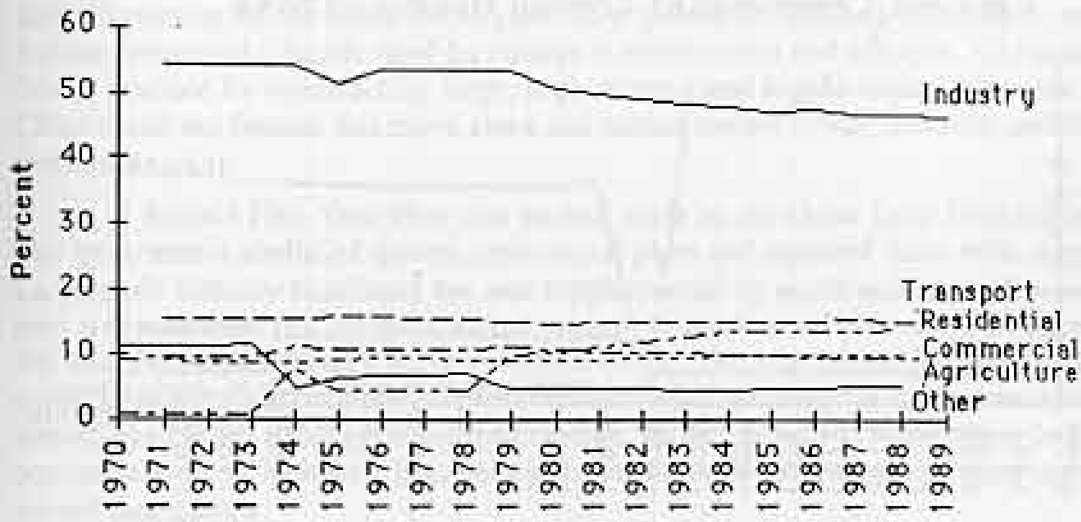
industry focuses on metallurgy and machine-building. Another popular industry is the production of nitrogenous fertilizers. Textiles also comprise about 15% of industrial output -- a major commodity for export. Unfortunately, across all areas quantity has been stressed at the expense of improvements in variety and quality.

Percent Commercial Energy Use -- USA

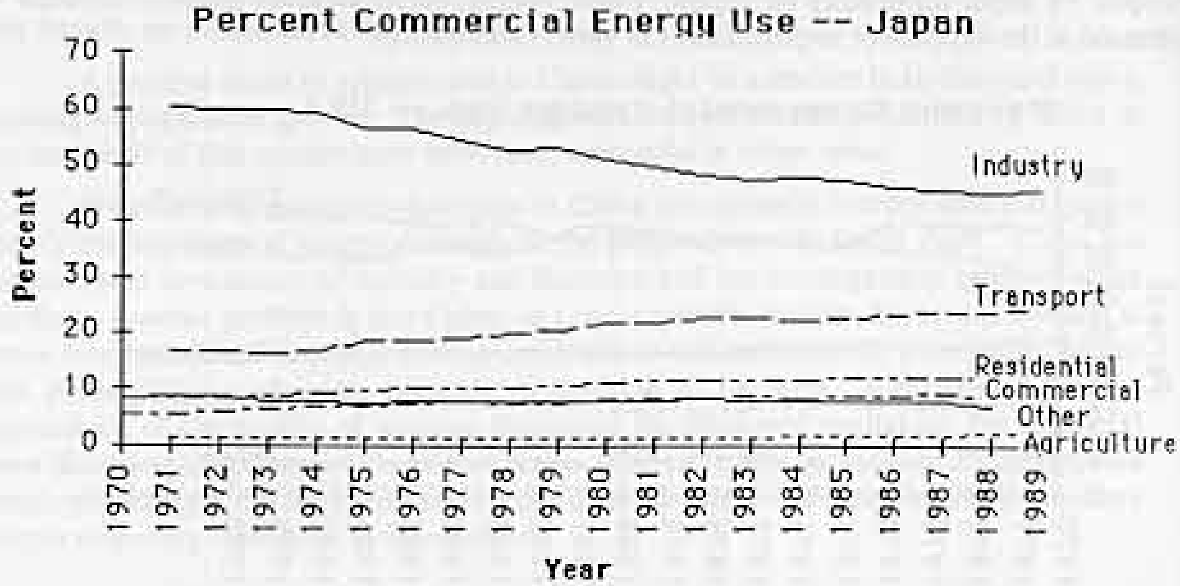


Taken from World Resource Institute Database -- Sources: United Nations Statistical Office and The World Bank

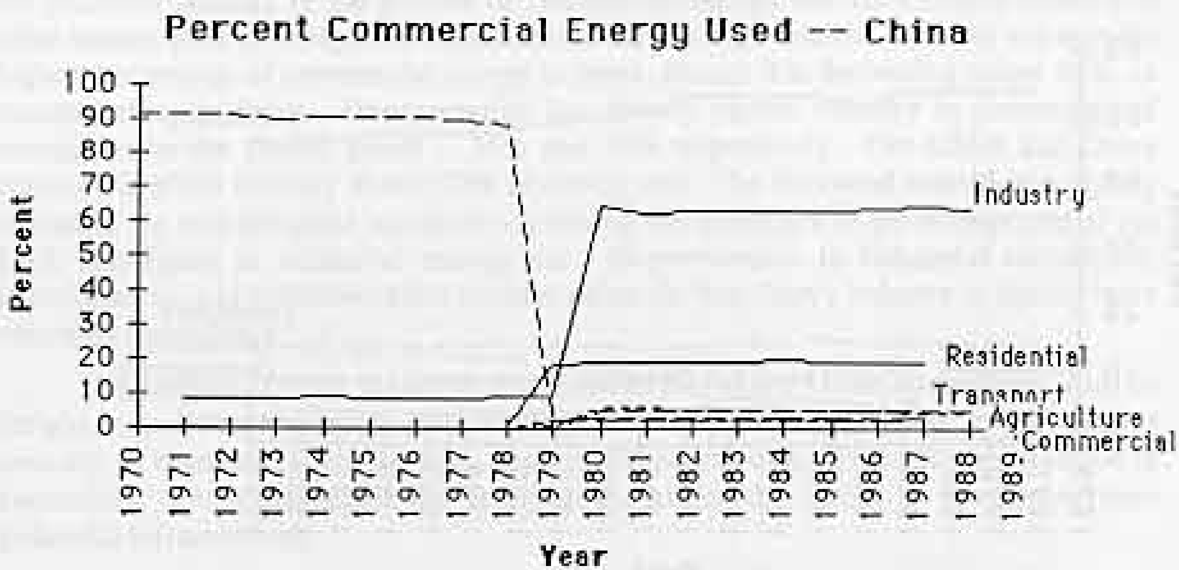
Percent Commercial Energy Use -- USSR



Data taken from World Resource Institute Database -- Source: United Nations Statistical Office



Data taken from World Resource Institute Database – Source: United Nations Statistical Office



Data taken from World Resource Institute Database – Source: United Nations Statistical Office

Industries have also become highly energy intensive, resulting from artificially low energy prices that do not encourage factories to adopt more advanced and economically sound energy-conserving practices. Similar government subsidies have been present in the USSR. Low energy costs encourage industries to waste energy.

As China is a socialist country, the government owns firms that produce more than 60 percent of industrial output.[48] The remainder of the firms are owned collectively. The government further controls industry by fixing prices, allocating energy resources, setting wage levels, and controlling the financial and banking system. The 1980s, however, witnessed a gradual loosening of government control, allowing private initiative and market forces to increase.

The bureaucracy remains a top-down organization. It is highly complicated and thus encounters restraints in enforcing policies. Ministries govern a vast variety of specific areas, breaking up control of the economy and public policy. For example, the Ministry of Coal controls the coal industry. Kenneth Lieberthal and Michel Oksenberg point to the bureaucratic structure as fragmented among various ministries that are expected to express the interest of the people. Unfortunately, this mode may lead to misrepresentation, as is now apparent in former Soviet states.[49]

Furthermore, the State Council holds tight control over resources important to the economy. It allocates energy resources to sectors that it believes to be most valuable to the economy. With the introduction of a communist government, China adopted an economic policy in the 1950's emphasizing rapid industrial development at the expense of other sectors of the economy such as agriculture. This policy was developed under the First Five-Year Plan (1953-57). Considering that agriculture at the time occupied more than 80 percent of the economically active population, devoting investment to heavy industry presented a drastic need for change in employment and lifestyle. China followed Soviet practice by constructing large, sophisticated and highly capital-intensive plants. China could not finance this move alone and turned toward Soviet technical and financial assistance.

A Second Five-Year Plan was pushed aside by the Great Leap Forward in 1958. The government abolished private agricultural plots and replaced them with communes. Large-scale industry continued but was supplemented by small-industry. However, this plan was much too fast for the Chinese peasant to adapt to. The Soviets withdrew their aid, and the country faced a grave economic crisis. The response of the government was a reactionary reversal of policy, returning land to private ownership and transferring the unemployed from industry to the countryside. It cut industrial investment in order to concentrate on agriculture. This policy continued until 1963 when industry once again gained momentum.

Industrial production suffered under the 1966 "Great Proletarian Cultural Revolution." China took on the policy of hiring the unemployed to work in industry.

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[48]Enc. Brit,. 56

[49]Kenneth Liebertha and Michel Oksenberg, *Policy Making in China*, (Princeton University Press, Princeton, 1988)

Ensuring workers of a job eliminated incentives to work hard. Rural industry provided jobs for former workers in agriculture. Between 1982 and 1987, 68 million peasants moved out of agriculture. However, the shift in population away from land has not been accompanied by improved agricultural practices, and agricultural output has remained constant.[50]

Since 1970, China has slowly been moving away from a Soviet-type economic system -- participating more heavily in world markets, de-collectivizing agriculture, and shifting toward light rather than heavy industry. The state gave priority in energy consumption to light industrial enterprises that produced high quality goods. Radical changes in economic ideology have occurred since 1978. However, because of the bureaucratic structure and scale of the proposed changes, actual practice has lagged far behind. Gradual reforms brought frustration to the people, and the government reverted in 1989 to once again emphasizing centralized planning and large state-run enterprises.

The Toxicity Transition

The United States remains far in the lead concerning industrial pollution, particularly in the production of greenhouse gases such as carbon dioxide. However, comparing the total industrial carbon dioxide emissions of the USA, the USSR, Japan and China clearly shows that China, though it falls between the USSR and Japan in emissions, exhibits the greatest change in emissions over time. This fact bodes ill for the future, particularly when we take into account China's growing population.

Global carbon dioxide emissions from industry show a current equality in emissions resulting from solid and liquid fuel consumption. However, the contribution of solid fuel (coal) in China far exceeds its contribution from liquid and gas fuels, unlike Japan and the USA where liquid fuel dominates. Emissions in the USSR are relatively equal for solid, liquid and gas.

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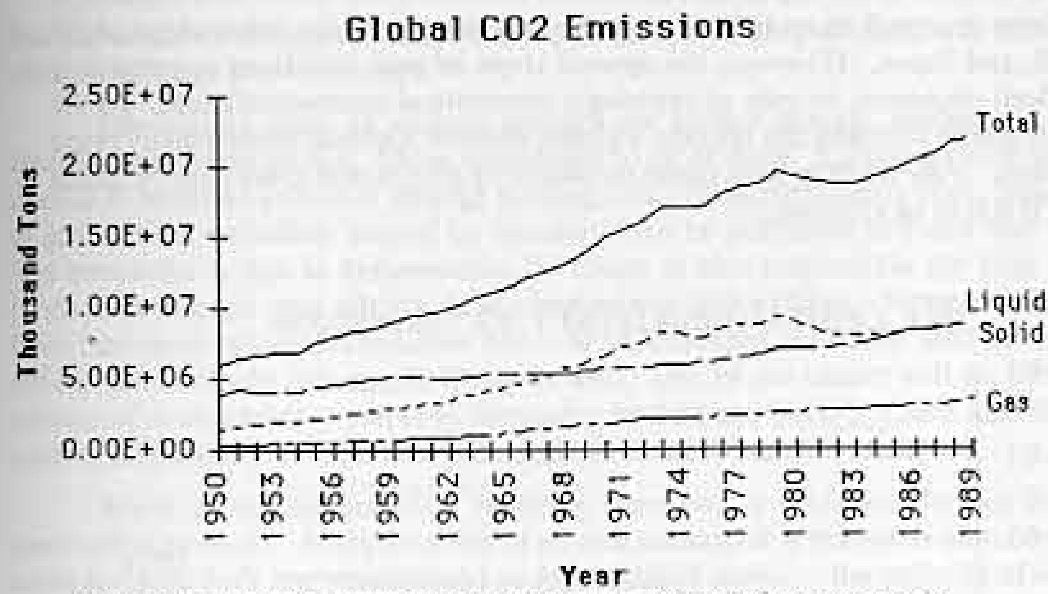
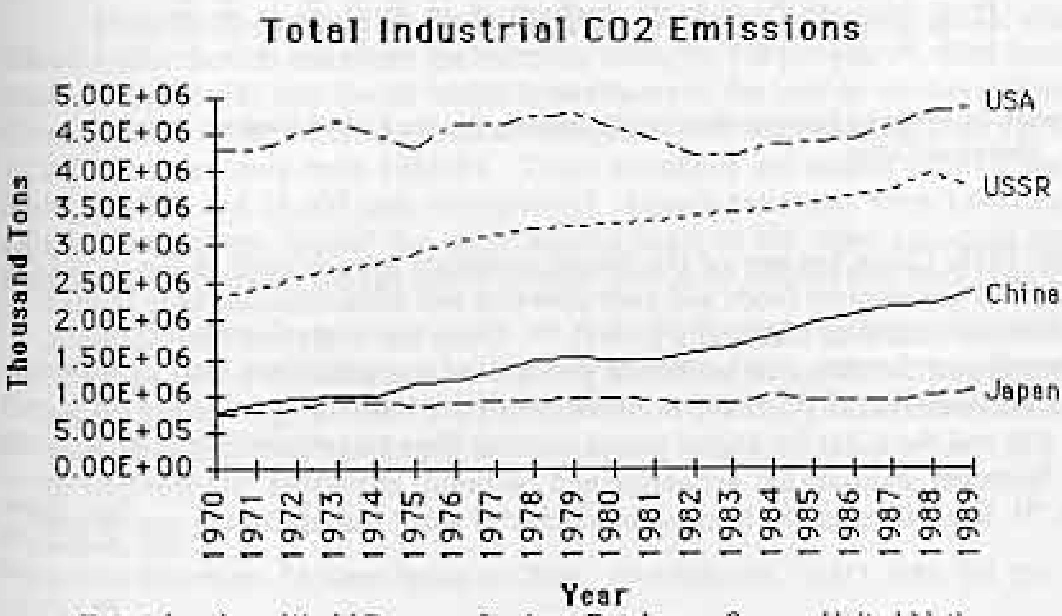
[50]Forestier, 53

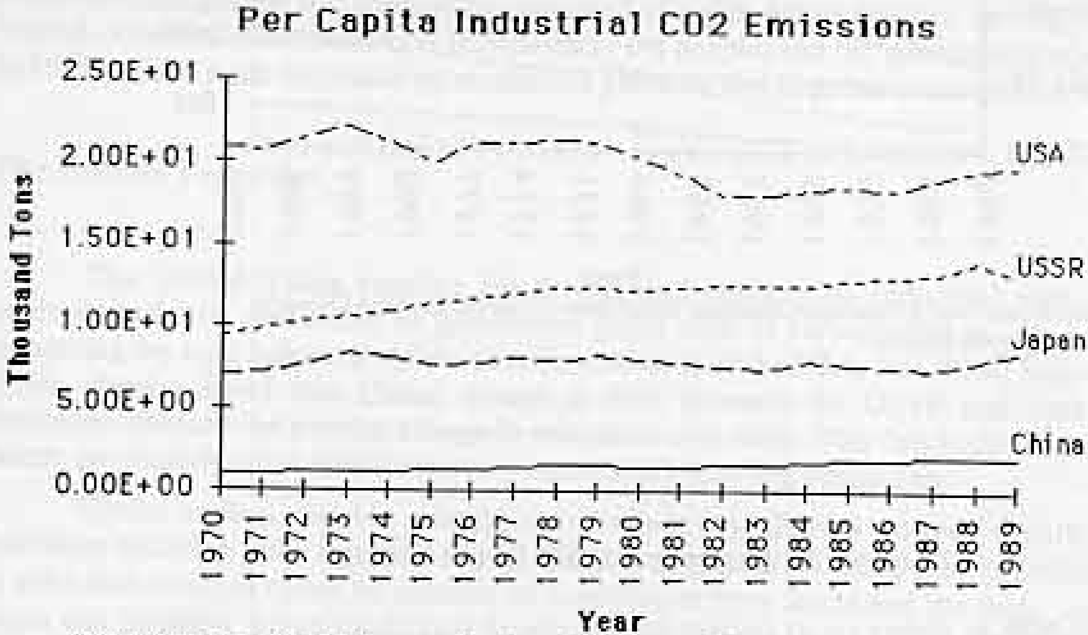


Taken from World Resource Institute Database -- Source: Carbon Dioxide Analysis Center



Data taken from World Resource Institute Database -- Source: United Nations Statistical Office

When we look at per capita carbon dioxide emissions we realize how unfair it is to expect China to curtail its emissions when they are per person far below those of the USA, USSR, and Japan. However, the upward slope in total emissions suggests that action is indeed necessary, in spite of seemingly hypocritical recommendations. As the possibility of global warming has become a global concern it should consequently result in global action. "Any effort to limit future emissions of greenhouse gases must be global in character if it is to be effective."[51]



Data taken from World Resource Institute Database -- Source: United Nations Statistical Office

Since 1979, China has one of the fastest economic growth rates in the world. However, lack of government funds and poor planning and administration have limited adequate pollution control to match this growth.[52] China has neglected environmental concerns because of the focus on economic growth and the political events of 1989. "Significant achievements in [China's] environmental policy are being swamped by the population tide and the quest for higher prosperity...the huge transfer of humanity from fields to factories cannot be accomplished without extensive environmental destruction."[53] In rural areas, the increase in number of small manufacturing enterprises

[51]Jesse J. Ausubel and Hedy E. Sladovich, ed., *Technology and Environment*, (National Academy Press, Washington, D.C., 1989)
[52]Forestier, 54
[53]Smil, 1989, 277

has had major environmental impact in noise pollution, air pollution, and uncontrolled disposal of waste into waterways.[54]

Greenhouse gases of greatest concern are carbon dioxide, methane gas, sulfur dioxide, and nitrous oxides. China contributes to all of these. Carbon dioxide and sulfur dioxide is produced primarily through burning fossil fuels, particularly coal. Indeed 75 % of global CO2 emissions caused by humanity can be attributed to fossil fuel burning. The remainder is due to deforestation.[55] China is also responsible for high methane production through coal mining, land clearing and rice paddies. Nitrous oxides come from fuel combustion and fertilizer use. With increased economic well-being nitrous oxides will no doubt increase in China as well. One of the causes will be a rise in the number of automoblies -- currently increasing by 20% per year.[56] China also has a high level of suspended particle matter pollution, particularly in urban areas.

Much of the air pollution resulting from coal production derives from poor combustion methods. More than half of all coal consumed is burned in either medium or small furnaces with low smokestacks or in household stoves -- the majority of which are inefficient and outdated.[57] Primary emphasis is now being placed on renovating old industrial processes and upgrading energy efficiency in industry. Domestic improvements have proven more difficult because they require replacing traditional fuel with electric and gas stoves. From 1980 to 1985 the number of urban households using gas for cooking increased from 15 to 22 percent.[58] Thus, progress is being made, albeit slowly.

Fossil fuel combustion emits 85-90% of global manmade sulfur dioxide.[59] Global sulfur dioxide emissions are currently rising by 4% per year.[60] Coal combustion emits sulfur dioxide into the air which later returns to the land in the form of acid rain. China's annual sulfur dioxide emissions averaged 14,210 thousand tons from 1979-81 and 12,920 thousand tons from 1982-84. These emissions are second only to the United States (23,330 and 21,100 tons respectively). Japan's emissions were 1,640 and 1,610 tons in comparison, around the same relative scale as the other countries studied.[61] Recent estimates report China's sulfur dioxide level at 16 million tons each year.[62]

Sulfur dioxide emissions can be reduced through washing the coal before combustion, coal gasification, selecting low-pollutant fuels, removing pollutants from flue gases (spraying a lime slurry into the stack to absorb SO2), and increasing overall demand for fuel through energy efficiency.

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[54]Ibid., 280
[55]Hodlren, 159
[56]Jonathan Silvertown, "A Silent Spring in China," New Scientist, (July 1, 1989, Vol. 123 n1671), 55
[57]UNEP and WHO, "An Assessment of Urban Air Quality," Environment, (Oct 1989, Vol.31 n8), 30
[58]Ibid., 30
[59]Ibid., 10
[60]Ibid., 10
[61]Ibid., 12
[62]Ibid., 12

Sulfur dioxide pollution is especially prominent in urban areas. For example, Shenyang experiences an average of 146 days per year where the SO2 levels exceed guidelines (150 micrograms per cubic meter of air), compared to 8 days in New York city, and 0 in Tokyo. No other city in the GEMS study approached the high levels of Shenyang. Indeed urban pollution has risen to the top of the charts worldwide. In July 1988, Benxi vanished from satellite photographs beneath a cloud of smog![63] Air pollution is affecting rural areas as well. Acid rain from sulfur dioxide is killing forests in southwest China.

When assessing the public health impact of local air pollution, we must keep in mind effects of traditional fuel on human health. The outdoor pollution of the air remains far lower than indoor pollution caused by smoke from primitive stoves. Approximately 80% of global human exposure to particle pollution occurs not outdoors, but indoors in developing countries, because of burning traditional fuels for cooking and heating.[64]

Carbon dioxide production appears more difficult to solve through technology than sulfur dioxide. China currently emits more carbon from fossil fuel burning than any other country in the developing world. Most of China's industrial carbon dioxide emissions result from burning solid fuels (coal). Compared to the other countries addressed in this paper, China is unique. The USA contributes slightly more carbon dioxide to the atmosphere from liquid fuel use than solid fuels. In the USSR solid, liquid, and gas fuel carbon dioxide emissions are relatively equal. In Japan, liquid fuels emit much higher rates of carbon dioxide than solid fuels, while gas emissions are quite low.

Reduction in carbon dioxide emissions would require capturing the gas after combustion, a process which remains extremely expensive and undeveloped. An alternative solution is to concentrate energy production on natural gas, which emits far less CO2 than coal. This would provide a short term solution until technology for safer coal combustion can be attained.

However, the known world supply of natural gas is far below that of coal reserves. Estimates place coal consumed at the current rate as lasting for 1,500 years, in contrast to natural gas lasting only 120 years. If natural gas were substituted for coal, the gas resources might last only 55 years.[65]

One fact to keep in mind is that the industrialized nations, which make up only about a third of the world population, emit 80 percent of greenhouse gases. However, because of population and economic growth, CO2 emissions in developing countries (including China) could exceed that of developed nations during the next decade.[66]

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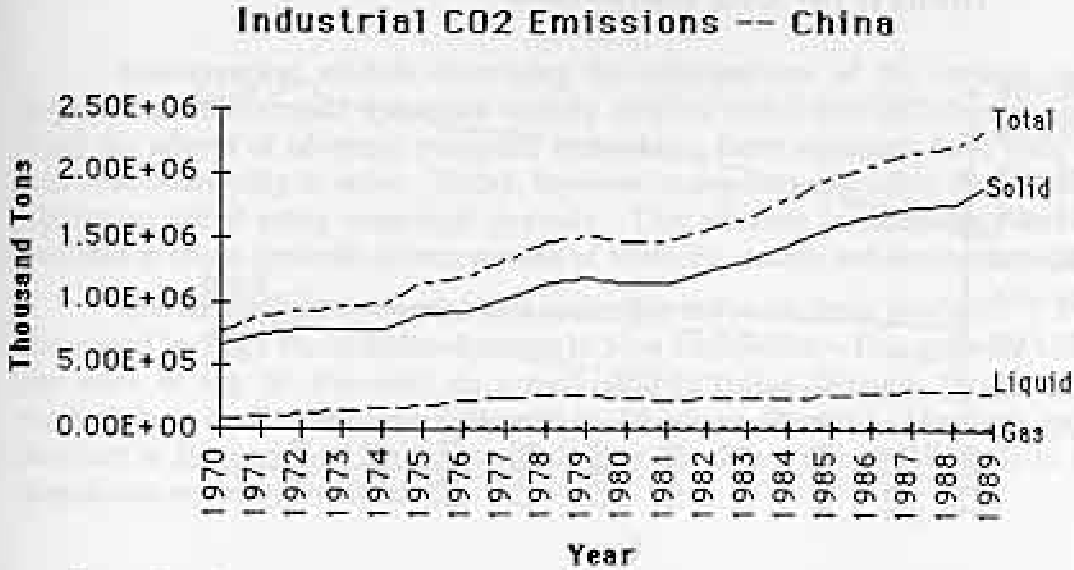
[63]Silvertown, 55
[64]Holdren, 160
[65]William Fulkerson, Roddie R. Judkins, and Manoj K. Sanghui, "Energy from Fossil Fuels," Scientific American, (Scientific American, Inc., New York, Sept 1990, Vol 263 n3), 132
[66]Ibid., 135



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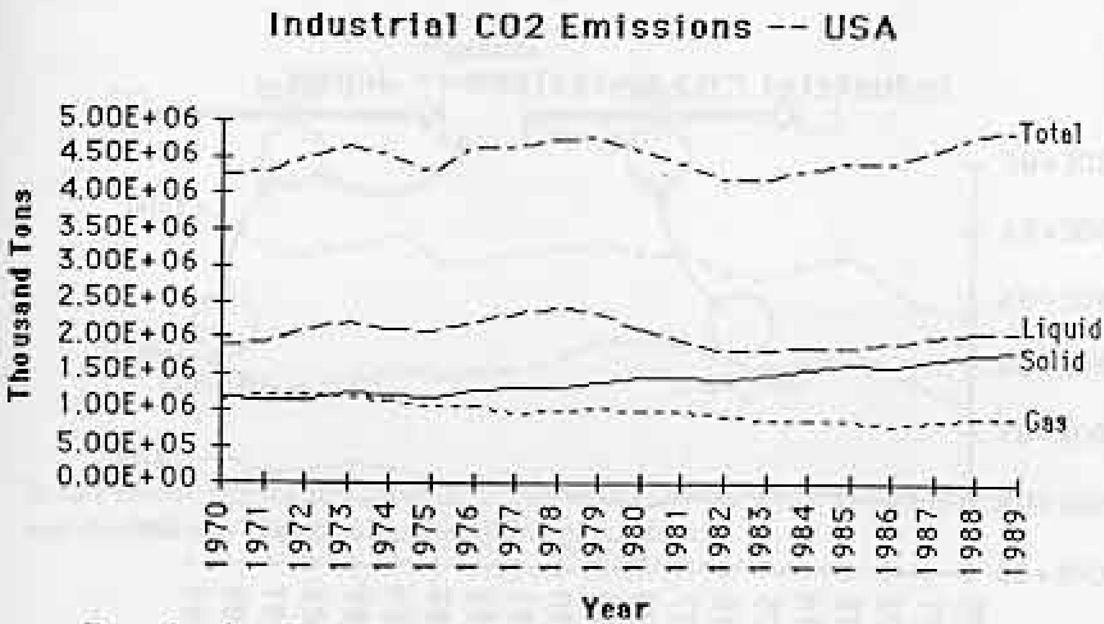

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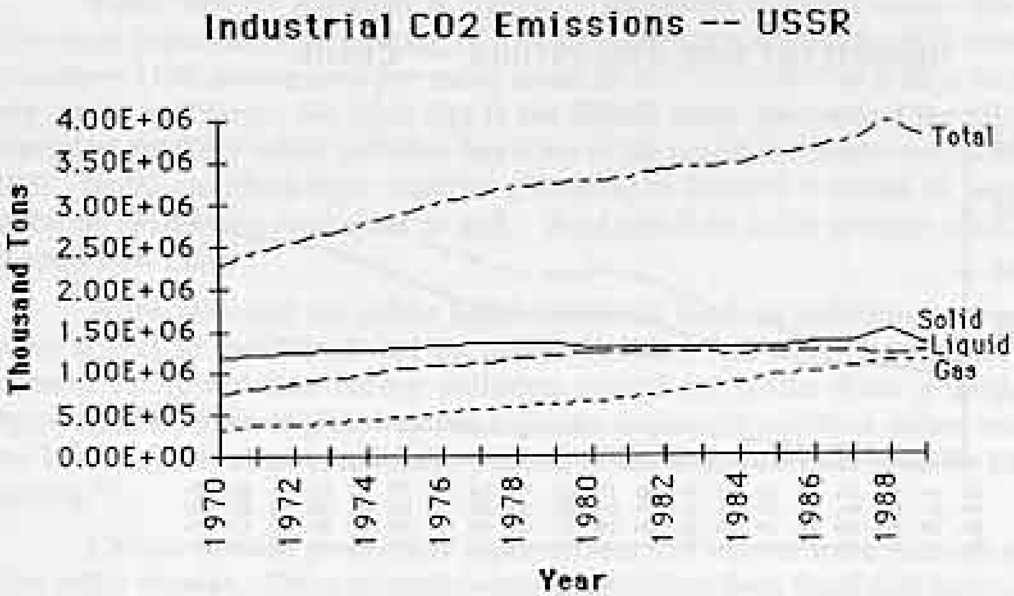

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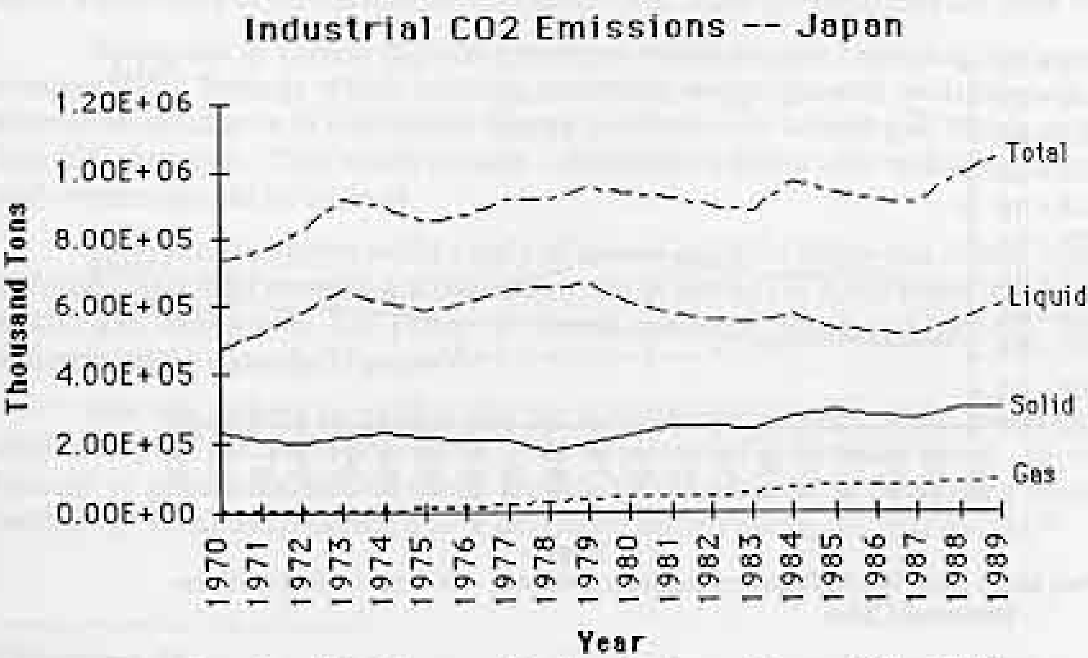


Data taken from World Resource Institute Database -- Source: United Nations Statistical Office

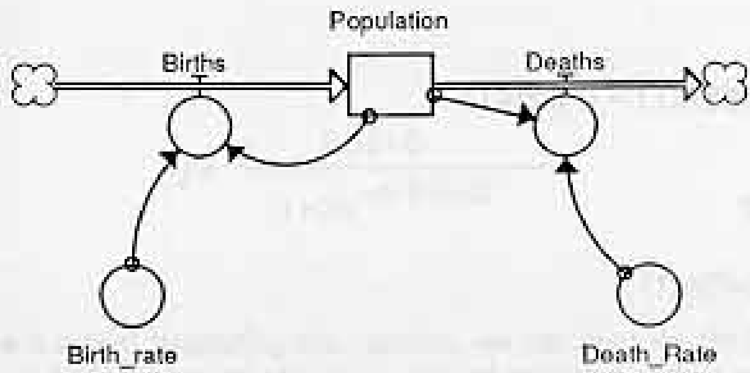
Dynamic Modeling Using STELLA

Mathematical models describing the relationships of the various sectors in population-environment dynamics usually employ non-linear differential equations. Until the advent of advances computer technology, these equations have been difficult and time-consuming to solve. Today, however, computers can solve these equations at lightening speed using numerical analysis. This advance in technology has made it possible to create dynamic system models of scientific, social, and economic relations.

One of the most powerful and accessible software tools available is STELLA, developed by High Performance Systems in New Hampshire. This software is based on the work of Jay W. Forrester on a methodology called "System Dynamics." This methodology is also the basis of Donella H. Meadows, Dennis L. Meadow, and Jorgen Randers in Beyond the Limits, in which they develop a model (World3) to describe population-environment dynamics.

Simple Model

To introduce the modeling process of the energy sector in China's population-environment dynamics, consider the simple model of population, births, and deaths.



In this model, population depends on births and deaths, which in turn depend on birth rate and death rate. The equation describing population is:

$$n(t) = \text{population}$$

$$\frac{dn}{dt} = \text{Births} - \text{Deaths}$$

OR

If the Birth Rate and Death Rate depend on Population

$$\frac{dn}{dt} = \text{Birth Rate} \times n(t) - \text{Death Rate} \times n(t)$$

In the case of China, let's consider a birth rate of 0.065 and a death rate of 0.02. Substituting in to the above equation gives:

$$\frac{dn}{dt} = 0.065n(t) - 0.02n(t)$$

OR

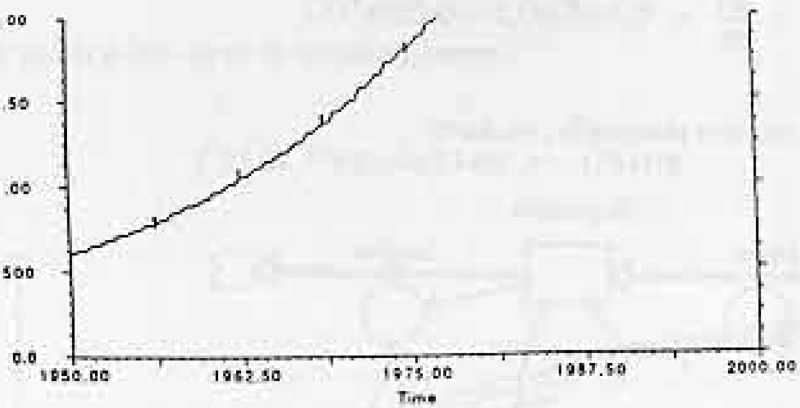
$$\frac{dn}{dt} = 0.045n(t)$$

The solution to this equation, separating the variables, is:

$$n(t) = n_o e^{0.045t}$$

Where n_o is the starting population

When we run this model, setting the initial value (starting population) as 6 (China's population in unit of 10E+8), *STELLA* creates the following graph:



The graph represents unbounded exponential population growth. Obviously, this graph does not accurately describe China's population. Instead, we are searching for a model to describe logistic growth. Recall that the equation I fitted to the curve of Total Population of China in thousands was:

$$y = \frac{1.5E+6}{1+2e^{-0.0454t}}$$

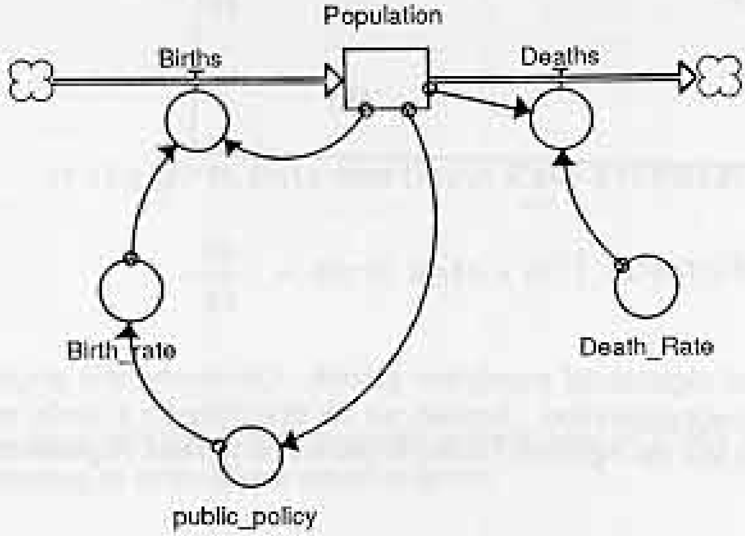
To obtain a model simulating this relation, we can draw on the fact that birth rates are dropping in China, because of increases in urbanization, public policy, and other factors influencing the demographic transition. Let's assume then that the birth rate includes a second term which dampens the effect of the first:

$$\text{Birth Rate} = \underbrace{0.065n(t)}_{\text{normal birth rate}} - \underbrace{0.03n^2(t)}_{\text{decline from policy, etc.}}$$

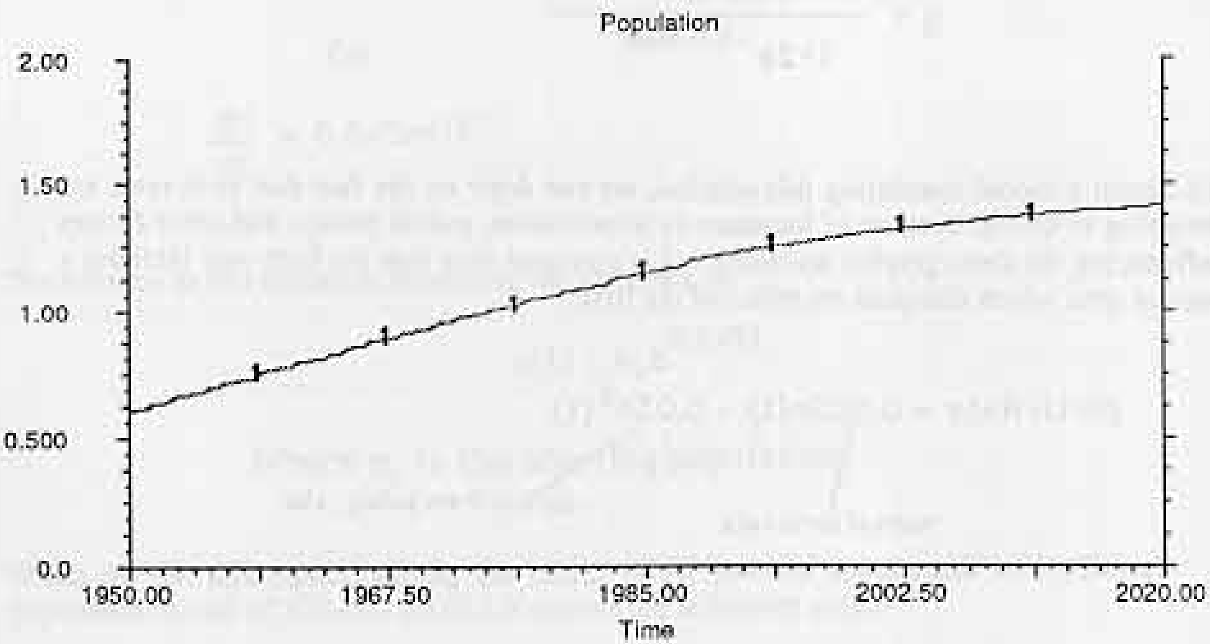
This relation gives us a logistic equation:

$$\frac{dn}{dt} = 0.045n(t) - 0.03n^2(t)$$

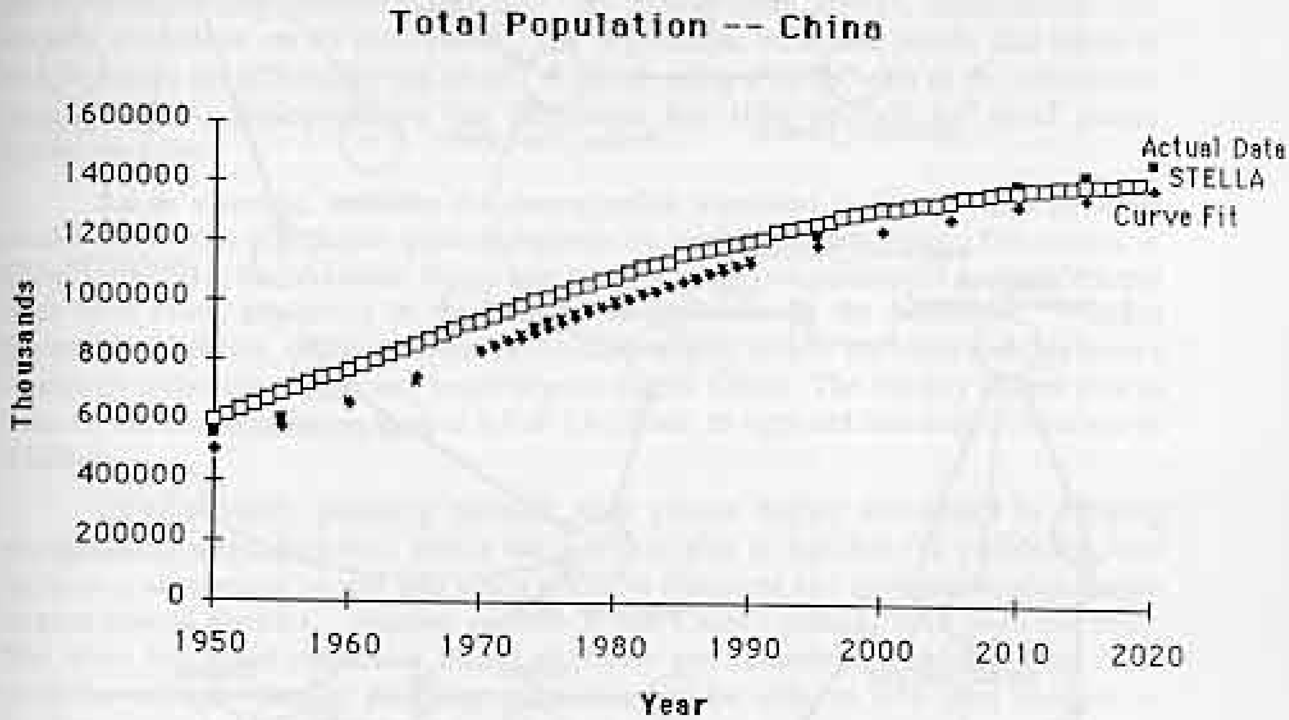
Representing this relation pictorially, we have:



This model produces the following graph for population:



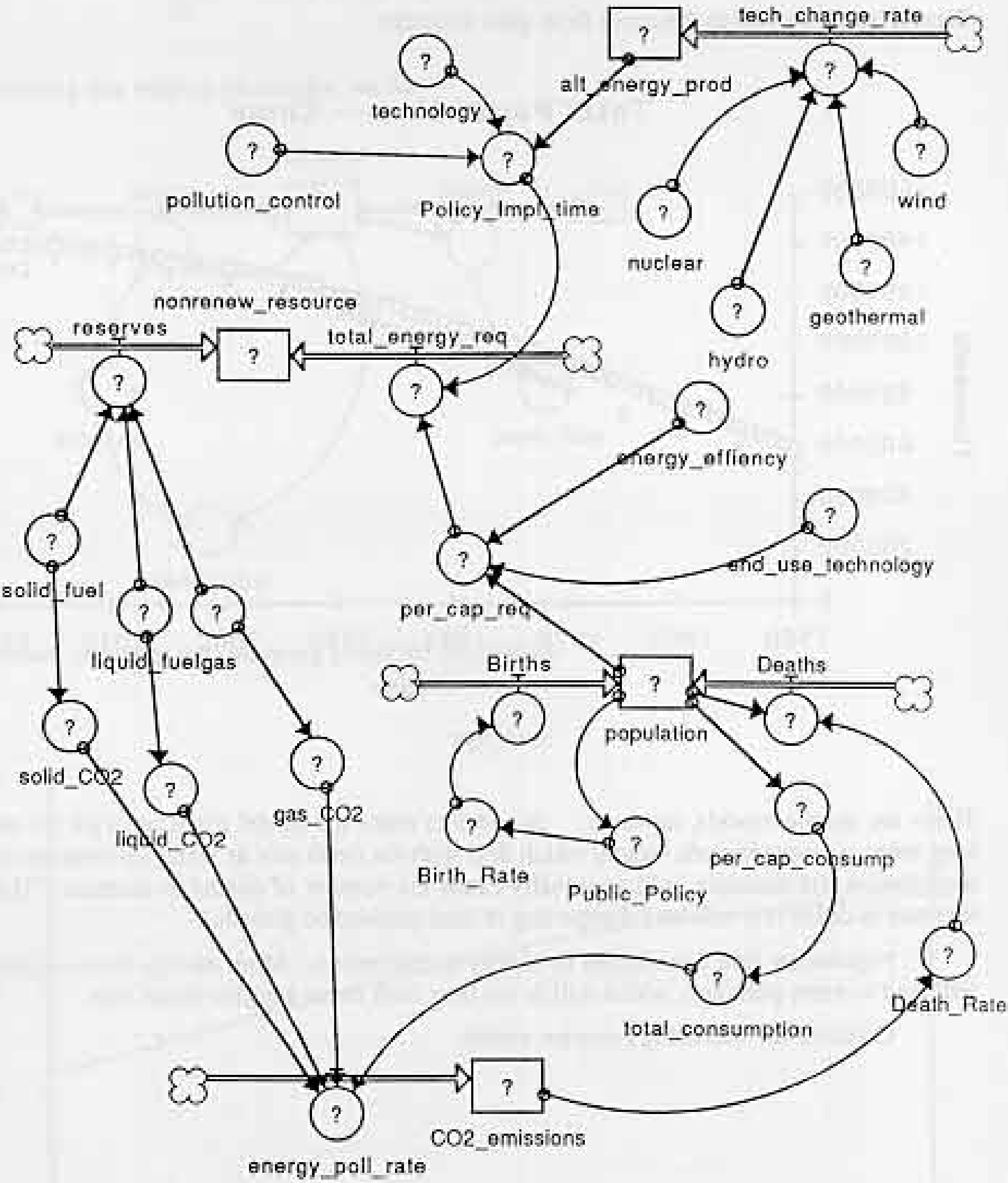
Comparing this graph to the curve fit is quite accurate:



These are simple models, however. In order to make the model more accurate for the long term, we must include factors which deal with the death rate as well. Environmental degradation, for example, will eventually cause the number of deaths to increase. This increase in death rate will lead dampening of total population growth.

Population also contributes to energy consumption. More energy consumption will lead to more pollution, which will in the long term cause a higher death rate.

Consider the following complex model:



tech_change_rate
alt_energy_prod
technology
pollution_control
Policy_Impl_time
nuclear
wind
hydro
geothermal
nonrenew_resource
reserves
total_energy_req
energy_effiency
end_use_technology
per_cap_req
solid_fuel
liquid_fuelgas
Births
Deaths
population
solid_CO2
liquid_CO2
gas_CO2
Birth_Rate
Public_Policy
per_cap_consump
total_consumption
Death_Rate
CO2_emissions
energy_poll_rate

Conclusions

Complex dynamic systems modeling can provide valuable insight into the relationships among various transitions. The demographic, energy, urbanization, and toxicity transitions are all interrelated. The beginnings, inflection points, and limits of one transition are affected by the others. Through using a model such as the one created with STELLA, policy-makers can determine key time periods for strict policy implementation.

As an example, consider the demographic transition in China. The dynamic model shows that population growth depends on birth and death rates. Discussion of China's demographic transition shows that governmental policy allowed a strong control over birth rates, beginning in the 1950s -- a key point in the transition. Without governmental policy, China's population would probably follow the same trend as India's -- with an inflection point many years beyond that of China. The country is now able to forecast the total population limit at 1.5 or 1.6 billion, as opposed to a natural limit above 2 billion.

China's family planning policies have proven highly successful in limiting population growth. However, policy has not been able to stabilize the population, and increasing numbers of people will strain available resources and environmental pollution in next several decades. Another concern is that China's policies have been too strict. The West has heard rumors of forced abortions and infanticide resulting from these policies. Future family planning policies must be able to mix past success in implementation with policies protecting individual human rights.

The energy transition depends on the total energy requirements of the country as well as its remaining energy reserves. The graphs and curve fits on energy consumption demonstrate that China is just beginning this transition. Considering the fact that China is presently in the middle of its demographic transition, we can add the two factors together to study the effect of the increase of per capita energy consumption on total energy consumption. The predictions of future energy consumption are staggering -- particularly if they continue at an exponential rate. Such leaps in energy consumption will place great stress on available energy resources. Furthermore, if coal continues to provide the dominant source of energy, air pollution levels in China will soar. Therefore, there is a definite need for energy consumption policies. However, these policies should focus not only of limiting per capita consumption, but also on shifting resource use to renewable energy alternatives.

Hydropower and geothermal energy appear to have the highest potential for providing alternative energy sources for China. It would be wise for the government to provide incentives for the development and use of this type of energy. Implementation of alternative energy technologies will be slow. Consequently, it appears crucial that China begin increasing the development and use of these technologies immediately -- to ensure their dominance in the distant future.

The current urbanization transition portends positive and negative effects on energy consumption and pollution. Higher urban migration will place heavier demands on non-traditional fuel sources -- particularly coal. However, urbanization may slow population growth, dramatically aiding both the energy and toxicity transitions.

The toxicity transition depends on the energy pollution rate, that is the amount of pollution resulting from each unit of energy production. The total amount of pollution in turn depends upon the total energy consumption, the type of energy source used, and the technology employed to control pollution in energy production and end-use technology. Policies aimed toward the toxicity transition will have to address incentives toward improved end-use efficiency, higher efficiency in fuel combustion technologies, and strict controls on allowable polluting emissions in industry.

Of course, China is only one example of the many countries facing simultaneous transitions. China has already proven the effect of policy on reducing birth rates, albeit highly debatable in its methods of implementation. Policy on energy use and polluting emissions are now needed to ensure that runaway growth will not turn China's pollution concerns into global threats.

Dynamic systems modeling and transition theory can be important methods of prioritizing areas for governmental policy. With the infinite number of variables affecting each sector of population-environment dynamics, simple models often provide the best means of pointint to directions for future policy.

> Undertake difficult tasks
> by approaching what is easy in them;
> Do great deeds
> by focusing on their minute aspects.
>
> All difficulties under heaven arise from what is easy,
> All great things under heaven arise from what is minute.
>
> For this reason,
> The sage never strives to do what is great.
> Therefore,
> He can achieve greatness.
>
> -- Lao Tzu, *Tao Te Ching*

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Chapter 4: Eugene A. Fosnight

POPULATION TRANSITION AND CHANGING LAND COVER AND LAND USE IN SENEGAL

Introduction

In Senegal, as in all other nations, the relationships between changing land use patterns can be directly related to population dynamics. The changes in land use among range, forest, agriculture, and non vegetated land (including desert) are related to demands made by shifting population patterns and climate. Historically land use and land cover change were controlled by climate patterns. Whenever weather or climate changed, the population would move to accommodate the change in growing conditions; however, with increased population the capacity of the land to support the population is nearing saturation. There is no longer anywhere to go.

Population-environment dynamics is built upon the acknowledgment of limits. Meadows and others (1992) discusses limits as consisting of sources and sinks. A tendency exists to consider all land in relationship to its agricultural potential and in fact the ability to produce food is the most obvious limit to population growth. Each of the land use types and population have limits beyond which they cannot grow. These limits cannot readily be defined, but their existence cannot be denied. Each limit is a function of constraints defined by climatic, land, technological and economic/political variables for any given point in time. For the purposes of this paper the forest, desert, range, agriculture and population variables are stocks, the quantity of which is defined by the number or area of each that exist. A rate of change can be associated with each of these stocks. The relationship between the land uses is direct in that each land use can be considered a state and any change in land use effects a change of state.

Population is a pressure that effects a change in state of the land use. Population is a moveable stock. As population influences land use change, the changes in land use, particularly as limits are reached, force a relocation of population. This paper describes the changes in the distribution in population since 1951 by looking at differential growth rates in several distinct administrative departments. Senegal will be treated as a closed system even though significant out and in migration are occurring.

Transitions

The complex dynamics of population and the environment can be described as a family of transitions according to Drake (1992). Drake has defined a transition "to describe a specific period of time which spans the shift from slow to rapid change in the sector and then usually a return again to relative stability." Two subfamilies are (1) the transitions among agriculture, forest, range, and nonvegetated land, and (2) the demographic and urbanization transition.

The amount of available land is fixed. The division of land area into elemental range, agriculture, forest and nonvegetated land use/land cover classes provides a simple, but not unrealistic, model of land cover. Other classes are either variants or mixtures of these classes. Historical uses of the land stressed mixed and cyclic utilization of the land. Agricultural land use was frequently intermingled with forest, wood and range land uses and land covers, both in time and space. Mixed use of the land gave the land time to recover from intensive agricultural use and provided a ground cover for all times of the year thereby reducing land degradation.

The paths among these land use types are many. For example, rangeland-to-agriculture-to-nonvegetated, forest-to-agriculture, agriculture-to-urban are among the possible transition paths. Soil type and climate set limits for each of these land use types and many of the land uses compete for suitable land. At this time the most rapid transitions include the transitions from forested and range lands to agriculture for increased food production and the transition from forested to non-forested land for sawwood or fuelwood. Some of these paths have adverse outcomes, such as desertification and deforestation to the extent that the biodiversity or soil no longer exists to return the land to its original state. Any rapid increase in one of these transitions must be balanced by a decrease in one or more of the others. Unfortunately, if the transitions were to proceed without control the inevitable result would be massive land degradation to desert or near desert conditions.

In Senegal, the population growth rate has been relatively stable at 2.7 percent since 1976; however, a significant difference exists between the urban and rural growth rates (3.83 versus 2.02) for the years between 1976 and 1988. The movement of the population is from the more rural east to the more heavily industrialized west central near Dakar. This disparity and growth are mirrored in the increased population density (25 persons per square kilometer in 1976 to 35 in 1988) and with six of the administrative units having over 100 persons per square kilometer (Moore and others, 1992). Since the rural agricultural lands can only support a limited population, the population tends to move toward urban centers to find employment.

As population grows range lands are overstocked, marginal land is brought into grazing or agriculture, forests are cut for building material, firewood or for increased grazing or agriculture (Figure 4.1). These changes necessitate the consideration of land degradation as it relates to both desertification and deforestation. Both desertification and deforestation are cyclic events if land degradation is not too severe and population pressures allow the land the opportunity to recover.

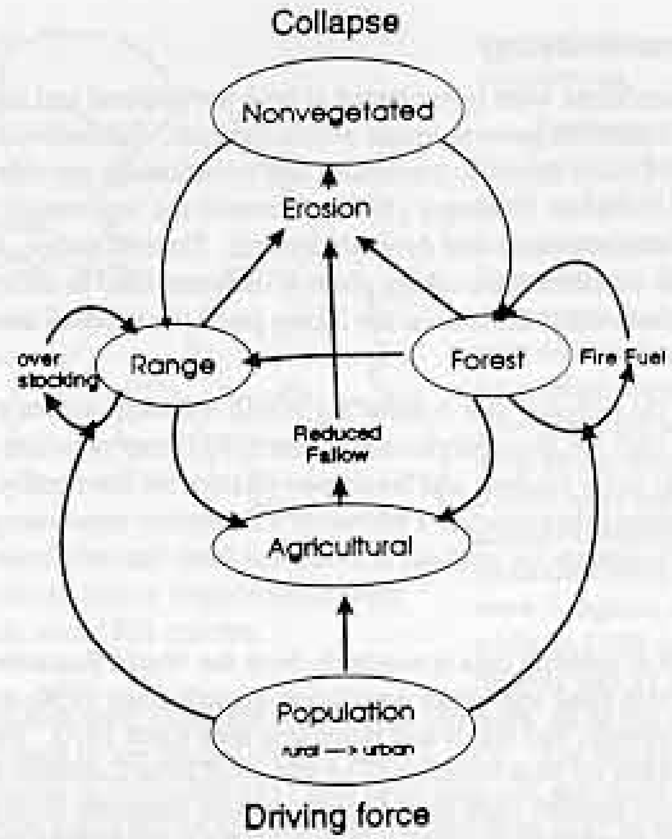

Figure 4.1. Population and land use land cover dynamics

Grainger (1982) identified "four causes of desertification, each made more acute by increasing human populations: overcultivation; deforestation; overgrazing and unskilled irrigation." The agricultural lands are left fallow for shorter periods of time in an effort to support the increased population. Marginal lands with correspondingly low yields are brought under agriculture during wet years and when the climatic cycle returns to dry, the lands are denuded and become unsuitable for agriculture or grazing. Deforestation causes soil erosion, lower water, reduced shade for ground cover. Deforestation in Senegal is occurring at a rate of 50,000 hectares per year, while reforestation is lagging behind at a rate of 2,800 hectares per year. Fuelwood and charcoal production nearly doubled between 1970 and 1990 driven by the needs of the rapidly growing urban population (Grainger, 1982). Overgrazing is caused by increased herd size on less available grazing land and leads to soil compaction and soil erosion. Irrigation can provide substantial short term and highly visible gains in agricultural production, but unless irrigation projects are well designed and well managed increased salinity quickly turns irrigation projects into deserts. Salt flats are also created through the deforestation of wetlands. Grainger (1982) noted the growth of salt flats covering a quarter of the area of one department in the region of Fatick, and conversely Rodriguez-Bejarano (1986) described the destruction of mangrove swamps through the use of tidal dams that prevent salt water from coming into areas under conversion to irrigated agriculture.

Data and methodology

The transitions were investigated at both the national and subnational scales. National statistics describe the general trends within Senegal. Subnational statistics allow the description of more dynamic transitions and occasionally provide a better understanding of the national statistics. Grainger (1992) discussed the importance of understanding the interaction between static and dynamic models. Desertification, deforestation, and demographic transitions are taking place at different rates in different parts of Senegal. By analyzing where these transitions are taking place the national trends can be better understood.

All of the national data is from the World Resource Institute's (1992) data base and all subnational data are from Moore and others (1992) except where otherwise noted. Time series data to study landuse and land cover change are not readily available for Senegal. Remotely-sensed data provide a source of information concerning land cover. Satellite coverage appropriate for analysis at a national level has only been available since 1972.

Population

Historical national data is available from the World Resource Institute data base describing both rural and urban population growth since 1950, and changes in cropland, permanent pasture, and forest and woodland area since 1970. The population data has been augmented by data between 1914 and 1958 from Lombard (1963). The population data from both sources have been fit with smooth functions hiding the actual data and assumptions concerning the data collection and adjustment procedures. Four data points are known. The two most reliable are the 1976 and the 1988 national censuses which also are a rich source of subnational data. The 1951 and 1958 censuses are less well documented, but do provide a source of older subnational data an intermediate resolution.

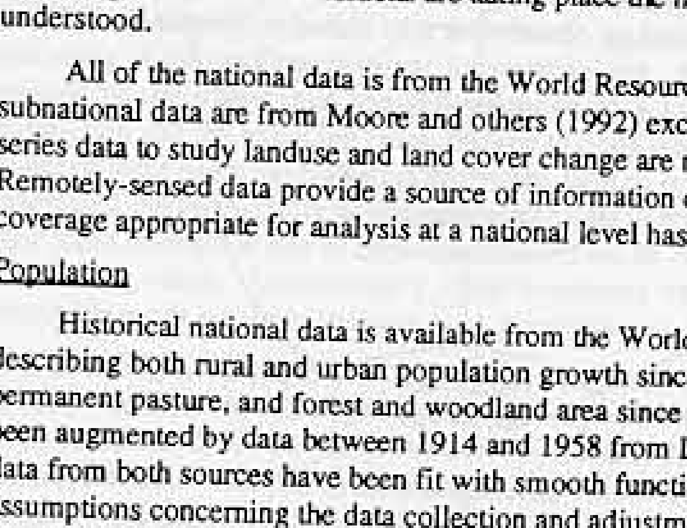

Figure 4.2. Map of administrative regions in 1988

Subnational population data from the 1976 and 1988 census is available as a baseline data set. Population data for the 1988 census is available at four levels of aggregation: region, departement, arrondissement/zone urbaine, and communaute rurale (Figure 4.2). Population data for the 1976 census is available at three levels of aggregation: region, departement, and arrondissement/zone urbaine. Population and rate of population growth are

Figure 4.3: Map of administrative departements from 1988 census coincident with 1958 cercles.

reported by rural and urban populations.

Earlier data is available at the level of 1958 cercles for 1951 and 1958. These cercles are approximately equivalent to departements (Figure 4.3). Administratively Senegal has split administrative units that have large populations. Therefore, the administrative units in the west south and central have been split into smaller administrative units since the fifties. In 1958 there were 7 regions and 13 cercles, while in 1988 there were 10 regions and 31 departements. Since spatially detailed data were available for the later censuses, all of the administrative units were aggregated back to the cercles as they were in 1951. The reported population data were very inconsistent between the 1951 and 1958 censuses and the relative boundaries for all cercles could not be conclusively tracked from 1951 to the 1976 and 1988 censuses. Seven of these administrative units were confidently identified for 1951, 1958, 1976 and 1988 and were used for the subnational analysis (Figure 4.4). The mapping between the 1958 cercles and departments in the 1976 and 1988 censuses are identified in table 1.

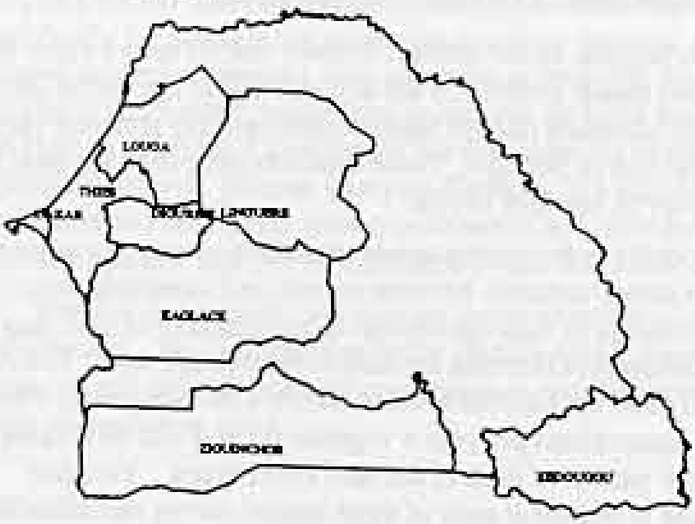

Figure 4.4: Map of 1958 administrative cercles coincident with 1988 administrative units.

Table 1. Linkages from 1951 & 1958 to 1976 & 1988 administrative boundaries

Cercles (1951 & 1958)	Departements (D) or Regions (R) (1976 & 1988)
Dakar	Cape Vert (R)
Thies	Thies (R)
Diourbel	Diourbel (R)
Kaolack	Kaolack (R) and Fatick (R)
Ziguinchor	Ziguinchor (R) and Kolda (R)
Louga	Louga (D) and Kebemer (D)
Linguere	Linguere (D)
Kedougou	Kedougou (D)

Remotely-sensed data

The Advanced Very High Resolution Radiometer (AVHRR) satellite has been in use since 1982. Data from this satellite is available at both 1 kilometer and at 7.36 kilometer sampling rates. These data sets are not suitable for detailed studies of land cover change; however, both of the data sets provide a data base of manageable data volumes. The 7.36 kilometer data set exists for all of Africa and extends back to 1982. This data set is very coarse and can only detect very extreme land cover changes. The primary utility of this data set will be for model simulations and for broad regional studies.

The Landsat satellite carrying the Multi Spectral Scanner (MSS) sensor since 1972 and the Thematic Mapper (TM) sensor since 1978 are at much higher resolution (80 and 30 meters respectively). The high sampling rates of these sensors quickly generate very large data sets even for a country the size of Senegal. These data sets were used for base line mapping of the vegetation cover in the mid 1980's.

Variance component models can be used to assess variations in periodic seasonal patterns between years and to assess variation between subnational sampling units (Milliken, 1992). The determination of land use change using remotely-sensed data requires the ability to detect differences between the land cover through time. The AVHRR satellite samples the earth daily and the Landsat satellite samples the earth about every two weeks. From these multiple observations per year a vegetation curve can be created that will describe the annual growth pattern of each of the land cover types. Variance component models can be used to represent each of these annual curves and allow the detection of changes between years (many of which will be climate related). Variance component models can be used to model growth curves for multi year data sets by subnational regions and can be used to detect outliers or anonymous regions.

The accurate classification of land into agriculture, range, forest and urban classes using remotely-sensed data is difficult to accomplish. The definition of these classes is particularly difficult in tropical developing countries where agriculture can be interspersed with range and forest and occurs on plots near the resolution of the sensor. Urban development is usually confused with range or barren lands since urban structures are often built from natural materials. Remotely-sensed data provide a qualitative consistent estimate of the land cover classes. A careful evaluation of the classification can provide a user with knowledge of the confusion associated with each estimate.

The Human Carrying Capacity project described by Moore and others (1992) is based on the interpretation of Landsat TM data produced by Stancioff and others (1986). The vegetation and soils maps were manually interpreted from early 1980's wet and dry season imagery and were verified by visiting nearly 600 field observation locations. Rodriguez-Bejarano (1986) provides an excellent description of the use of remote sensing techniques to monitor deforestation and related agricultural and range activities. He discusses sources of data for West Africa and Central America and appropriate scales for interpretation.

Capacity (limits) data

Capacity data sets define the upper limits on transitions. Soils and climate data define limits upon the spatial extent of each vegetation cover. The rainfall is highly variable from year-to-year and in good years some range land can be converted to agriculture with the risk of desertification once rainfall returns to normal levels. The nutrient levels of many of the forest and range lands are not suitable for agricultural.

As part of the Human Carrying Capacity project four major data sets were compiled to calculate the number people that could be sustained by the land (Moore and others, 1992). These four data sets are soils, precipitation, agricultural yield, and population. The soils and precipitation data determine the maximum extent of potential agricultural land. Specifically for Senegal the maximum extent of potential agricultural land was determined to be all moderate potential soils receiving at least 400 mm of rainfall per year. This maximum was further constrained to exclude all lands that are presently legally protected. The Human Carrying Capacity (HCC) data attempts to define upper limits of supportable population growth. Human Carrying Capacity is a function of the potential food crop production and the human food requirements and provides an estimate of the maximum number of people that can be supported by the maximum agricultural potential of the land.

The soil and climate data also set limits on potential range and forest land development. This information helps identify areas, that if stressed, would be in greatest danger of soil degradation and conversion to nonproductive soils for any purpose without major rejuvenation costs.

Results

Land Use and Land Cover Change

Land use and land cover change was only investigated at the national level (Figure 4.2). The relationships as reported by the World Resource Institute are very simple.

Pasture land has remained constant. Agricultural land has increased sharply at the expense of forest and woodland land. Other land area including urban and desert land has increased slightly. The picture may not be as simple as it seems. Even though agricultural land is the big gainer, some agricultural land may have been lost to urban development. Some of the forest and woodlands were probably converted to pasture and then pasture was converted to cropland. Some pasture was likely lost to desert. The paths through the land use transitions will be convoluted.

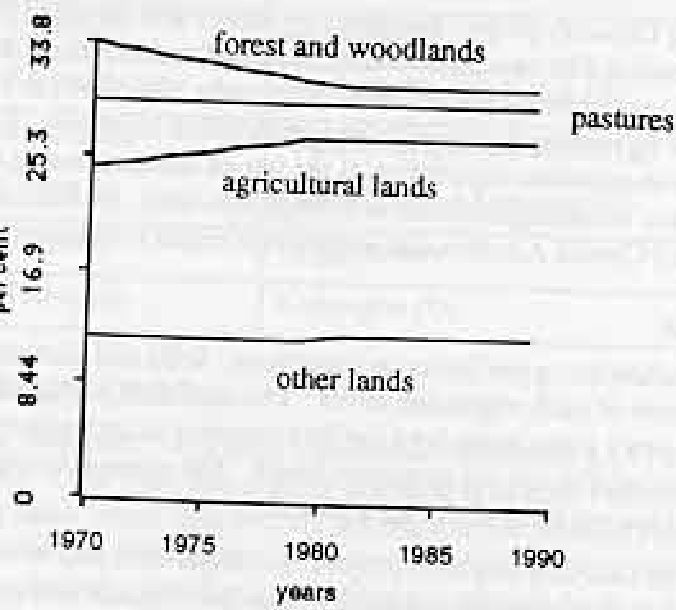

Figure 4.2. Percentage of total for each land use land cover class (Source: World Resources Institute, 1992)

Remotely sensed data could be used to provide historical subnational estimates of land cover back as far as 1972. Of particular interest would be amounts of land converted to agriculture and the amounts of range and forest land that have become nonvegetated and that have remained so through wet weather cycles.

Population growth

Logistic models are frequently employed for population growth models. The idea of transitions are well represented by logistic models that are typified by low and upper bounds representing initial and final equilibriums connected by a change in state. The upper bound can be estimated by the human carrying capacity model.

The rural population growth is represented effectively with a logistic model, while the urban population growth shows an exponential growth (Figure 4.3). Birth rates by urban and rural populations were not available; however, the birth rates are not likely to parallel the population growth rates for those populations. The disparity between the two growth rates is likely to be due to migration from rural to urban populations, which allows the rural population to come into equilibrium. As a consequence, exponential growth in the urban population is even more pronounced.

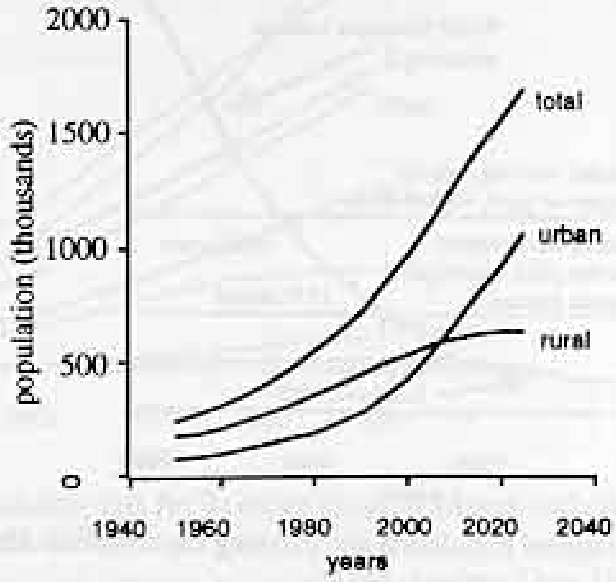

Figure 4.3. Total, urban and rural population from 1950 to 2025 for Senegal (Source: World Resources Institute, 1992)

The total population for Senegal was extended back in time to 1910 using data from (Lombard, 1963). The curve based on 1950-present smoothly can be extended to approximate the data from the earlier years (Figure 4.4). Three estimates of human carrying capacity were superimposed on the population data. The first estimate the number of people that can be fed assuming the current area planted, current crop yields and present mixture of crops. The second estimate assumes an expanded area planted, improved crop yields and present mixture of crops. The third estimate assumes an expanded area planted, improved crop yields and only food crops (no cash crops). The area planted is based on three criteria; the half of the land must lie fallow every year, no crops are planted in protected areas, and 50 percent of the natural vegetation was preserved to maintain biodiversity and local habitat.

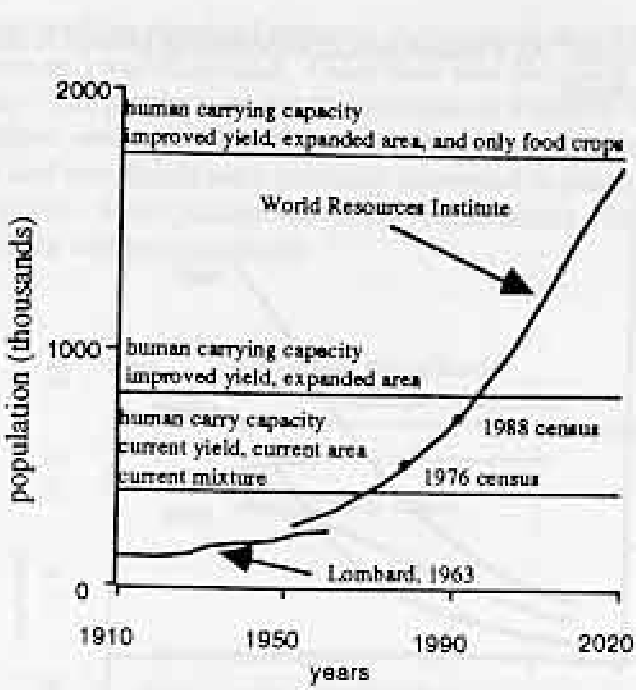

Figure 4.4. National population and carrying capacity data (Source: World Resources Institute, 1992 and Lombard, 1963)

The carrying capacity based on the first estimate was passed in the early 1970's, the second estimate was passed in the early 1990's, and the third estimate is projected to be passed in the early 2020's. Food requirements for the present population is being met through food imports using cash crop proceeds, and with food aid.

Subnational data was available for 14 cercle administrative units in 1951 and 1958. Not all of the cercles covered the same spatial extent for both reporting periods. Eight of the cercles were identified for which the boundaries were constant for all four reporting periods (1951, 1958, 1976, and 1988). Rural vs. urban population data were not available for 1951 and 1958. The curves for these eight cercles can be seen in Figure 4.5. The most urban cercle is Dakar which experienced a dramatic four fold increase in population since 1951. Dakar has negligible agricultural, range or forest land in comparison to its population. Kaolack, Thies, and Ziguinchor are all coastal cercles in the mid to south western section of Senegal with the highest precipitation. These four cercles also had high growth rates. The next two cercles, Diourbel and Louga, are both in the agricultural center of the country, but with less precipitation than the previous four. The last two, Linguere and Kedougou, are in the western section of the country away from the urban centers and had lower rates of growth.

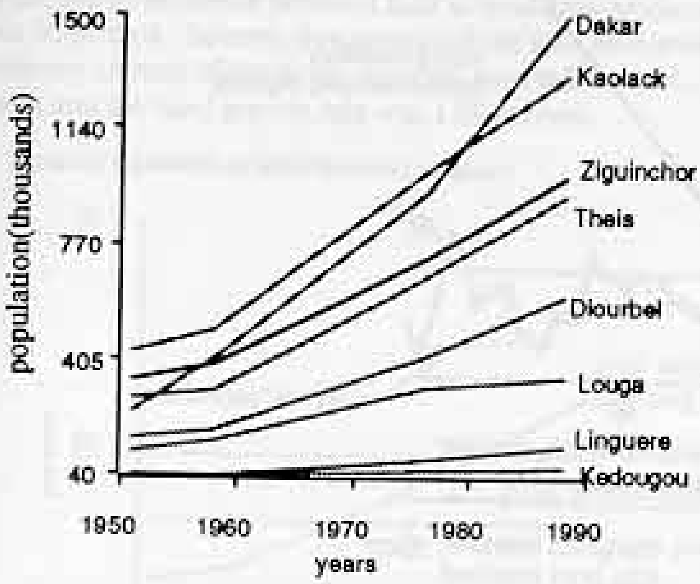

Figure 4.5. Population data for 8 cercles (Source: Moore and others, 1992, and Republique du Senegal, 1988)

Four of the 1951 cercles (Thies, Kaolack, Ziguinchor, and Diourbel) corresponded to present regions. Dakar also has not changed its boundaries, but has insignificant agriculture production. Agricultural statistics for the 1988 regions were available for between 1960 and the present (Senegal, 1991). Six variables were plotted for each of these four cercles. The variables are the population as the percent of the human carrying capacity, human carrying capacity (100 percent), percent rural population for the 1976 and 1988 censuses (rural/total population), hectares of food crops planted as percentage of total land with moderate potential or better, hectares of food crops planted as percentage of total land with moderate potential that are not inside protected areas, and percentage of land with moderate potential of total land.

The population of Thies has been beyond its carrying capacity since the 1950's (Figure 4.6). The percent of moderate potential land in food crop production has varied widely from 70 percent to 120 percent. Significant marginal lands is cultivated in Thies during peak production years. Only 50 percent of the total land has moderate potential. Thies is the only cercle that shares an adjacent boundary with Dakar and therefore is most immediately impacted by Dakar's rapid population growth. The percentage of the rural population is decreasing in all four of the cercles. In Thies the urban growth rate between 1976 and 1988 was 4.18 percent compared to the rural growth rate of 2.13 percent.

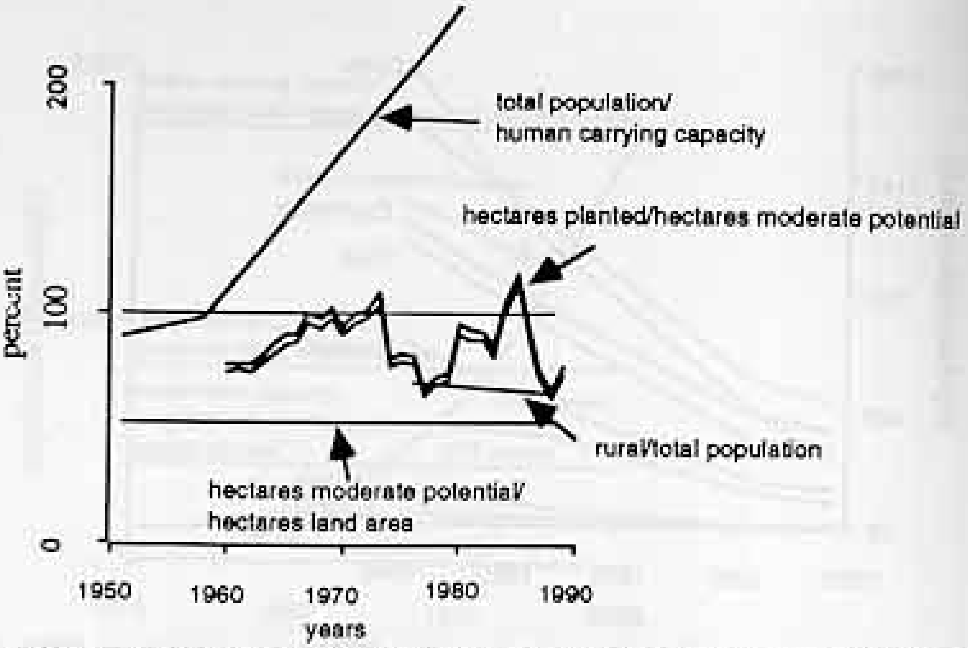

Figure 4.6. Population and agricultural land for Thies (Source: Moore and others, 1992, and Republique du Senegal, 1988, USAID, 1991)

The population of Kaolack has not yet reached its carrying capacity (Figure 4.7). The percent of moderate potential land in food crop production has steadily increased from 30 percent to 60 percent. Eighty percent of the total land area has moderate potential and a significant amount of moderate potential land is protected. The urban growth rate was 3.23 percent and the rural growth rate was 2.33 percent.

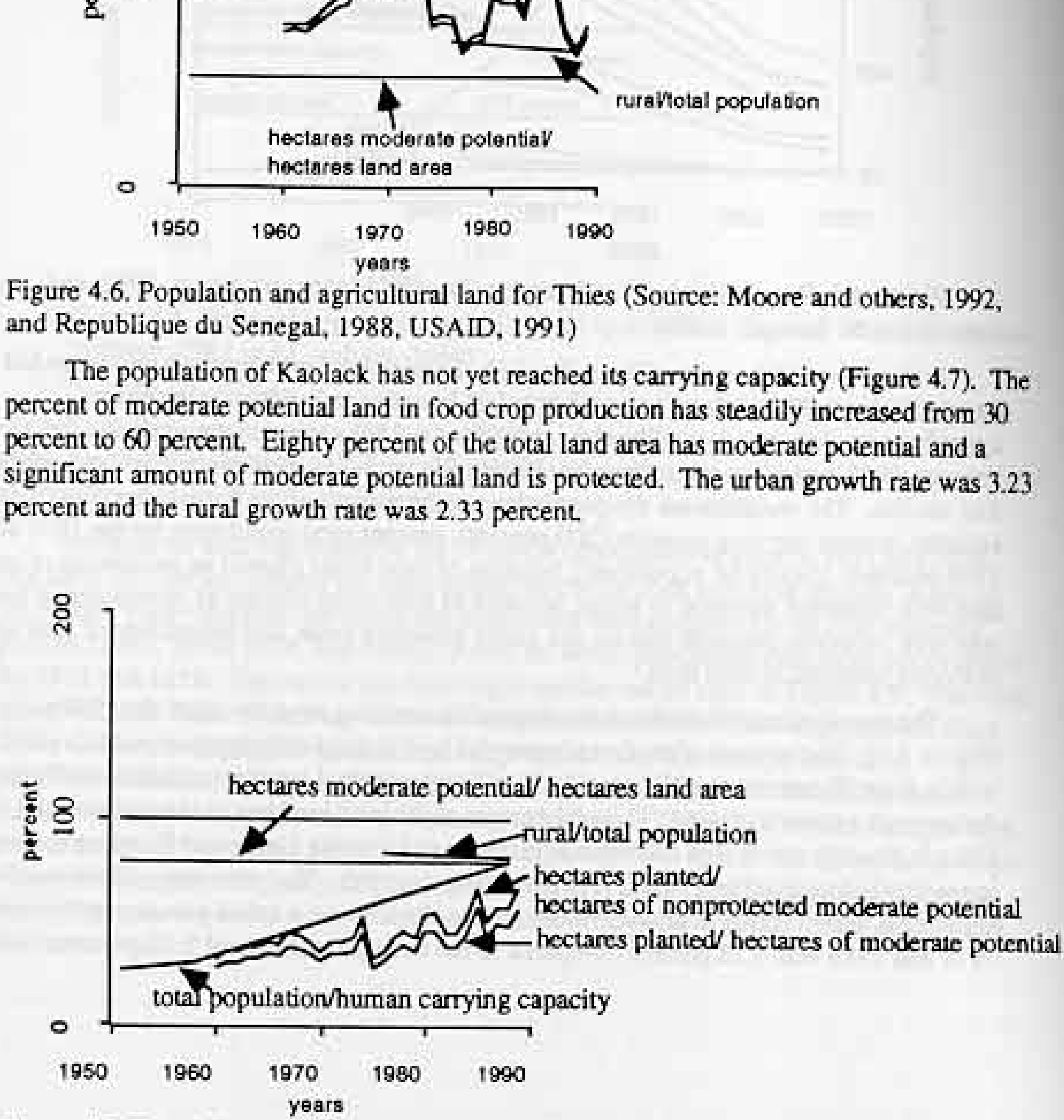

Figure 4.7. Population and agriculture land for Kaolack (Source: Moore and others, 1992, and Republique du Senegal, 1988, USAID, 1991)

The population of Ziguinchor passed its carrying capacity about 1980 (Figure 4.8). The percent of moderate potential land in food crop production has remained steady at about 20 percent. Seventy five percent of the total land area has moderate potential and a significant amount of moderate potential land is protected. The urban growth rate was 4.71 percent and the rural growth rate was 1.59 percent.

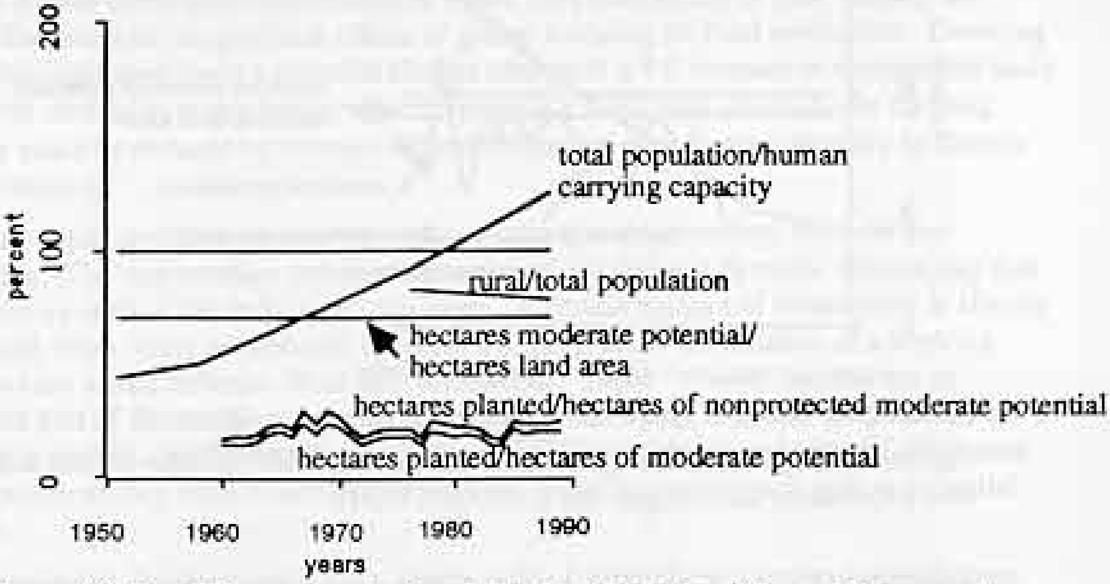

Figure 4.8. Population and agricultural data for Ziguinchor (Source: Moore and others, 1992, and Republique du Senegal, 1988, USAID, 1991)

The population of Diourbel passed its carrying capacity about 1970 (Figure 4.9). The percent of moderate potential land in food crop production has increase with wide fluctuations from around 50 percent to 90 percent of the available moderate potential land. The urban growth rate was 3.45 and the rural growth rate was 3.11. The percent change in rural population was smallest in Diourbel of the four cercles studied.

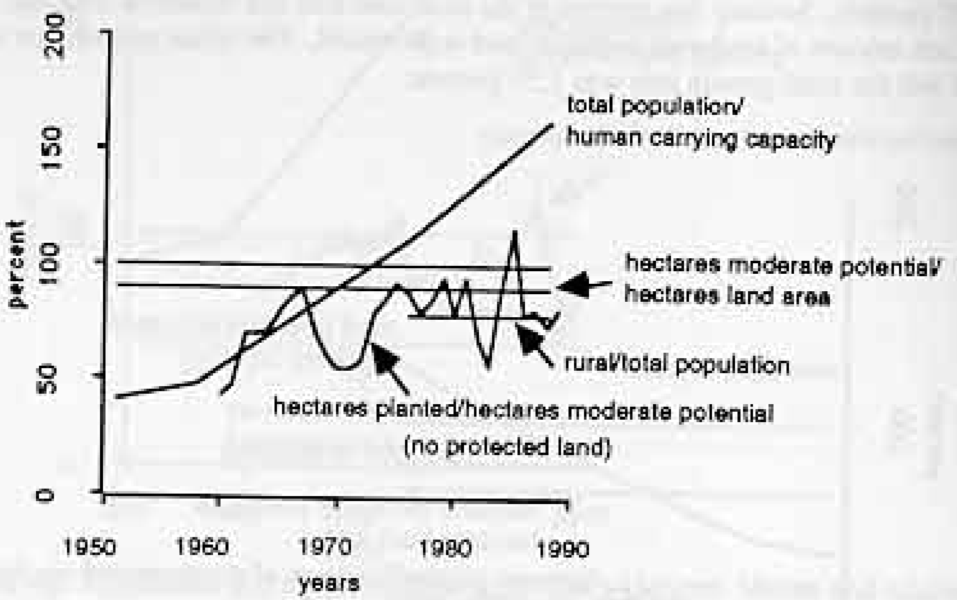

Figure 4.9. Population and agricultural data for Diourbel (Source: Moore and others, 1992, and Republique du Senegal, 1988, USAID, 1991)

Discussion

The relationship and potential shortfall between population growth and agricultural productivity has been described in terms of food security. Martin (1988) assembled a number of definitions of food security that can be summarized simply as the ability to provide food for human population both now and in the future. He identifies the time horizon and level of aggregation as two key dimensions for understanding food security. An inspection of the data in this paper does not provide an encouraging view of the time horizon. The population growth shows no sign of diminishing and agricultural growth shows every sign of having leveled off. Furthermore, an inspection of the data at the cercle level do not show any local regions that have the potential for future support of the population at the present rate of growth. Food import will continue to be required.

The definition of human carrying capacity data used in this paper is limited. A more complete definition requires the incorporation of a individual's ability to purchase food. For example, densily populated countries such as Japan or Taiwan may never be able to support themselves on their own food production capability. If countries such as the United States, Australia, and Argentina with higher agricultural potential can continue to produce more food than their population requires then the world as a whole could survive. The exchange of food for service, raw material or industrial production is certainly rational and justifiable; however, the world cannot, under any condition, support exponential growth curves. No scenario allows food production to grow at exponential rates.

An apparent ironies concerning agricultural productivity in Senegal is that the major cash crop is peanuts and the peanuts are being grown for export to Europe for cattle feed. So not only is overproduction of cattle damaging the range land in Senegal, but the European perceived requirement for meat reduces the agricultural land available for food crops in Senegal. Perhaps one the major refocusing of both the industrial and less industrial countries is a reassessment of the important of meat as a food source.

To further complicate calculations of future food availability or food security are studies that estimate the potential effects of global warming on food production. Downing (1992) has estimated given a potential climate change of a 4 C increase in temperature and a 20 percent decline in precipitation, which represent a worst case scenario, the carrying capacity could be reduced by between 62 and 89 percent even further intensify an already critical situation.

This paper describes two very broad and interrelated transitions; land use and population. The relationships between these transitions define a dynamic relationship that sets limits on each of the individual transitions. A certain amount of subjectivity is always introduced when limits are defined; however the limits allow the creation of a working model within which different ideas can be explored. These "what if" models are an important part of determining the outer thresholds when trying to assess the potential of different remedies. Both Meadows and others (1992) and Moore and others (1992) used this approach as they tried to identify alternatives to continuing upward with exponential growth.

Sustainable development is not a simple ratio of agricultural development to human population. Sustainable development must consider the continued ability of the land to support the land use, as well as the long term and hard to quantify implications of biodiversity. Senegal contains an interesting mix of land use and land cover types including desert, rangeland, irrigated agriculture, rainfed agriculture, woodlands, tropical forest and extensive wetlands spread across several climate zones from arid to semiarid to humid. Within Senegal many issues of scale and time can be effectively analyzed.

Grainger's (1992) deforestation model provides a useful starting point for future research in population-environment dynamics. Grainger's model proposes a relationship between farmland area and per capita food consumption and yield per hectare, and equates gain in farmland area to deforested area. Remotely sensed data could be used to produce a very crude estimate of land cover for range, agriculture and forest classes for the years from 1972 to the present. A confounding problem in Senegal is the introduction of rangeland as the primary land use being converted to agriculture. In a forested environment the transition from forest to agriculture to barren/fallow can be detected; however, in a range environment the transition is obscured through a general similarity between range and subsistence agriculture, and by the physical transition from range to forest through a woodland-savanna class as the crown closure becomes more complete. Significant generalization of his model is required to the incorporate vegetation covering the forested south, the woodland central and the rangeland north.

To better understand scale and the level of aggregation on transition theory analysis of subnational data should be continued. Of particular interest would be the introduction of diffusion models to provide a mechanism for tracking potential changes in land use patterns and in population patterns (Olsson, 1965). Diffusion models help us explain spatial patterns that underlie national statistics. An example is the analysis of the diffusion of population from rural areas to urban areas, the movement of a line of demarking areas of desertification into lands that had previously been productive, or the expansion of agricultural lands into range and forest lands. The inspection of these spatial diffusion patterns can lead to a better understanding of the spatial and temporal relationships between population and land use transitions.

Knowledge of the interrelationships between population growth and land use change must be translated into changes in government policy and personal attitudes that can help us bring the present trends into equilibrium with reality. Why do the perceptions exist that meat is a required food, that eight children are optimal, that living in rural areas is undesirable, and that success must be measured in terms of quantity rather than quality. Changes that could mediate in favor of an improved perception of rural life style would be increased education, increased communication, and increased involvement of rural populations. One possible result of the computer and communication revolution now underway in the industrialized world, would be to extend this capability to the individual level worldwide.

A first step in such a revolution are Population-Environment Monitoring Systems as defined by Zinn, Brechin and Ness (1992). PEMS are designed to: (1) be driven by requirements important at the local level; (2) use appropriate technology that is available, maintainable and understood at the local level; (3) use simple methodologies to analyze and display the data; (4) be flexible and adaptable; and (5) must feed into regional and national level management requirements. PEMS are designed empower local officials. Drake has discussed the importance of feedback between different levels of a governmental hierarchy. The importance of each level in the success of the overall structure must be recognized. At the lowest level the individual must perceive the government structure is providing a useful function and in turn recognizes the importance of the individual.

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Chapter 5: Katharine Hornbarger

THE ENERGY CRISIS IN INDIA: OPTIONS FOR A SOUND ENVIRONMENT

Introduction

Energy is considered to be the fuel of economic progress, the essential indicator of economic growth and development. A direct correlation exists between aggregate economic growth and aggregate energy consumption, as well as between per capita income and per capita energy consumption. Thus, countries that have had an abundant supply of energy available to them have enjoyed significantly higher rates of industrial growth and corresponding increases in gross national product (GNP) than countries that have not had such supplies available to them. The differences in the levels of per capita energy consumption among developing and industrialized nations are extreme. For example, the developing countries of Asia, Africa, and Latin America, which contain 71% of the world's population, consume only half as much commercial energy annually as does the United States alone, which contains only 5.5.% of the world's population.[1] In 1985, per capita energy consumption in India was 201 kg. of oil equivalent, as compared to 4958 kg. in industrial countries as a whole, and 7278 kg. in the U.S. alone.[2]

If one examines the *growth rate* of energy consumption in both developing and industrialized countries, however, it is clear that these dramatic differences will become less significant in the future. The growth rate of energy consumption in developing countries during 1980-85 was 5.7%, compared to 0.1% on average in industrialized countries.[3] Given such a high growth rate, the need to examine current patterns of energy usage in developing countries becomes apparent. What forms of energy currently are being employed in developing countries, and what are the trends in terms of future energy development and consumption? What impact will these trends have upon existing energy reserves and resources? Will certain developing countries face an energy crisis in trying to meet their ever-increasing demands? Such questions must be answered if one is to provide an adequate description of the 'energy scene' in developing countries today. However, another and perhaps more important question must be asked concerning the impact of current and future energy development and consumption patterns upon the environment.

In considering the environmental impacts of a country's energy development and consumption patterns, one must necessarily examine the role of fossil fuels in that country. The potentially devastating global environmental impacts of fossil fuel emissions are now fully recognized, but the recent behavior of developing countries has not necessarily reflected this awareness. Indeed, fossil fuel consumption in developing countries is expected to double within the next 20 years, as countries attempt to expand their energy base and bolster their economic well-being.[4] Thus, industrialized nations currently are faced with the challenge of trying to reduce global reliance on fossil fuels while developing countries are attempting to better domestic conditions by increasing their energy supply. Given these seemingly conflicting goals, forecasts for reducing fossil fuel-derived emissions throughout the world tend to be rather dim.

The purpose of this paper is to show that such forecasts do not have to become self-fulfilling prophecies. By examining the current energy consumption and development trends within India, I hope to show that developing countries, in the course of their energy transition, can avoid the heavy reliance on fossil fuels that developed countries have traditionally exhibited. This paper begins by examining the prevailing forms and sources of energy within India, as well as the various sectors of energy consumption within the country. The paper then explores the extensive relationships among demographic, economic, and energy variables. Finally, it addresses alternative forms of energy which, if employed successfully and on a large scale, could provide a solution to India's energy crisis while simultaneously contributing to a reduction of the threat to the global environment.

Forms and Sources of Energy

India's energy resources can be broadly grouped into two categories: commercial energy and non-commercial or traditional energy. Commercial energy denotes energy that is used primarily for commercial purposes, although small amounts of this type of energy are used for noncommercial purposes, such as in households. Commercial energy sources include coal, crude oil, natural gas, electricity (hydro and thermal), and nuclear energy. Non-commercial or traditional energy, as its name implies, is energy that is used for non-commercial purposes. Non-commercial energy sources include firewood, vegetable wastes, and animal wastes. Other energy sources available but not currently under development include solar, geothermal, tidal, and wind power.

Commercial Energy Sources

Coal

Among commercial fuels, coal is the most dominant source of energy in India, as well as the cheapest in terms of heat content. India possesses approximately 39 billion tons of extractable coal reserves, sufficient to last for 390 years at the current rate of production.[5] Coal provides more than two-thirds of India's commercial energy needs, while oil, hydro, and nuclear resources supply the remaining one-third.[6] From 1900 to 1980, coal *production* increased from 6 million tons to 107 million tons (see Figure 5.1).[7] A corresponding increase in coal *consumption* was caused by the substitution of coal for fuel in industries, establishment of low-temperature carbonization plants, commissioning of three coal-based fertilizer plants, setting-up of additional thermal power stations, and increased steel production.[8] The electric power, steel, railways, and cement industries currently account for about 70% of the total coal consumption in the country.[9] Of these industries, the power sector accounts for the greatest consumption of coal. New developments in power-generation technology with large unit sizes of generating plants will require enormous quantities of coal. For example, a power plant with 1000 MW capacity may require as much as three million tons of coal annually.[10]

Figure 5.1A compares two possible futures for coal consumption to actual data. The base year for both of these projections is 1971, and the numbers can be compared to a level of coal consumption in 1987 of just over 35 million tons of oil equivalent (*toe*).[11] One possibility (the logistic curve) assumes that coal consumption will reach a limit of 75 *toe* but never exceed this level, while the other scenario (the exponential curve) allows coal consumption to grow exponentially. While both curves appear to be following the same course for the first 40 years or so (until the year 2011), soon thereafter they pursue dramatically different paths. The logistic curve levels off, nearing its limit of 75 million *toe* by the year 2071, while the exponential curve surpasses 140 million *toe*, approximately double the level of consumption projected by the logistic curve, by the year 2071. The implications of these projections are clear: if *actual* coal consumption indeed is following a path similar to that of the exponential curve shown in Figure 5.1A, then India's CO_2 emissions can be expected to rise dramatically over the next century. The ramifications of such increased reliance on fossil fuels and thus, increased CO_2 emissions, will be discussed later.

With the increase in the coal requirements of thermal power stations, the quality of coal has deteriorated from an average calorific value of 6000 kcal/kg in 1960 to 4500

Figure 5.1
Coal Production in India
Source: M. Sengupta, "Energy and Power Policies in India," 1985

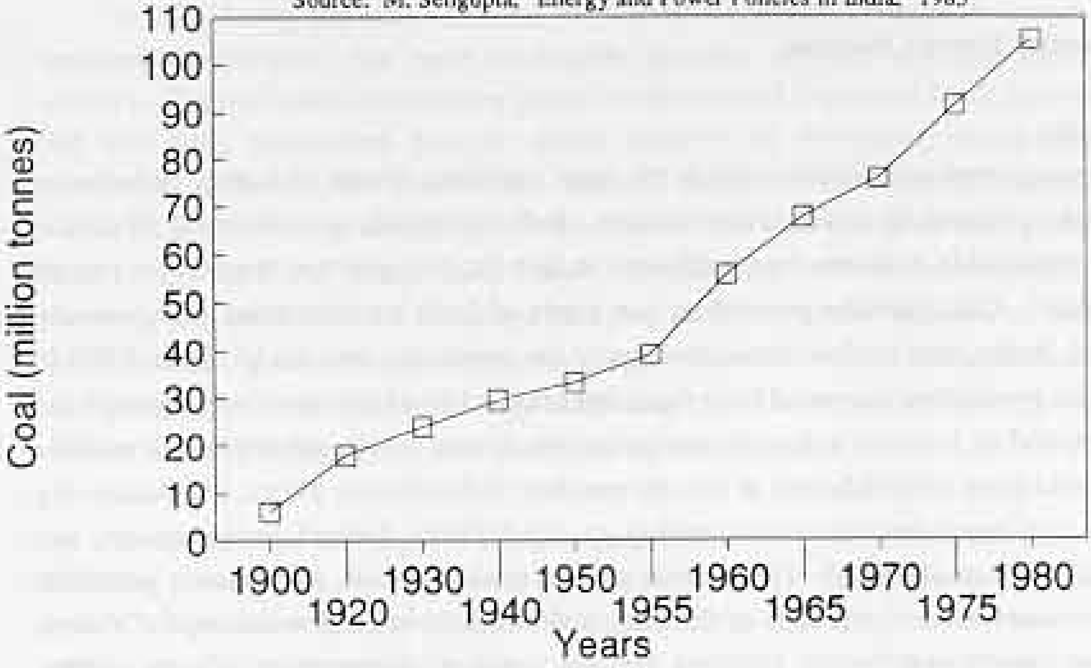
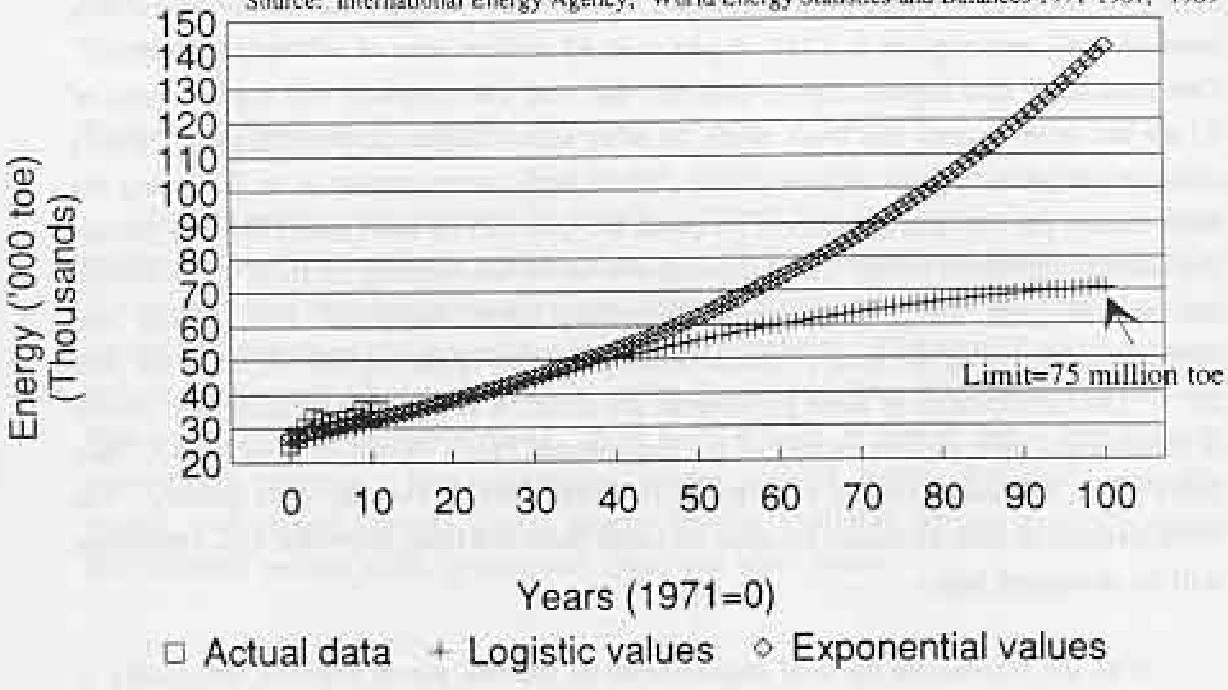


Figure 5.1A
Possible Futures for Coal Consumption
Source: International Energy Agency, "World Energy Statistics and Balances 1971-1987," 1989



kcal/kg in 1985, and this downward trend is likely to continue.[12] Thus, power-generating facilities will require even more coal to produce less power. To make matters worse, although India has large reserves of coal, the bulk of the resources have high ash content, generally 25-40%.[13] The high-ash content of the coal has lowered the capacity factor of the coal-based plants to approximately 62%, and the new power stations are expected to receive even more inferior coal, resulting in even lower plant capacity.[14]

Oil

Oil reserves in India are estimated to be approximately 17 billion metric tons (bmt), four bmt of which have already been established.[15] Between 1980-85, demand for petroleum products increased by 58%, with total demand in 1985-86 estimated at 53 million tons of crude oil equivalent.[16] Some forecasters estimate that total petroleum product demand will be almost 92 million tons by the year 2000, thus implying a growth rate for demand of over 6% annually.[17] From 1970 to 1989, oil production increased by a factor of 5, from 285.075 petajoules in 1970 to 1427.866 petajoules in 1989 (see Figure 5.2).[18] However, more than 50% of India's petroleum supply is still imported.

The transport and household sectors account for 80% of the total oil consumption in India. Within the transportation sector, oil is crucially important, as it is used both in road transport and railways. India's railways are still highly dependent on diesel oil, although there has been a recent push to electrify the railways and replace the diesel engines. Within the household sector, oil is used primarily as kerosene for lighting and cooking. Because kerosene is a mass consumption good, the supply and price of it are important policy variables for the Indian government, and India's national energy policies reflect efforts to prevent kerosene shortages and price increases. The government has used price increases on other oil products, primarily gasoline and furnace oil (used by industry) to control oil consumption. To meet its ever-increasing petroleum demands, the government established direct oil deals with Iran and Iraq and supported domestic oil exploration and production, including offshore exploration.

Natural Gas

In India, natural gas is found both alone and with crude oil. Natural gas is used in the manufacture of nitrogenous fertilizers, petro-chemicals, and liquid petroleum production. Natural gas reserves in India currently are estimated to be around 63 billion cubic meters, of which only 40% was used by the end of the seventies.[19] Recent efforts have focused on the exploration of new natural gas sources and the development of technology to ensure that natural gas is utilized efficiently. The result of these efforts has

Figure 5.2
Oil Production
Source: World Resource Data Base, 1992

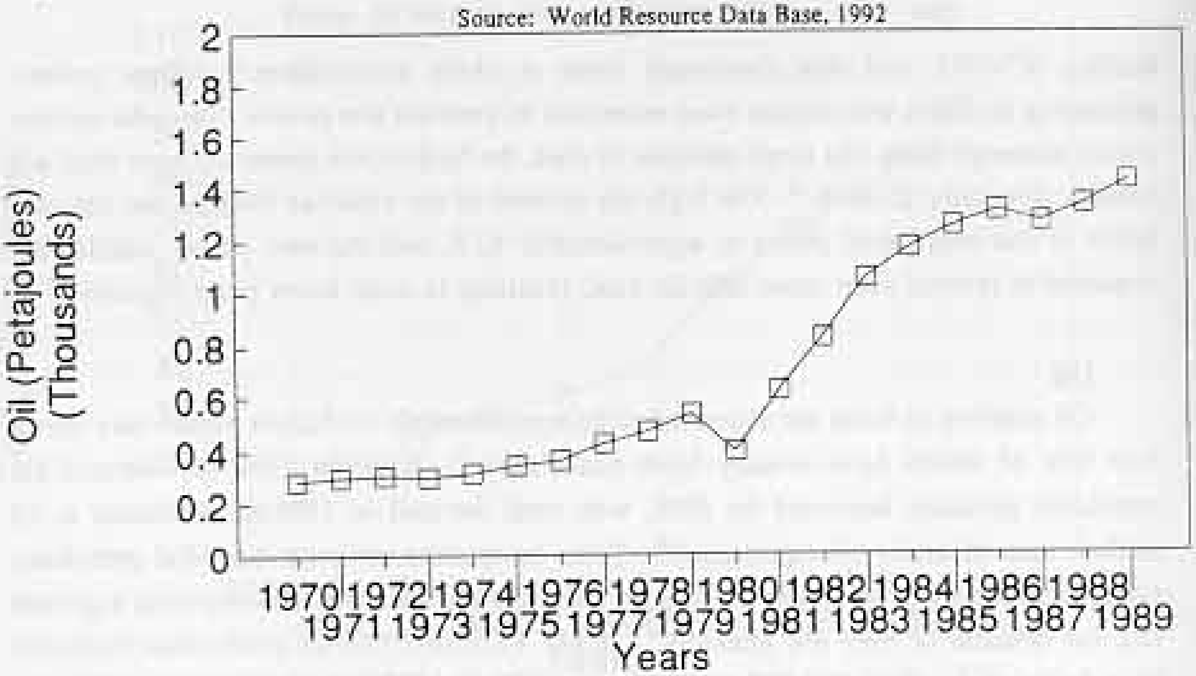
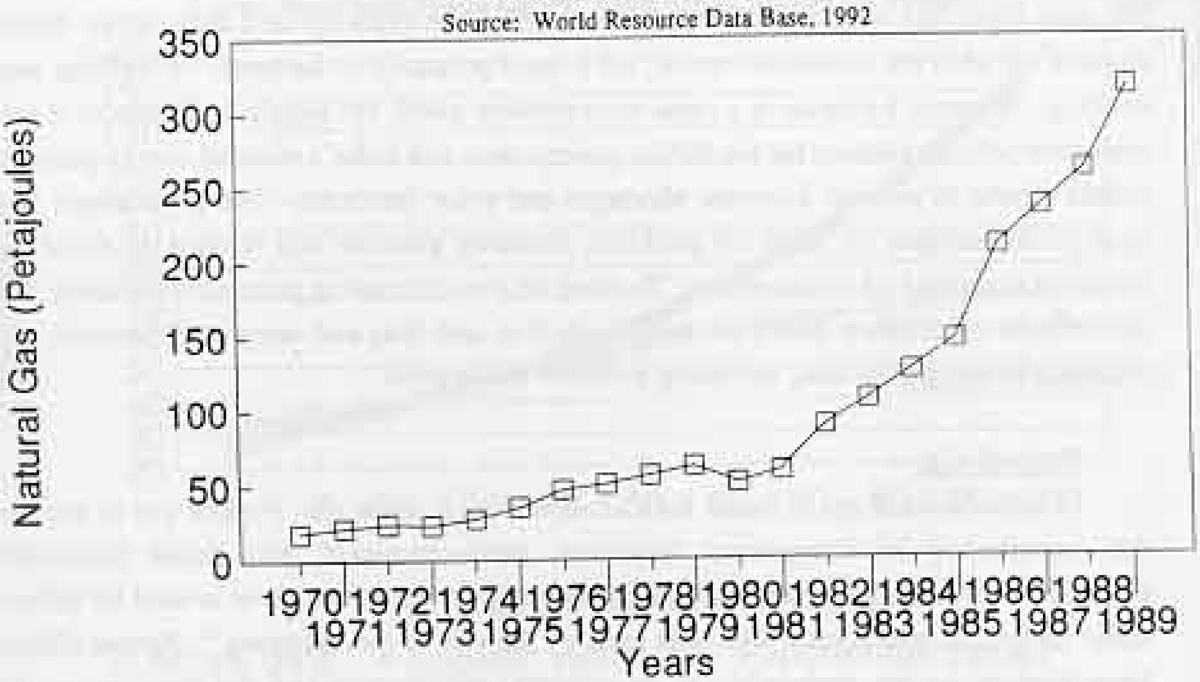


Figure 5.3
Natural Gas Production
Source: World Resource Data Base, 1992



been the construction of two large fertilizer plants in gas producing areas, and the planning of three other similar developments. Marketed production of natural gas increased from 18.786 petajoules in 1970 to 315.819 petajoules in 1989 (see Figure 5.3).[20] This corresponds to a 1580% increase in only 19 years, or an average increase of 83% per year. Such a dramatic increase in production can be attributed to the discovery of extensive on- and offshore natural gas reserves. Natural gas thus constitutes an important source of energy for India, all the more significant because of its role in agricultural production.

Hydroelectric Power

India's hydroelectric potential constitutes an important source of renewable energy which the nation has attempted to utilize. The country's major river systems originating from the Himalayan ranges flow from considerable heights to the plains below. Because of the hilly terrain and steep falls through which India's major rivers and streams pass, there are several sites where hydroelectric power can be generated. A recent estimate of India's hydro potential is 89,530 MW, which, if utilized fully, could provide the country with 533 trillion watt hours (TWH).[21] The significance of India's hydro potential can be seen from the fact that the nation's total power generating *capacity* at the end of 1984-85 was 42,440 MW, of which fully one-third, or 14,466 MW, was hydroelectric generation capacity.[22] Moreover, total power *generation* in 1984-85 was 145 TWH, with hydro power units contributing over one-third, or 53.81 TWH, to this total.[23] Thus, India's hydroelectric power represents a major source of renewable energy. Indian energy officials are beginning to realize the potential of hydropower and increase its exploitation, as evidenced by the 150% increase in hydropower generation over 19 years, from 90.941 petajoules in 1970 to two and one-half times this amount, or 229.537 petajoules, in 1989 (see Figure 5.4).[24]

Nuclear Energy

In the realm of nuclear energy, India possesses rather extensive uranium ore as well as thorium ore reserves. Although nuclear energy sources do not constitute a considerable portion of the national energy pool at present, both uranium and thorium are potentially significant forms of commercial energy. Uranium ore reserves are estimated to be 70,000 tons, while thorium ore reserves are estimated to consist of more than 360,000 tons of recoverable material.[25] The energy potential of India's uranium ore when utilized as fuel in a thermal reactor is equivalent to 120 billion metric tons (bmt) of coal.[26] On the other hand, the thorium reserves, when utilized in the same capacity, would provide the energy equivalent of 600 bmt of coal.[27] Thus, many energy forecasters see thorium as

Figure 5.4
Hydropower Production
Source: World Resource Data Base, 1992

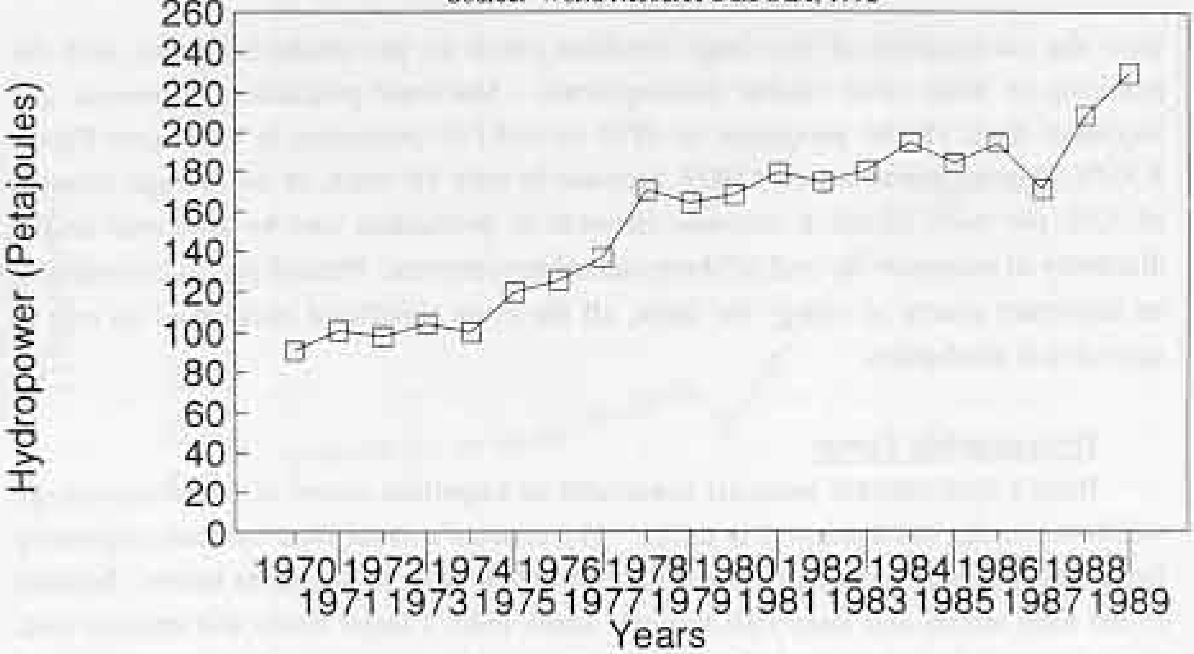
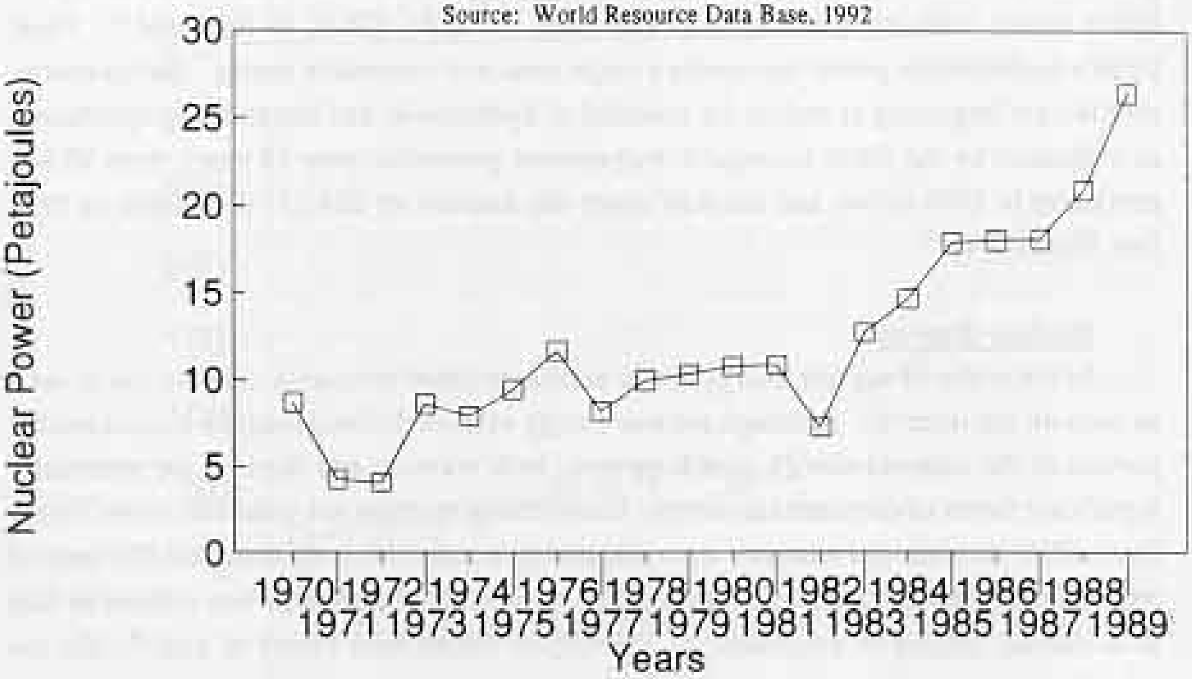


Figure 5.5
Nuclear Power Production
Source: World Resource Data Base, 1992



"the single most important energy resource of India."[28] Figure 5.5 provides an illustration of the growth of nuclear power production in India; in 1971, the country produced 8.704 petajoules of nuclear power, while in 1989, India produced three times this amount, or 26.465 petajoules.[29]

Overall, then, coal represents India's primary energy source, followed by oil, natural gas, hydropower, and nuclear power. Figure 5.6 compares the relative inputs to energy production from these five sources of energy. As previously noted, the environmental ramifications of such heavy reliance on fossil fuels will be addressed later in the paper.

Non-Commercial Energy Sources

Firewood constitutes the most important source of non-commercial energy in India today. Firewood is used as household energy by practically all of India's rural population as well as by the urban poor. Biogas, formed from processing human, animal, and vegetable wastes, represents another important source of non-commercial energy. Firewood, dung-cakes, and agricultural wastes constitute 65%, 15%, and 20%, respectively, of the energy used by India's rural population.[30] Consumption of all forms of non-commercial energy is higher in the rural sector, primarily because these fuels are more readily available to the rural population and usually can be obtained at zero cost. In fact, 80% of the energy consumed by rural citizens is in the form of non-commercial energy, as opposed to 50% for urban citizens. In general, India's heavy reliance on non-commercial sources of energy can be attributed to the non-availability of electric power in most rural areas and the inability of almost 3/4 of India's population to purchase electric power (if it is available) or cooking gas for domestic use. Overall, non-commercial energy's share of total energy consumption has decreased from 40.98% in 1970 to 24.73% in 1989 (see Figure 5.7).[31]

Commercial Energy, Non-Commercial Energy, and GNP

Currently, about 50% of total energy consumption in India is derived from commercial sources, and the remaining 50% comes from non-commercial sources.[32] From 1970 to 1989, total commercial energy consumption increased by a factor of 3.36, rising from 2237.5 petajoules to 7528.4 petajoules.[33] Conversely, during this same time period, consumption of traditional fuels increased by a factor of only 1.56, rising from 1692.3 petajoules to 2644.0 petajoules.[34] Figure 5.8 compares the respective increases in commercial and traditional energy consumption from 1970 to 1989. Also during the

Figure 5.6
Relative Inputs to Energy Production

Source: World Resource Data Base, 1992

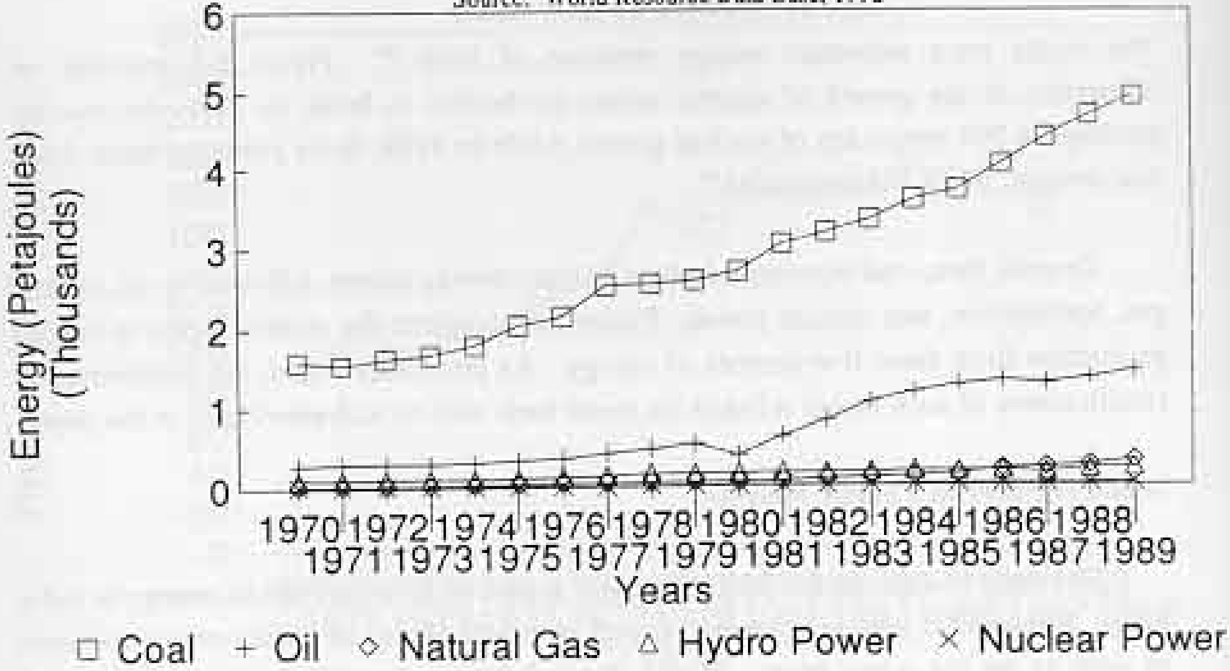


Figure 5.7 - Traditional Fuel as % of Total Energy Consumption

Source: World Resource Data Base, 1992

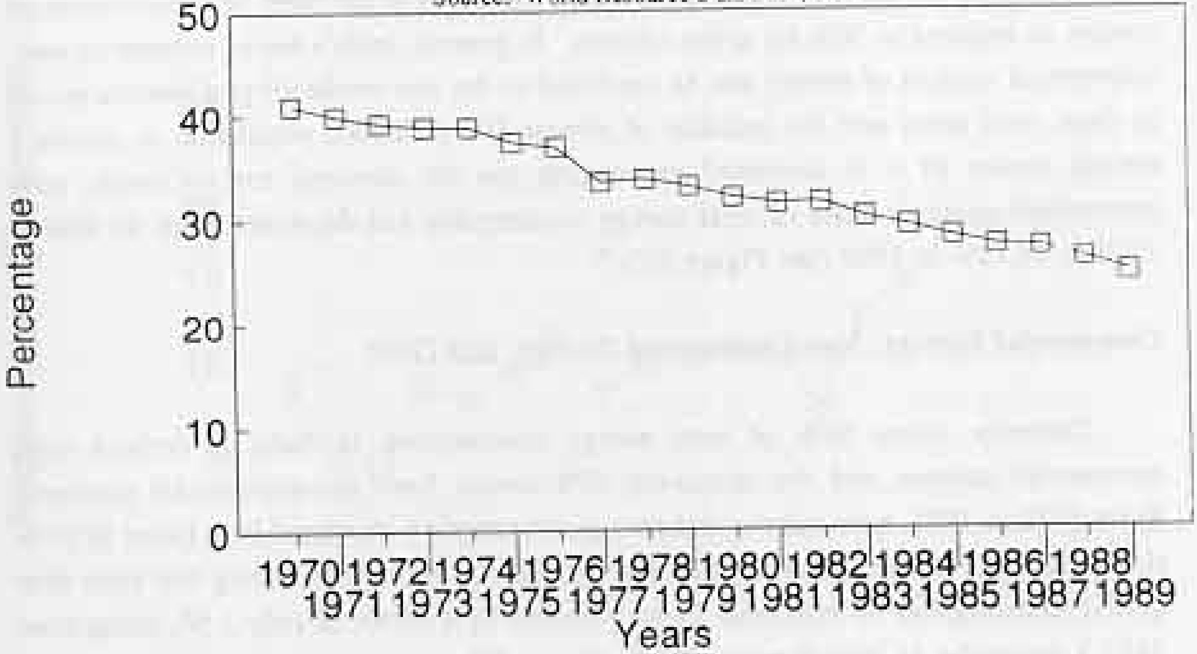
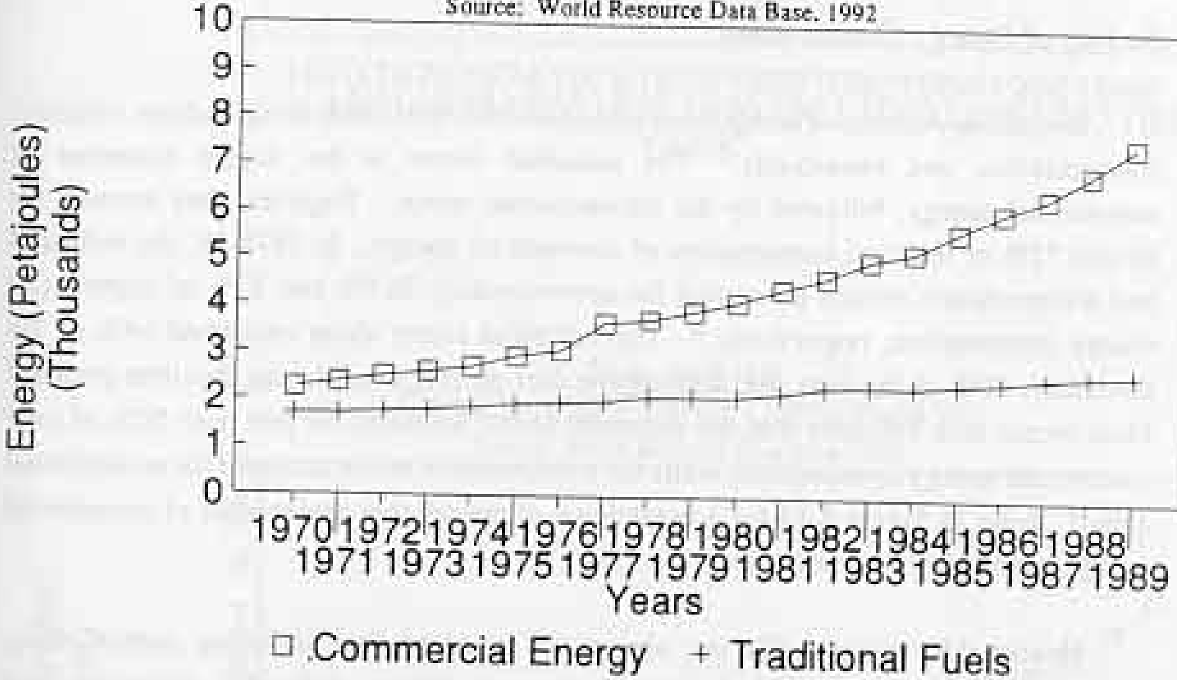


Figure 5.8 - Commercial Energy vs. Traditional Fuels Consumption

Source: World Resource Data Base. 1992



same period, GNP increased by a factor of 4.58, rising from $US 57,306.7 million to $US 262,414 million.[35] After comparing increases in both GNP and commercial energy consumption, it becomes apparent that these two variables are closely correlated, although GNP tends to rise at a slightly higher rate than does commercial energy consumption (see Figures 5.9 and 5.10). An examination of increases in per capita GNP and per capita commercial energy consumption reaffirms this correlation, analogously indicating that per capita GNP rises slightly faster than does per capita commercial energy consumption (see Figures 5.11 and 5.12). From 1970 to 1989, per capita commercial energy consumption increased by a factor of 2.24, rising from 4.03 gigajoules to 9.00 gigajoules. During this period, per capita GNP increased by a factor of 3.18, rising from $US 110 to $US 350.

Sectors of Energy Consumption

The primary sectors of energy consumption within India include agriculture, industry, transportation, and households. The industrial sector is the largest consumer of commercial energy, followed by the transportation sector. Together, they account for almost 75% of the total consumption of commercial energy. In 1978-79, the industrial and transportation sectors accounted for approximately 38.5% and 33% of commercial energy consumption, respectively.[36] The industrial sector alone consumed 64% of the electricity, 60% of the coal, and 65% of the fuel oil produced during this time period.[37] Most recent data indicates that the industrial sector accounts for just over 50% of total commercial energy consumption, while the transportation sector accounts for an additional 25%.[38] Refer to Figure 5.13 for a breakdown of the relative percentages of commercial energy used by all four sectors.

Households within India use almost all types of fuel including animal dung, agricultural wastes, firewood, kerosene, charcoal, lignite, soft-coke, gobar-gas, and electricity. Firewood, animal dung, and agricultural wastes account for the bulk of the energy used for domestic purposes. Consumption of commercial energy in the household sector was 40.3 million tons of coal replacement (mtcr) in 1978-79, up from 12.7 mtcr in 1953-54.[39] Still, as previously noted, commercial energy sources account for only 20% of the energy consumed in rural areas, and about 50% of the energy consumed in urban areas.

India's agricultural sector has demonstrated the largest increase in commercial energy consumption, rising from 3% in 1953-54 to approximately 11% in 1978-79.[40] The consumption of commercial energy has increased mainly due to the adoption of new

Figure 5.9
Gross National Product (Current $US)
Source: World Resource Data Base, 1992

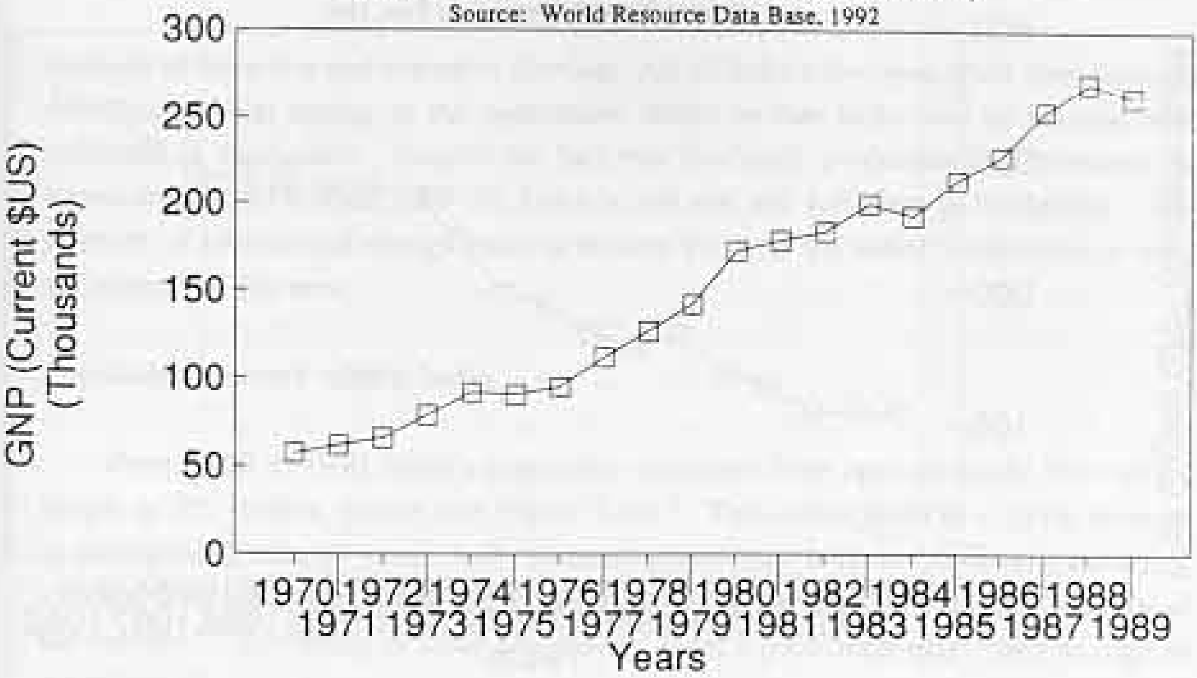


Figure 5.10
Commercial Energy Consumption
Source: World Resource Data Base, 1992

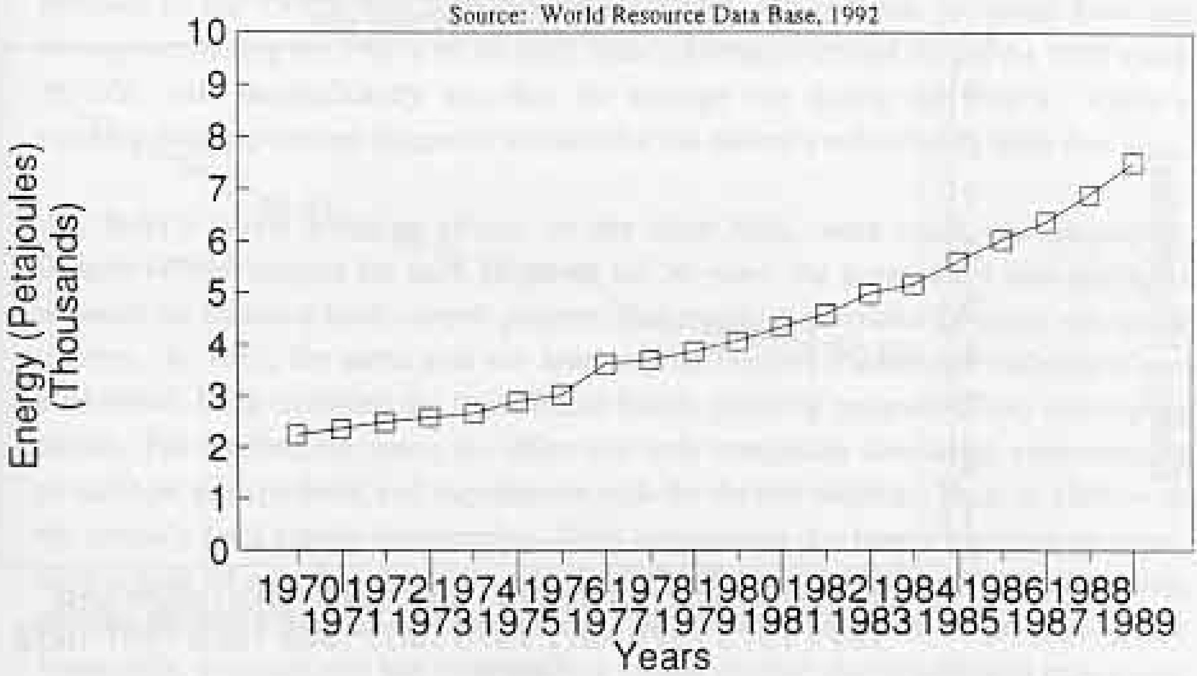


Figure 5.11
Per Capita GNP
Source: World Resource Data Base, 1992

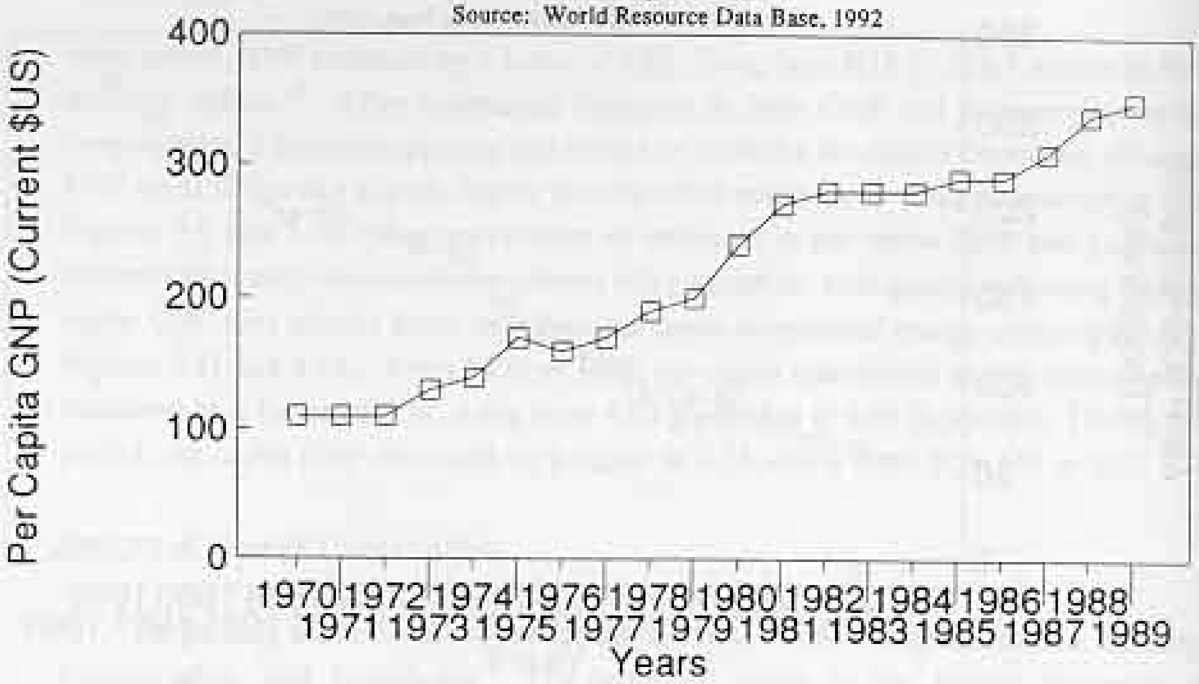
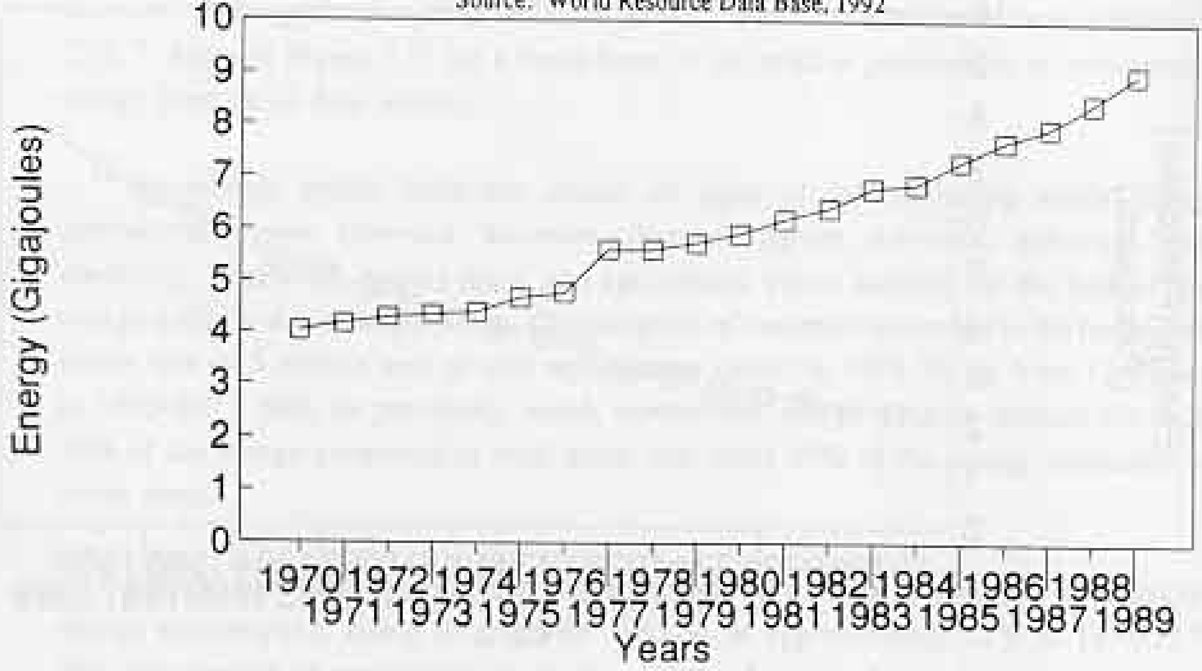


Figure 5.12 - Per Capita Commercial Energy Consumption
Source: World Resource Data Base, 1992



methods of intensive and extensive farming. All of India's five-year plans have directed more commercial energy to the agricultural sector so that India may be become self-sufficient in foodgrains. Despite the fact that foodgrain production has increased by approximately 50% since 1969-70, India is still not self-sufficient in foodgrains. The shortage of commercial energy poses a serious threat to the nation's objective of self-sufficiency in this area.

Population Growth within India

From 1950 to 1990, India's population increased from approximately 358 million people to 853 million people (see Figure 5.14).[41] This corresponds to a 138% increase in population in only 40 years. India's current growth rate is about 2.07%, and according to some forecasts, this growth rate is not expected to decrease until at least the turn of the century.[42] According to these predictions, India's population may climb as high as 1.2 billion.[43]

It is interesting to compare India to other nations that have experienced similar population growth, especially China. Although between the 1950's and the 1980's the population of both India and China increased by approximately 90%, China's growth rate declined substantially in the 1970's whereas India's did not.[44] While China's average birthrate in the 1970's was approximately 23/1000, a significant reduction from the average rate during the 1960's of 36/1000, India's average birthrate during the 1970's was 39/1000, only insignificantly less than the average rate during the 1960's. China's rigorous family planning programs account for the nation's reduction in birth rate.

India's family planning efforts, on the other hand, were much less successful. Despite official support for such programs for 30 years, the government was unable to organize an effective birth control program that regularly provided adequate service to citizens. In 1952, the same year the International Planned Parenthood Federation was established, India instituted the first official family planning program in any developing nation. For the first ten years, the effort was only marginally successful, concentrating on surveys, pilot projects, and experiments with the rhythm method. Then, in 1965, with the nation's food supply deteriorating, India restructured the family planning program, with a goal of reducing the birth rate from 43/1000 to 25/1000 by 1975. By 1975, though, the birth rate had decreased only to 35/1000, far short of program goals. Meanwhile, the death rate had experienced a similar decline, thus resulting in only a very slight decrease in the overall growth rate, from 2.3% to 2%. Too little emphasis on

Figure 5.13 - Consumption of Commercial Energy by Sector

Source: World Resource Data Base, 1992

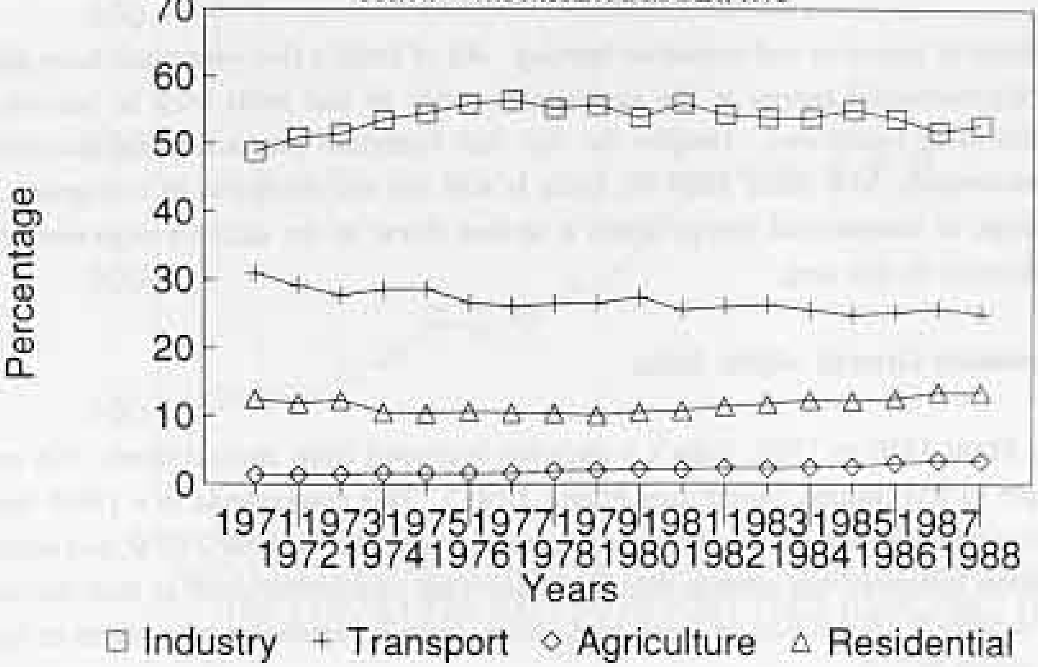
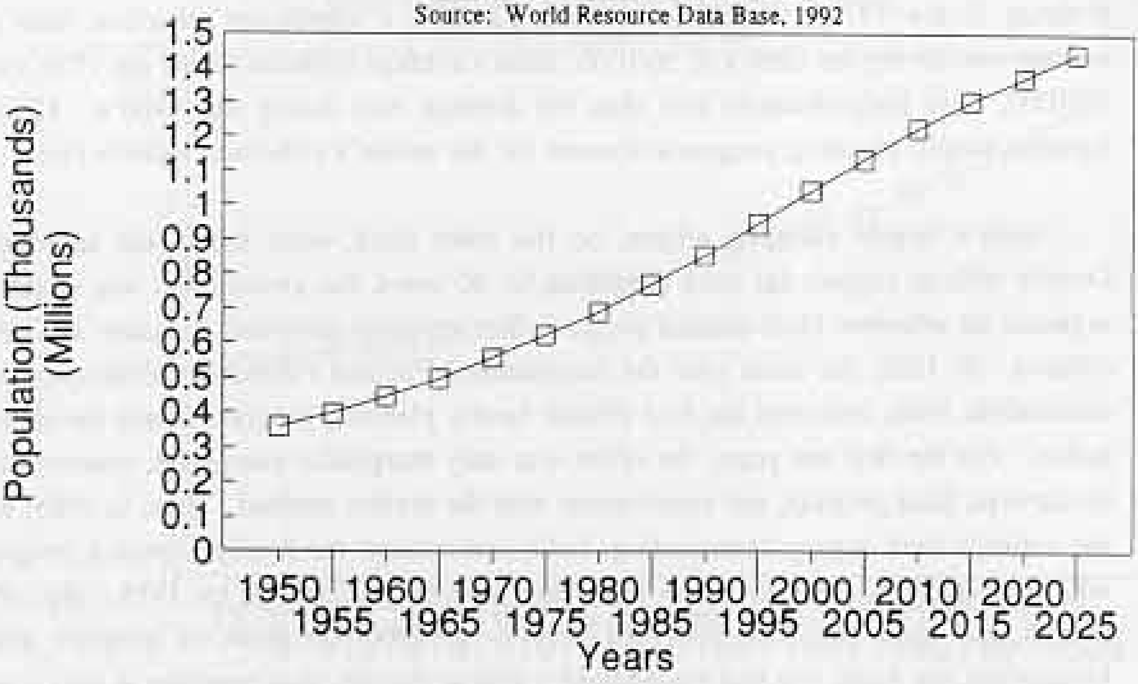


Figure 5.14
Total Population in India

Source: World Resource Data Base, 1992



needed social change and too much emphasis on the distribution of birth control technology are often cited as reasons for the failure of this program.[45]

Partly due to frustration at the ineffectiveness of previous family planning attempts, Prime Minister Indira Gandhi instituted a draconian sterilization program under the Emergency Act of 1975. Under this program, there were widespread charges of sterilization of Indian villagers against their will. Despite governmental denial of such practices, coercion was almost certainly used during this program, in part because local officials set quotas for the villagers. Resentment of the program contributed to Gandhi's defeat in the 1977 elections. Thereafter, rigorous family planning disappeared from the government's agenda. In 1989, Indian scientists noted that "the entire program was basically 'on hold' because elections were coming up and family planning was considered too controversial."[46]

Many analysts speculate that China's family planning programs were more successful than those of India due to China's governmental structure: China is a dictatorship, and its ability to impose a unified policy from the top down is relatively established. India, on the other hand, is a democracy, and such authoritarian policies would not be accepted by its populace. Furthermore, Chinese society is relatively homogeneous and has a widespread common written language. India, on the other hand, has dozens of languages and hundreds of dialects, a fact which greatly hinders the dissemination of information. The caste system in India serves to exacerbate this problem.[47]

Other policies in China have contributed to the success of the nation's family planning programs. The establishment of the 'barefoot doctors' basic-health-care program, which focused extensively on maternal and child health-care; the nation's huge and successful effort to educate all young people; and the opening of education and employment opportunities for women have been among these policies.[48]

India, in contrast, has not attached high priority to making these advances, instead putting its limited resources into such projects as the building of steel mills, huge energy projects, and the production of consumer goods.[49] The following statistics testify to India's misallocation of resources: India's infant mortality rate is twice as high as China's (96 deaths per 1000 live births, as compared to China's rate of 44/1000); 59% of India's adult population was illiterate in 1982, as compared to just over a third of China's; and enrollment of children in schools is not a priority in India as it is in China.[50]

Population growth in India has led to increased demand for and consumption of both commercial and non-commercial forms of energy. In the residential sector, increased population has translated to increased use of energy for cooking, heating, and lighting. In the agricultural sector, it has meant more energy consumed to produce food for all the nation's people. Similarly, in the transport sector, it has meant more energy used to deliver goods to all the people, and in the industrial sector, it has meant more energy used to produce non-food supplies for Indian citizens.

Urbanization within India

As population has grown, more Indians have moved into the cities to escape the hardships of rural living. Figure 5.15 illustrates the growth of India's urban population from 1950 to 1989. Between 1971 and 1981, India's urbanization rate was approximately 4%, and by 1981, there were 216 urban centers in the country, 12 of which had populations over one million. Calcutta (9.2 million), Bombay (8.2 million), Delhi (5.7 million), and Madras (4.3 million) are among the world's largest cities, and within these cities, 30%-40% of the people live in slums. Although the majority of urban dwellers in India lack electricity, sanitation services, or adequate shelter, the situation is still much better than in the rural areas. Some sources indicate that the average urban citizen in India manages to earn almost twice as much as his rural counterpart.[51] While this figure probably does not account for the many homeless urban dwellers whose living conditions are no better than those endured by rural citizens, the fact remains that *on average*, urban dwellers are slightly better off than rural citizens.

India currently has the largest number of urban dwellers in the world, and again, analysts predict that this trend will continue. Figure 5.16 portrays predictions by the World Resources Institute comparing India's urban and rural populations through the year 2025. Indeed, some forecasters estimate that the urban population will reach 350 million by the year 2000.[52] George Bryjak of the Institute for Socioeconomic Studies in White Plains, New York, compares the situation in China with that in India:

> India's urban problems are not unique. But nowhere in the world, with the possible exception of China, are they of such magnitude. As severe as China's urban difficulties may be, however, they are mitigated by a degree of governmental control over people's lives not permitted in a democratic society.[53]

Urbanization has increased the demand for all forms of energy, and for commercial energy in particular. As previously noted, the urban population tends to consume

Figure 5.15
Total Urban Population
Source: World Resource Data Base, 1992

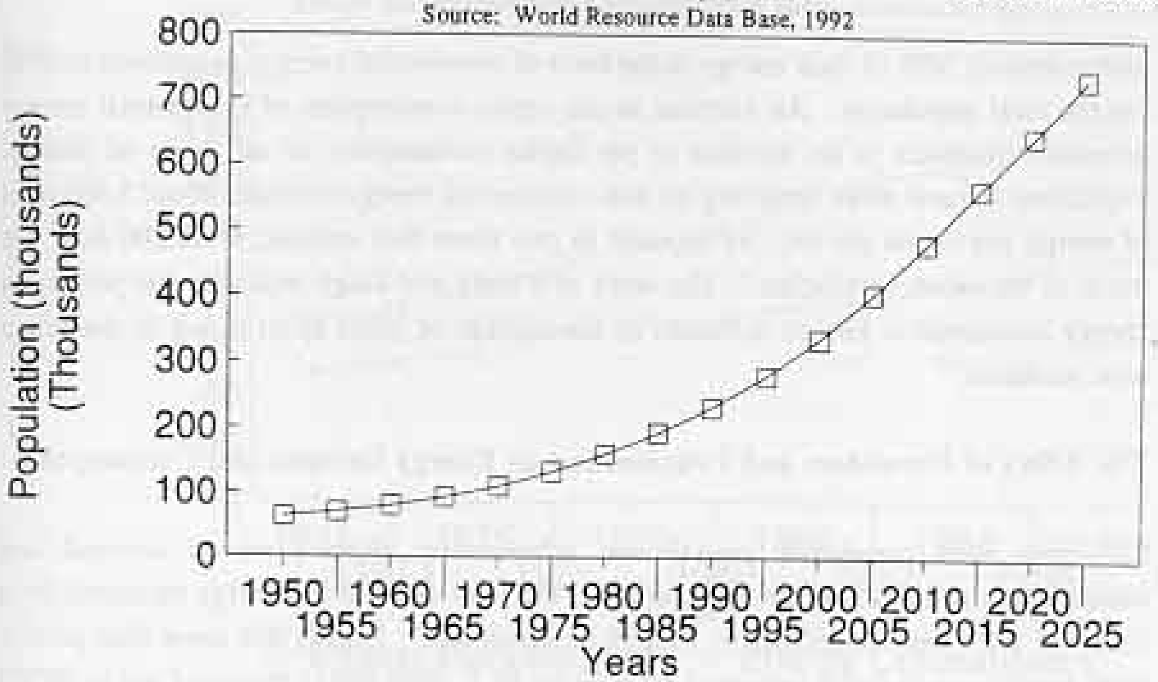
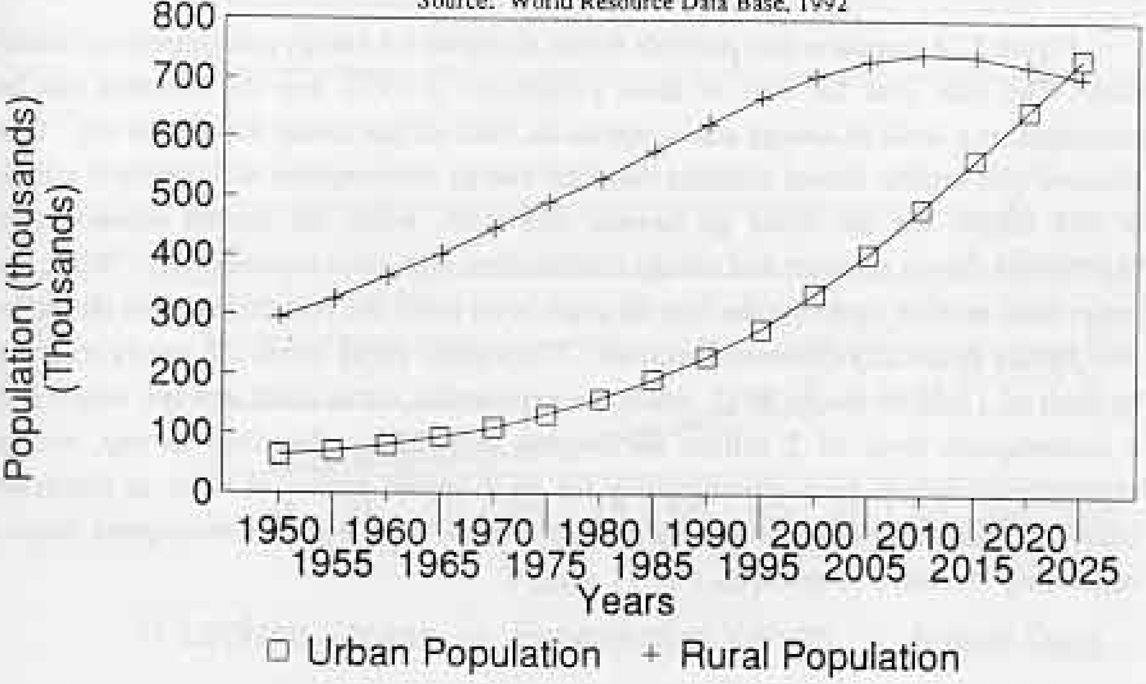


Figure 5.16
Urban vs. Rural Population
Source: World Resource Data Base, 1992



approximately 50% of their energy in the form of commercial energy, as opposed to 20% for the rural population. An increase in per capita consumption of commercial energy generally translates to an increase in per capita consumption of *all forms* of energy. Population in rural areas surviving on non-commercial energy consume about 5,600 kcal of energy per capita per day, as opposed to two times that amount, or 11,200 kcal, for much of the urban population.[54] The work of Raikhy and Singh indicates that per capita energy consumption further increases as the number of years spent living in the urban area increases.[55]

The Effect of Population and Urbanization on Energy Demand and Consumption

How have population growth and urbanization affected energy demand and consumption in India? From 1971 to 1987, the total *demand* for energy increased by a factor of 2.29, from 66830 *toe* to 153609 thousand *toe*.[56] During this same time period, total energy *consumption* increased by a factor of 2, from 48411 thousand *toe* to 96703 thousand *toe*.[57] This corresponds to an average growth rate for energy consumption of about 5.35%. (Thus, India comes in just below the 5.7% average growth rate of energy consumption in developing countries during the years 1980-85.) Figure 5.17 depicts the growth in both total energy requirements and total energy consumption during this time period.

Figure 5.18 compares two possible future scenarios for energy consumption to actual data. The base year for both of these projections is 1971, and the numbers can be compared to a level of energy consumption in 1987 of just under 97 million *toe*. One scenario (the logistic curve) assumes that total energy consumption will approach a limit of one billion *toe* but never go beyond this limit, while the second scenario (the exponential curve) assumes that energy consumption will grow exponentially. While the projections seem to agree for the first 40 years or so (until the year 2011), soon thereafter they pursue drastically different directions. The logistic curve levels off, nearly reaching its limit of 1 billion *toe* by 2071, while the exponential curve soars upward, surpassing a consumption level of 3 billion *toe* by the year 2071. Needless to say, energy consumption cannot grow exponentially for an extended period of time; as discussed below, supply has already limited and will continue to limit energy consumption despite continuing increases in demand.

Figure 5.17 - Total Energy Requirement and Total Energy Consumption

Source: International Energy Agency, "World Energy Statistics and Balances 1971-1987," 1989

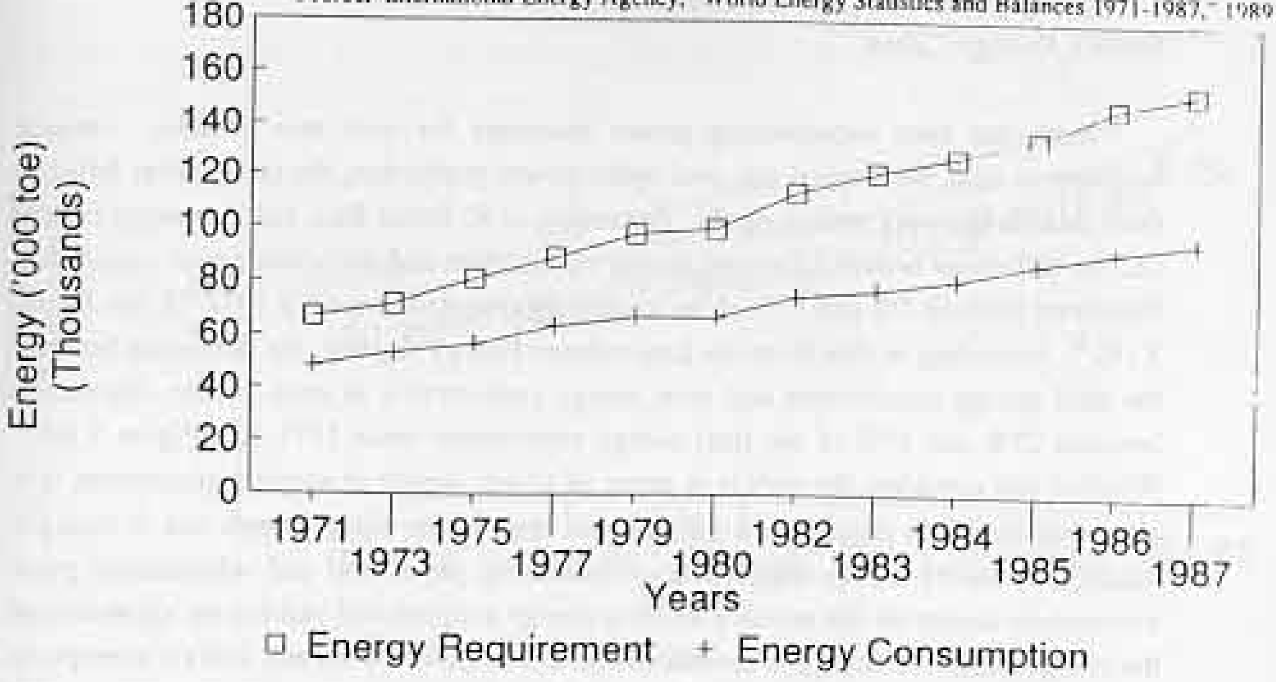
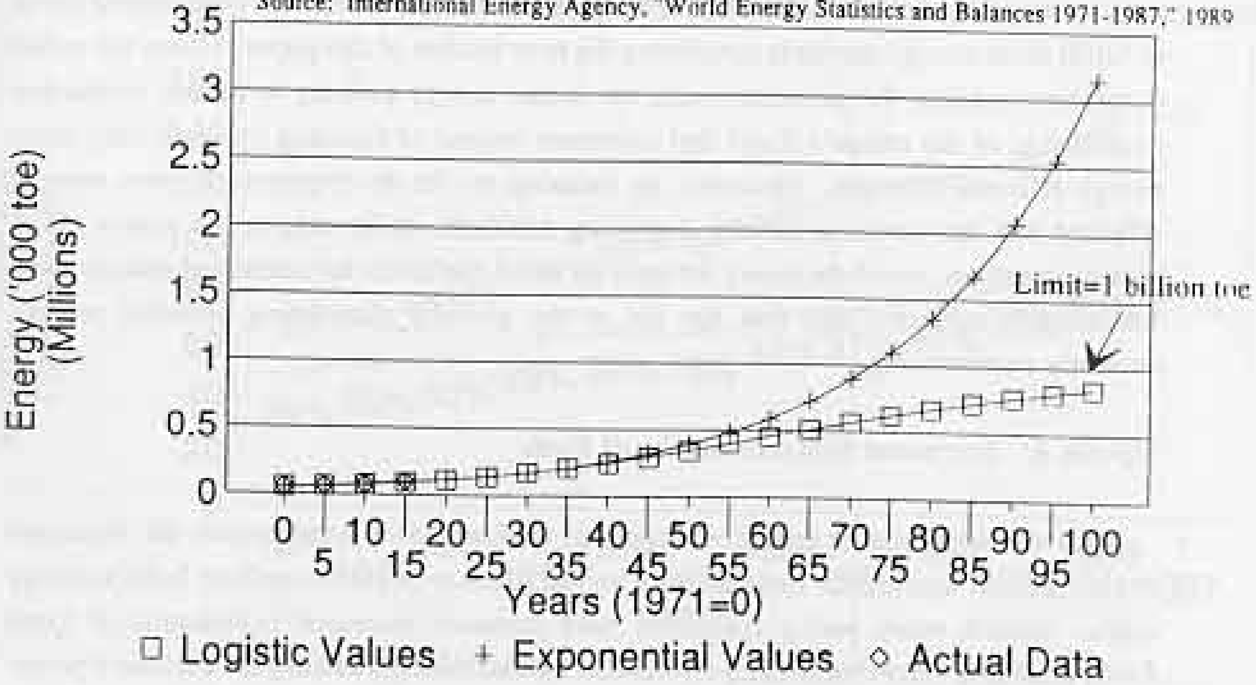


Figure 5.18
Possible Futures for Energy Consumption

Source: International Energy Agency, "World Energy Statistics and Balances 1971-1987," 1989



India's Energy Crisis

India has been experiencing power shortages for over two decades. Despite increases in coal, oil, natural gas, and hydro power production, the country has failed to meet its ever-growing energy needs. According to R. Rama Rao, India's energy deficit, i.e., the difference between the total energy requirement and the *actual power supply*, has fluctuated between 5% and 17% of the total energy requirement since 1974-75 (see Figure 5.19).[58] According to data from the International Energy Agency, the difference between the total energy requirement and *total energy consumption* is even greater, fluctuating between 25% and 37% of the total energy requirement since 1971 (see Figure 5.20).[59] Whether one considers the deficit in terms of power supply or actual consumption, it is clear that India has experienced difficulty in meeting its energy needs and is facing a crisis in terms of energy supply. Ever-increasing population and urbanization place tremendous strains on the nation's existing energy supplies and call for the expansion of the energy base. As energy is seen as the fuel of economic progress, India's attempts to improve domestic conditions will place added pressure on existing energy supplies and further emphasize the need to increase the nation's energy base.

India necessarily is in the midst of an energy transition, for its current energy policies are not meeting the needs of the population and must be restructured in such a way as to satisfy domestic demand. The question of how the Indian government plans to fulfill these energy demands constitutes the next section of this paper. Given the rather desperate situation, the potential exists for Indian energy policies to further emphasize exploitation of the nation's fossil fuel resources instead of focusing on more long-term, energy-efficient solutions. However, by focusing on the development of more energy-efficient and less environmentally degrading solutions, India can, in the course of its energy transition, avoid the heavy reliance on fossil fuels that industrialized nations have traditionally exhibited and that has led to the globally threatening situation we are currently experiencing.

Option A: Increased Reliance on Fossil Fuels

Given India's rather extensive supply of coal and, to a lesser extent, oil, increased exploitation of these fossil fuels seems a logical place to begin to confront India's energy crisis. Indeed, many policy specialists have espoused increased exploitation of fossil fuels, including expanded mining efforts and the development of larger coal-based power plants. M. Sengupta, Associate Professor at the University of Alaska's School of Mineral

Figure 5.19 - Energy Deficit as Percentage of Requirement

Source: R. Rama Rao, "India's Energy Scene: Options for the Future," 1988

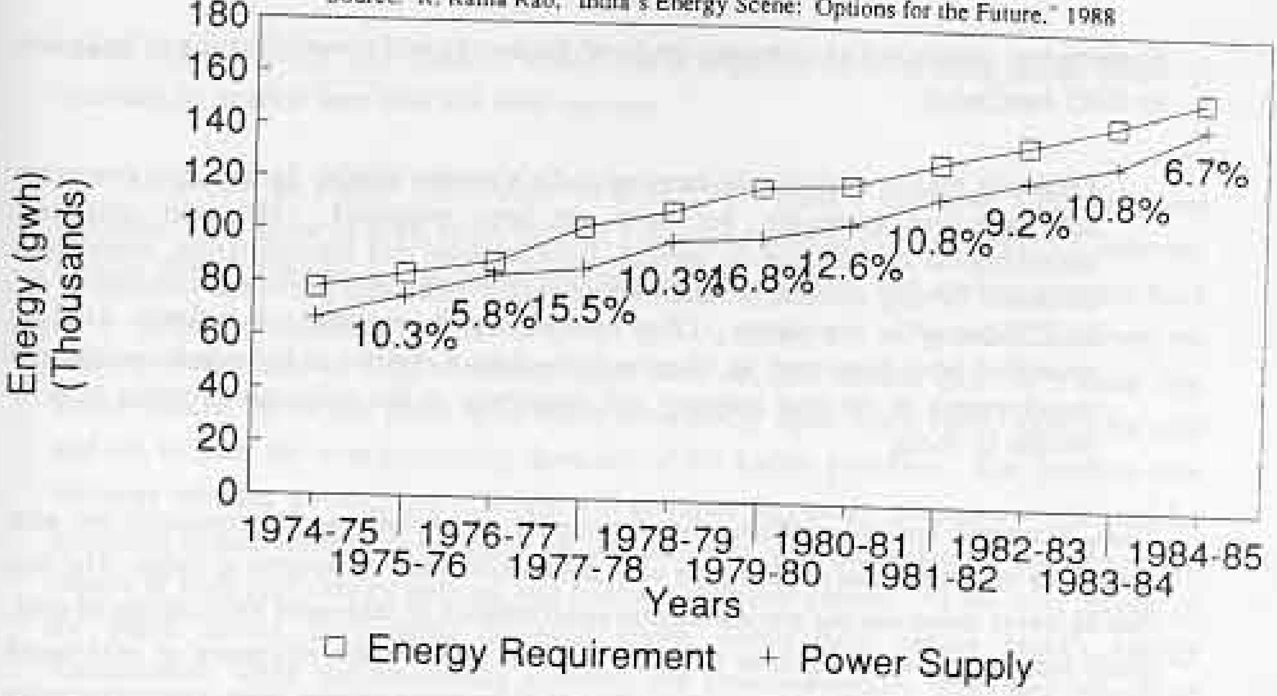
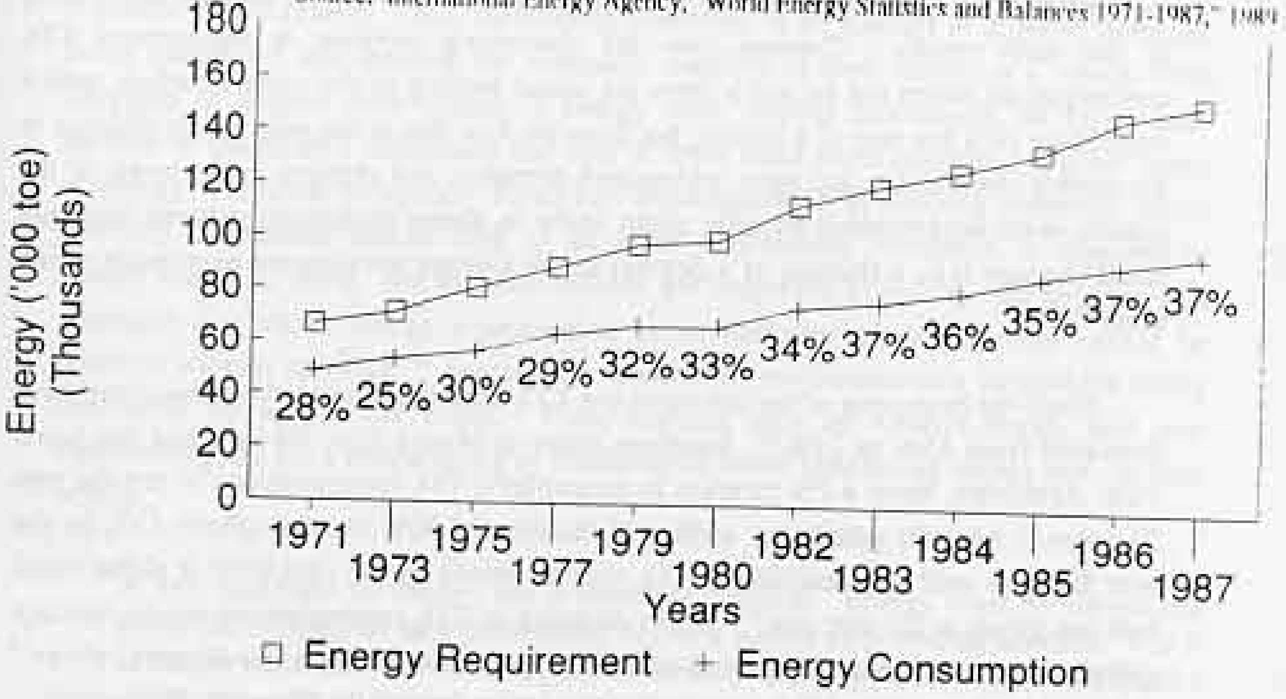


Figure 5.20 - Energy Deficit as Percentage of Requirement

Source: International Energy Agency, "World Energy Statistics and Balances 1971-1987," 1989



Engineering, conducted an extensive study of the energy and power situation in India and in 1985 concluded:

> Coal will play a vital role in meeting India's energy needs. India's coal resources are large and extensive, but have not been exploited. Her coal resources, technological capabilities in mining, beneficiation and transportation, established domestic mining machinery, and mining supply industries prove the viability of the coal industry in the future. The coal industry's capability to employ a large, unskilled labor force and its location in backward regions of India indicate that the development of the coal industry will contribute to the economic progress of poor people in India.

Thus, Sengupta not only affirms the desirability of exploiting coal resources but also associates increased coal exploitation with the amelioration of poverty in India. The fact that he never mentions the environmental ramifications of increased exploitation of coal, much less suggests the need, at the very least, to improve the efficiency of coal-based technologies, indicates the threatening nature of at least one current view concerning ways to confront India's energy crisis.

The environmental ramifications of increased reliance on fossil fuels are well-known. Increased exploitation of fossil fuels yields elevated carbon dioxide levels, and since CO_2 molecules in the atmosphere absorb the infrared radiation from the earth, a net heating of the earth results. Concern over the continuing increase in atmospheric CO_2 concentrations stems not so much from the actual heating of the earth's surface, which might only be a fraction of a degree, but from the fact that in the past, major changes in the earth's climate, i.e., ice ages, widespread droughts, and changes in the levels of the oceans, were accompanied by only slight shifts in global circulation patterns and only small changes (i.e., a fraction of a degree) in the average temperature over much of the earth.[60]

Since the beginning of the industrial era, CO_2 concentrations in the atmosphere have increased from 15% to 25%.[61] Readings taken at Mauna Loa, Hawaii, and the South Pole, Antarctica, show a 7% increase in atmospheric CO_2 concentrations in just the past 21 years.[62] Analysts predict an additional increase of 30% in atmospheric CO_2 by the year 2000, as well as a doubling of CO_2 concentrations by the year 2050 if global fossil fuel use grows at 2% per year.[63] If this doubling in CO_2 concentrations occurs, average global temperatures near the ground could be expected to rise by a few degrees celsius.[64] As a result, geographical shifts in the location of agriculturally favorable areas could occur and ice sheets and glaciers would likely begin to melt, causing ocean levels to increase by several feet over the next century.

As shown in Figure 5.21, from 1970 to 1989, India's industrial CO_2 emissions increased by a factor of 3.34, from 195148.3 thousand tons in 1970 to 651935.5 thousand tons in 1989. Clearly, increases in population, urbanization, and energy demand have been matched by corresponding increases in CO_2 emissions. Figure 5.22 shows the relative proportions of CO_2 emissions from coal, oil, and natural gas. It is clear that policy-makers up to this point have relied extensively upon fossil fuels, especially coal and oil, to meet the ever-increasing demands of the Indian populace. The question now becomes whether government officials will continue to pursue programs which call for increased exploitation of fossil fuels, or whether they will recognize the environmental effects of their past energy policies and follow a different course. As the next section of the paper shows, alternatives do exist which would fully satisfy India's energy requirements while simultaneously avoiding the environmentally degrading effects of extensive fossil fuel use.

Option B: Improved End-Use Efficiency and Reliance on Alternative Energy Sources

As previously noted, energy often is considered to be the essential indicator of economic development. Thus, developing countries, in an attempt to improve domestic living conditions and increase the economic viability of their nation as a whole, have struggled to expand their country's energy base, relying extensively on fossil fuels because of the relative abundance and cost of these fuels when compared to other forms of energy. As noted previously, fossil fuel consumption in developing countries, which currently contributes almost 20% of all fossil fuel-derived emissions, is expected to double within 20 years. But as some analysts are beginning to realize, "the conventional paradigm that views energy consumption as an indicator of development cannot be resolved without sacrifice,"[65] namely the sacrifice of environmentally sustainable living conditions throughout the world. Thus, analysts such as Amulya Reddy and José Goldemberg call for a restructuring of fundamental views concerning energy use. In their words,

> A new paradigm for energy use is therefore essential. Energy must be viewed not as an end in itself or as a commodity but as a means of providing services. For it is the services, and not the energy, that directly satisfy people's need: the quality of life in a village depends more on the amount of illumination, for example, than on the kilowatt-hours of electricity or liters of kerosene consumed for lighting. The

Figure 5.21
Industrial CO2 Emissions
Source: World Resource Data Base, 1992

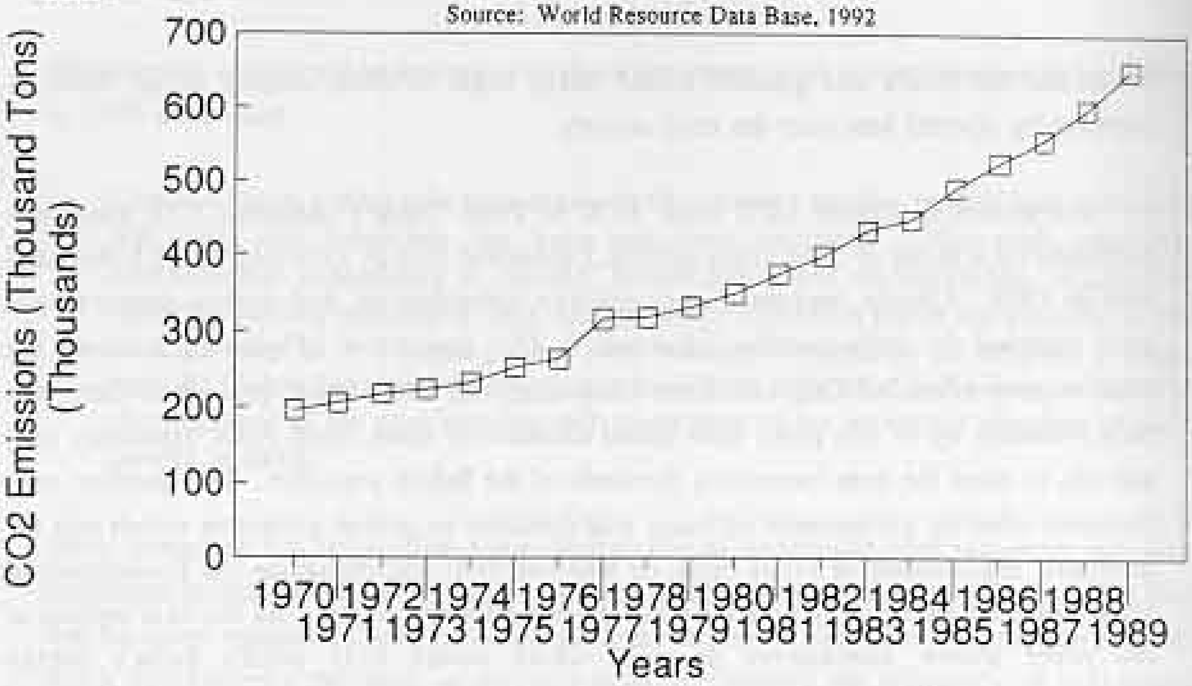
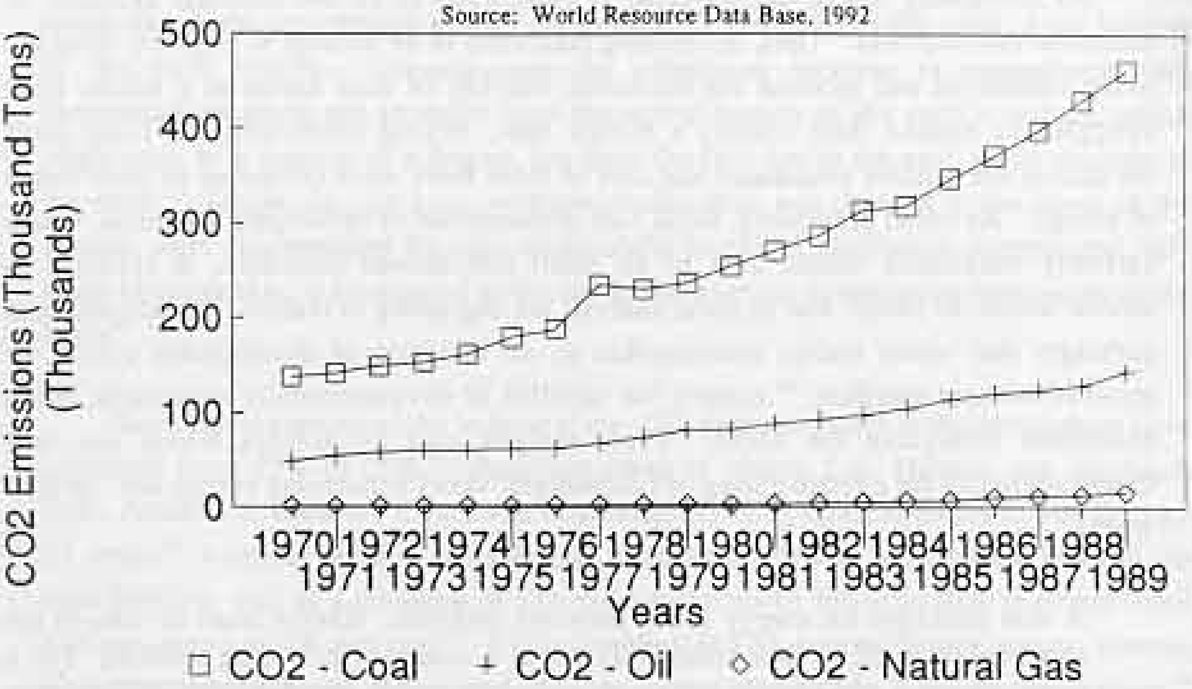


Figure 5.22
Relative CO2 Emissions
Source: World Resource Data Base, 1992



extent to which energy services are accessible is therefore the true indicator of the level of development.[66]

Thus, development requires significant increases in the per capita level of energy services. Such services, in turn, rely on end-use devices such as stoves, lighting fixtures, and motors that convert the energy for use. As Reddy and Goldemberg note, more efficient end-use devices can conserve energy by using less energy to provide the same services. In terms of overall energy strategies, Reddy and Goldemberg encourage planners to adopt what they call "development-focused, end-use oriented, service-directed (DEFENDUS) scenarios that incorporate conservation and renewable sources into a least-cost mix."[67] Indeed, Reddy, who is Chairman of the Department of Management Studies at the Indian Institute of Science in Bangalore and Vice-Chairman of the Karnataka State Council for Science and Technology, recently proposed a DEFENDUS scenario for the Indian state of Karnataka. A comparison of Reddy's DEFENDUS plan to the other program suggested for Karnataka illustrates the radical differences, in terms of forecasted energy requirements, energy efficiency, and environmental effects, between policies that embrace fossil fuel exploitation and those that do not.

The Long Range Plan for Power Projects (LRPPP), proposed in 1987, covered the years 1987-2000 and assumed an increase in power demands of 9% per year through the year 2000. The LRPPP embraced heavy reliance on massive coal-fired power plants that would have produced an additional 830,000 tons of CO_2 each year, more than doubling India's CO_2 emissions by the year 2000. The LRPPP suggested that the state of Karnataka spend about $17.4 billion to implement the plan, a figure 25 times the country's 1987 budget. Additionally, the plan would have required Karnataka to construct extensive energy infrastructure and massive centralized power-generating facilities, including a one-gigawatt coal-based thermal power station; divert 25% of the state budget to power; raise funds from the World Bank; and appeal to private industry to build up the country's generating capacity. Rather than focusing on improved efficiency, the LRPPP focused on increased fossil fuel dependence. Ironically, despite its recommendations, LRPPP predicted energy shortages continuing into the next century. The LRPPP was rejected by Karnataka officials.[1]

Reddy's DEFENDUS scenario is the first analysis of its type for a developing country, calculating energy requirements in terms of need, rather than supply. As noted, it focuses on improving the energy efficiency of end-use devices so as to enhance the level of services provided to citizens. Many of the more efficient end-use devices outlined in the plan, such as compact fluorescent lightbulbs and solar water heaters, are already on the market. The plan calls for electric lights in all homes in Karnataka, electric irrigation pumps, establishment of decentralized energy centers in villages, and promotion of industries to increase employment. The decentralized energy centers would employ small-scale hydroelectric power and biomass, which are cheaper and quicker to use than fossil fuels. Because it projects a greatly reduced energy requirement, DEFENDUS avoids the need for the most environmentally devastating energy sources, such as nuclear power plants, coal-based thermal power plants, and large hydroelectric dams. According to Reddy, DEFENDUS would cost one-third as much as LRPPP, while requiring only 40% of the energy projected by LRPPP. Additionally, the DEFENDUS plan would increase CO_2 emissions by only 11% of their current value. The DEFENDUS is currently under consideration by Karnataka officials.[2]

Clearly then, development of efficient end-use technologies is necessary to diminish or at least stabilize reliance on fossil fuels. However, above and beyond improvement of end-use efficiencies, utilization of alternative forms of energy such as solar, wind, and hydro power is required to complete the transition from fossil fuel reliance to dependence on more sustainable and environmentally benign energy sources.

Research and development efforts need to be directed toward the effective utilization of solar energy, a renewable energy source with virtually no environmentally harmful consequences. Rama Rao, in a study conducted for the Biral Economic Research Foundation in New Delhi, concluded that "there is immense scope for utilising solar energy provided state agencies and entrepreneurs exercise their initiative and develop appropriate photovoltaic devices which can collect solar radiation and convert it into electrical energy efficiently."[68] According to Rama Rao,

> Although our national resource endowments include oil and natural gas in modest quantities, coal in relatively greater abundance but generally of poor quality and radioactive metals . . ., our principal endowment is solar energy, which, because of our vast land area over the greater part of which we receive adequate sunshine during day-light hours practically throughout the year, can provide us with all the energy we need.[69]

Similarly, resources need to be directed to developing the technologies necessary to exploit wind power, which, like solar power, is a renewable energy source with no environmentally degrading consequences. Regarding the exploitation of wind power, Rama Rao asserts, "One has only to evolve inexpensive but robust designs of wind mills, which could provide power for the individual householder, the farmer, and the entrepreneur." As Rama Rao points out, there is considerable scope for tapping wind energy in India, especially in the coastal and hilly areas. Where wind conditions are favorable, a number of wind mills could be erected in a 'wind farm' to generate electrical energy for a community or industry.

Small-scale hydro power projects should also be developed, as hydropower constitutes an extensive source of renewable energy. As noted previously, the hilly terrain found throughout much of India, especially in the Himalayan ranges, increases the desirability of and potential for hydropower generation. Because large hydroelectric plants require the construction of huge dams which impound millions of tons of water, submerge large areas of land, and extensively denude tree cover, the construction of these plants should be avoided altogether or pursued only on a very limited scale. Even in the selection of locations for the construction of small hydroelectric plants, extreme caution must be exercised, given the geologically unstable nature of many parts of India, as well as the nation's soil condition generally.[70]

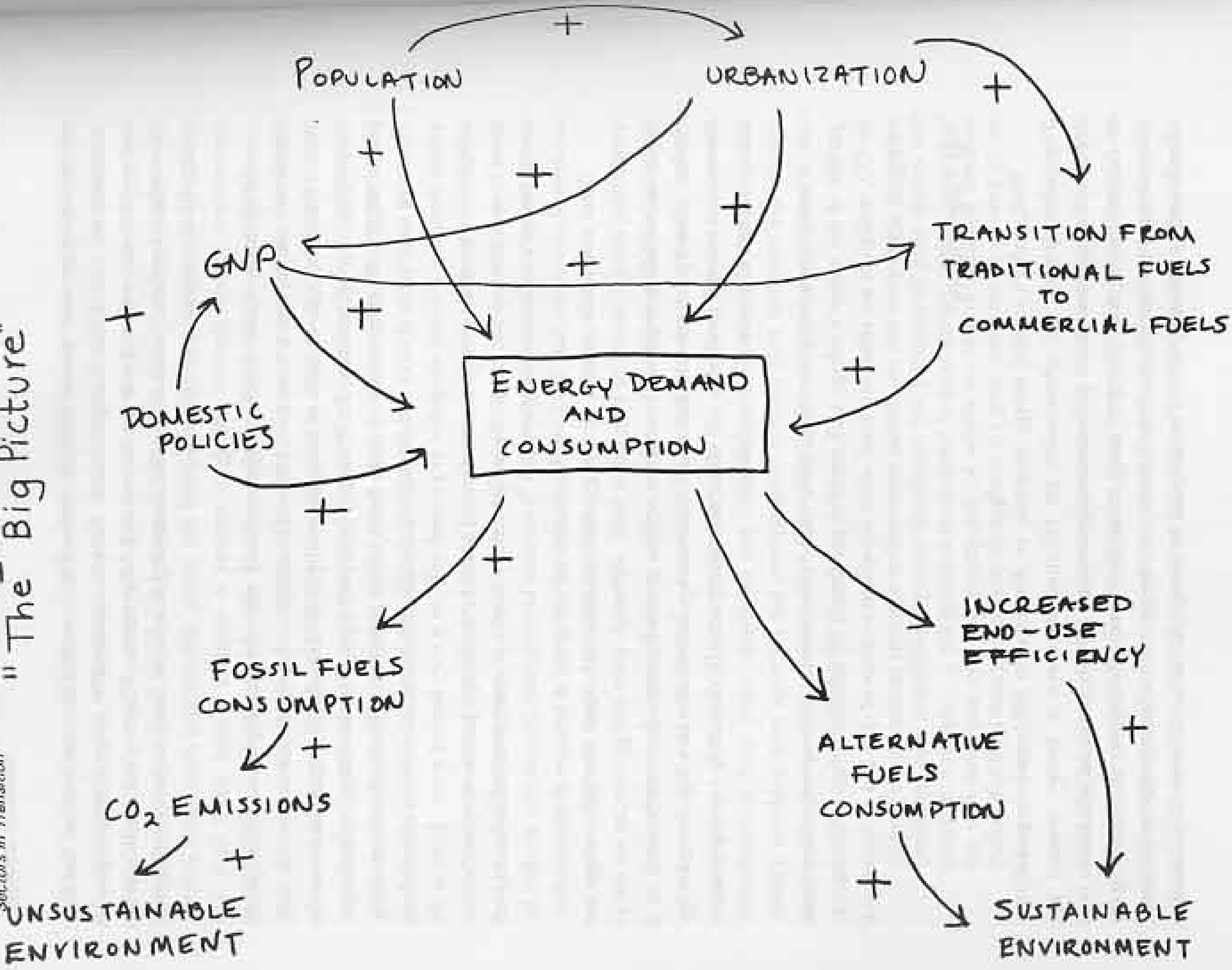
Other renewable sources of energy, such as tidal and ocean thermal energy and geothermal energy, should be pursued as well. Although these energy sources are not as easily accessible or exploitable as solar, hydro, or wind power, they can be used on a modest scale by households and small businesses. Indeed, the fact that these energy sources are entirely renewable and effect no environmentally degrading consequences is reason enough to pursue their exploitation.

Finally, considering that fossil fuels likely will continue to comprise at least some portion of the nation's energy base, natural gas should be the 'fossil fuel of choice,' as its CO_2 emissions are relatively small when compared to those of coal and oil (refer back to Figure 5.22).

The "Big" Picture

Thus, India's current energy scenario, as discussed in this paper, is as follows: Population growth and urbanization are effecting increases in energy demand and consumption. Urbanization increases energy demand directly, since urban citizens tend to consume more of *all forms* of energy than their rural counterparts, and indirectly, as it encourages citizens to use more *commercial* energy, which corresponds to increased overall energy consumption. The demand for energy is further increased by domestic

Figure 5.23 "The Big Picture"



policies aimed at improving living conditions and increasing the economic viability of the nation as a whole. Increased energy demand is causing Indian policy officials to further exploit fossil fuels in an attempt to satisfy domestic energy demand. In turn, increased fossil fuel exploitation is effecting corresponding increases in CO_2 emissions. Figure 5.23 illustrates these relationships pictorially; all the "+" signs indicate that those variables, i.e., population, urbanization, transition from traditional fuels to commercial fuels, GNP, and domestic policies, have an augmenting effect on energy demand and consumption. Note that there are no signs indicating the effect of increased energy demand and consumption on alternative fuels consumption and increased end-use efficiency; whether the former will have a positive effect on the latter is yet to be determined.

Choices for the Future

Clearly, Indian policy officials first need to address population growth and urbanization, for without the stabilization of these two parameters, energy demand will continue to increase despite heroic efforts to improve end-use efficiency and/or establish dependence on renewable, environmentally benign sources of energy such as solar, hydro, and wind power. However, efforts to control population growth and urbanization *must* be accompanied by the energy strategies discussed above. The environmental consequences of continued heavy reliance on fossil fuels are well-known and but a few decades away unless energy policy-makers in both developing and industrialized countries restructure their current energy policies so as to encourage reliance on alternative energy sources and development of efficient end-use technologies. Will policy-makers choose to implement plans similar to the LRPPP, or will they execute the policy alternatives DEFENDUS lays out?

In India, there are indications in both directions. On the one hand, the fact that the Karnataka state government is even considering a plan like DEFENDUS indicates that progress has been made, at least toward more widespread recognition of the need to institute energy-efficient options. On the other hand, Karnataka has not yet implemented the DEFENDUS plan, nor has any other Indian state government even considered a similar plan. On the positive side of the equation, India has been attempting to electrify the railways and replace the diesel engines that are so heavily dependent on oil. On the negative side, India plans to build several new coal-fired power plants in the near future. Moreover, many policy officials hold views similar to those expressed by M. Sengupta. Fossil fuels, especially coal, are seen as the most inexpensive way to expand the nation's energy base. In a country where the average standard of living is as low as it is in India, it is easy to understand why policy-makers are so anxious to increase the level of energy consumption throughout the country. Furthermore, it is *almost* as easy to understand the impetus to secure this increased level of energy consumption regardless of the environmental ramifications. When one's basic welfare is at stake, environmental concerns hold very little importance. Many Indian citizens believe they first must escape their own plight before they can concern themselves with how their actions will affect future generations.

Thus, environmental considerations often are viewed as concerns of the industrialized nations, which can afford to concentrate on issues other than the day-to-day welfare of their citizens. Developing nations resent the implication that they should utilize environmentally benign energy sources, when industrialized nations for so long have exploited fossil fuels and degraded the environment. According to developing nations, the fact that industrialized countries now can afford to use more energy-efficient fuels and technologies does not mean that the developing nations should 'miss out' on the chance to exploit fossil fuels. Moreover, developing nations cannot afford energy-efficient, alternative technologies. In the views of developing nations, if industrialized countries are so adamant about the use of alternative energy sources and energy-efficient technology by developing countries, then the industrialized nations should pay the extra costs associated with such use. Thus, issues concerning development assistance come into the picture: should industrialized nations be expected to subsidize the developing nations' transition to environmentally sustainable patterns of energy consumption?

Hence, the current economic situation in India, as well as in other developing countries, will make the transition toward employing energy-efficient fuels and technologies a difficult one. More than likely, India and other developing countries will have to enlist the help of industrialized nations to effect this transition. Without such assistance, most developing countries will not be able to curtail their exploitation of fossil fuels, considering the relative costs of alternative fuels as compared to fossil fuels. Given this premise, however, several policy options do exist which will assist in effecting this transition.

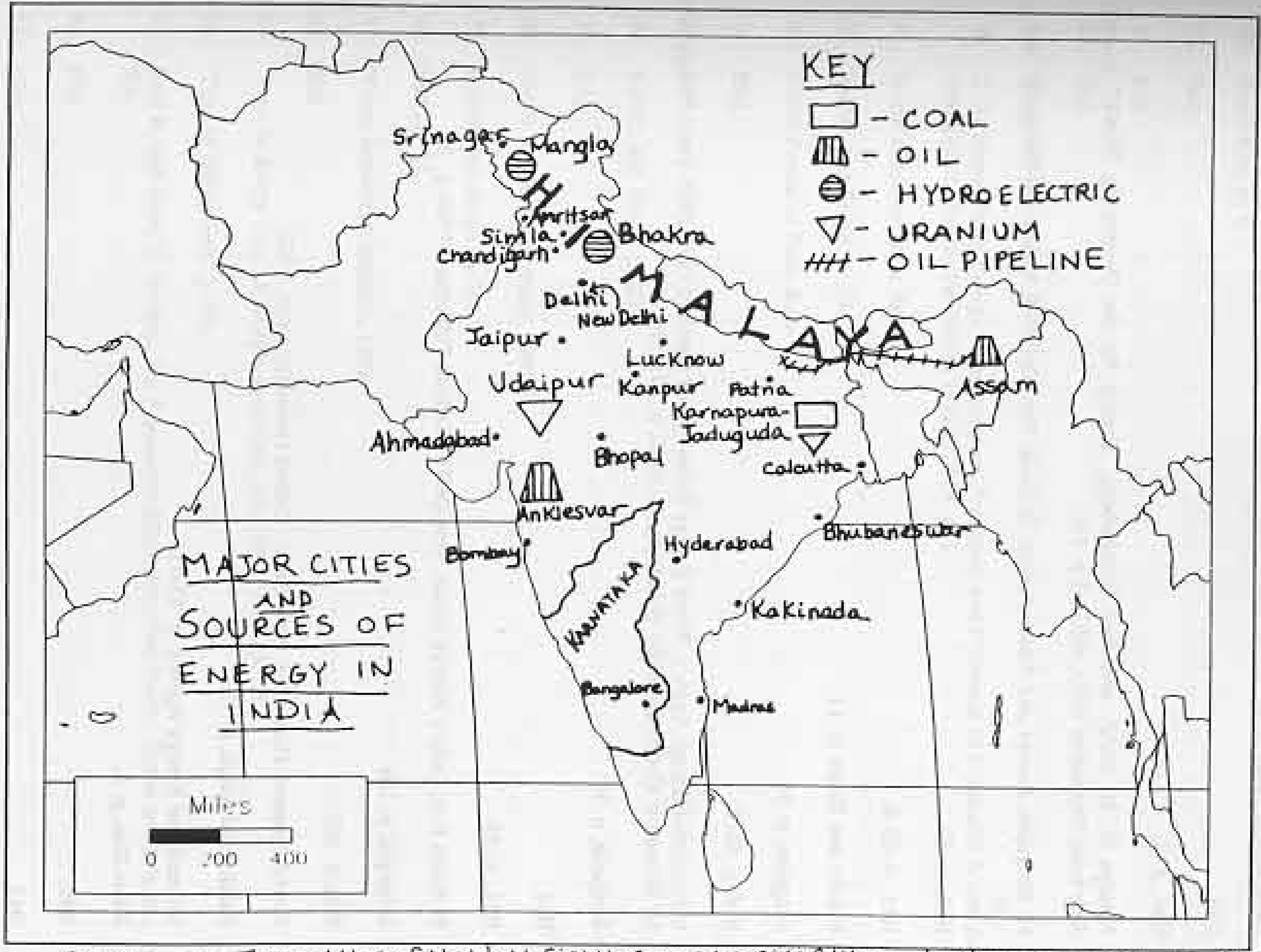
First, developing nations must, as a group, recognize the devastating potential of continued reliance on fossil fuels and incorporate as one of their national goals the transition to more energy-efficient fuels and technologies. In so doing, developing nations would demonstrate to the industrialized world their willingness to change their energy consumption patterns. Developing nations should hold some type of international, or at least regional, energy forum both to discuss and plan for this reorientation of national energy policies, as well as to announce it to the rest of the world. Delegates from the developing nations should then be encouraged to hold annual or biannual meetings to discuss options, share ideas, and report on their progress toward developing energy-efficient technologies as well as mechanisms to exploit alternative energy sources.

Second, the industrialized nations must become involved in the transition process, both financially and otherwise. These "First World" nations should be encouraged to provide some fraction of their GNP directly to an 'international energy fund,' created specifically to assist developing countries in the transition to environmentally sustainable patterns of energy consumption. This fund could be administered by some international organization such as the International Energy Agency (IEA). IEA could then allocate the funds based on a particular country's economic conditions as well as its demonstrated willingness to promote energy efficiency within its borders. Indications of such willingness might include national policies, including the percentage of GNP allocated toward promoting the energy transition, official statements of the nation's policy-makers, and the amount of public and private funds dedicated to researching ways to improve energy efficiency. In addition to direct financial assistance, industrialized countries should provide economic incentives such as tax breaks to developing countries that demonstrate the willingness both to curtail their use of fossil fuels and to promote the transition to more energy-efficient fuels and technologies. Above and beyond financial assistance, industrialized nations should provide technical support to these countries as they attempt to implement new technologies and rely on alternative fuels. Industrialized nations should participate in the energy forum previously mentioned, to offer ideas and technical advice as leaders in the energy arena. Along these same lines, a viable technology transfer program should be commenced, so that developing countries can benefit from, rather than duplicate, the research efforts of industrialized countries.

Third, and perhaps most important, *citizens* throughout the world must recognize the urgency of the current energy crisis. Then, to the extent possible, they should modify their own energy consumption habits and influence others to do the same. Obviously, this advice is more applicable to citizens in industrialized nations than it is to individuals in the developing world, who consume only a fraction of the energy that First World citizens consume. Above and beyond modifying their own energy consumption habits, however, citizens in both industrialized and developing nations should be encouraged to lobby their government officials to promote policies which champion the use of alternative fuels and the development of energy-efficient technologies. Citizen advocacy can be a very effective means of influencing public policy; government officials (at least in democratic societies) usually realize that if they do not respond to public opinion, they risk losing public support as well as their seat in the government.

Conclusion

These are just a few of the policy options that exist to promote the transition to environmentally sustainable patterns of energy consumption in developing countries. As these ideas demonstrate, increased reliance on fossil fuels, and thus increased CO_2 emissions and increased environmental degradation, do not have to become self-fulfilling prophecies. The first step toward reversing these trends involves promoting increased recognition throughout the world of the *dire need* for an energy transition of the type discussed in this study. The next step *must* be a unification of industrialized and developing countries alike to effect this transition. This is a global crisis, and a truly global solution is required. Without the help of all nations, an effective solution will not be possible, and environmental degradation will continue. Thus, it is up to all members of the international arena -- policy-makers as well as citizens who have the power to influence these policy-makers -- to secure the transition toward utilization of alternative fuels and development of more energy-efficient technologies. Options for a sound environment do exist, but the question remains -- Which option will actors throughout the industrialized and developing nations pursue in the coming decades?



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Chapter 6: Deepak B. Khatry Chhetri

AN ANALYSIS OF THE MAJOR SECTORAL TRANSITIONS IN NEPAL'S MIDDLE HILLS AND THEIR RELATIONSHIP WITH FOREST DEGRADATION

Introduction

Concern over the degradation of the world's mountain ecosystems has risen significantly over the last two decades, especially after the publication of Eckholm's (1976) *Losing Ground*. This growing concern led to the establishment of the United Nations University's (UNU) project on Highland-Lowland Interactive Systems in 1977. The Mohonk Mountain Conference was held in New York State on April 6-11, 1986, under the Chairmanship of Maurice F. Strong to discuss the Himalaya-Ganges problem. A series of resolutions was passed and directed to senior administrators of the United Nations System and to the heads of state of the concerned governments of the region. To draw attention to the deteriorating condition of African mountain environments, the first international workshop on African mountains and highlands was organized in Ethiopia on October 18-26, 1986. This workshop was sponsored by UNU and the Commission on Mountain Geoecology of the International Geographical Union (IGU) and attended by 53 scientists from 10 African countries and 11 countries outside Africa.

Recently, however, the validity of such concern in the Himalayan environment has begun to be questioned by some authorities, most notably by Ives and Messerli (1989) and Thompson and Warburton (1985). In their book *The Himalayan Dilemma: Reconciling Development and Conservation*, Ives and Messerli (1989) have challenged the viewpoint that the Himalayan region is inevitably drifting into a situation of *supercrisis* (their italics) and collapse. They have named this viewpoint "the Theory of Himalayan Environmental Degradation." The main argument of Ives and Messerli, Thompson and Warburton, and others who challenge the Theory of Himalayan Environmental Degradation is based upon data uncertainty. Ives and Messerli (1989) argue:

> Simply to call for a world-level effort to avert a portending catastrophe in the Himalayan region ignores the sea of uncertainty that surrounds it. By this we mean that our understanding of the processes operating in the region, whether geophysical, environmental, social, economic, or political, is tenuous at best. Differentiation between cause and effect is thwarted by lack of data in all fields, by unreliable, even manufactured, data. This situation, in our estimation is further confounded by a pervasion of assumptions, conflicting convictions, and latter-day myths, most of which lead into the perceived, and preconceived, downward spiral of environmental disaster.

Deforestation and soil erosion are two of the most hotly-debated issues, particularly in the case of the Nepal Himalayas. Although considerable debate surrounds the issue of "deforestation" (whether it is occurring or not; and if it is occurring, what is the rate) [see, for example Thompson and Warburton (1985); Thompson, Warburton and Hatley (1986); Ives and Messerli (1989); Gilmour and Fisher (1991)], there is wide consensus amongst both academicians and practitioners that "forest degradation" should be a matter of concern in the Himalayan region. Other than the general acknowledgement that forests are being degraded, I have not encountered any attempt to define "forest degradation" in the Himalayan literature. For the purposes of this paper, I will present working definitions of "deforestation" as *a reduction in the total area under forest cover*, and "forest degradation" as *a decline in the production and productive capacity of a forest from what would be expected of a normal, relatively undisturbed representative forest type of the region.* Because forest degradation is intricately related with population growth, and the functioning of other sectors within societies, it can be studied from the viewpoint of Drake's (1992) "transition theory." As a major sector within a subsistence society, forestry is not only impacted by transitions occurring in other sectors, but in turn also impacts other sectors. Consequently, there are many feedback loops [as explained by Meadows et al. (1992)] that form a cycle of events leading to forest degradation, and negative impact on the local quality of life.

According to Drake (1992), one way of viewing the complex dynamics of population and the environment is to visualize these relationships as a *family* of transitions. Although he accepts that transition implies change and that change is everpresent, he clarifies his definition of *transition* as one meant to describe a specific period of time which spans the shift from slow to rapid change in a sector followed by relative stability. Drake considers transitions to be part of a family because of the following reasons: (i) they exist in many different sectors of societies and, in each case, have some common properties; (ii) they affect society in a similar way, with each transition having a critical period when society is especially vulnerable to damage; (iii) they interact with each other; and (iv) they not only occur at different sectors but also at different scales, both temporal and spatial. In trying to develop a "*theory of transitions*," Drake acknowledges that transitions can have differences and, in fact, argues that each local setting may have its own unique passage through a transition. His examples of transitions include the following: demographic, epidemiological, agricultural, forestry, toxicity, urbanization, fossil fuel, technological, educational, and bureaucratic. Among the general characteristics of transitions, he includes the following: similarity of trajectory across sectors, applicability across scales, timing, societal vulnerability, and societal opportunities during transitions. He believes that transitions have analytic and mathematical properties and can be modelled and described with mathematical techniques. Drake sees practical implications in the further development and validation of his theory, particularly in recognizing periods of vulnerabilities in societies and prioritizing social interventions.

In this paper, I will examine the changes and trends in three major sectors that are fundamentally important in subsistence societies of the middle hills physiographic zone of Nepal. These sectors are: human demography, agriculture, and forestry. Two other sectors, epidemiology and urbanization, which at the moment are less significant in the Nepalese hills from the viewpoint of a transition theory, will be briefly summarized.

Data unavailability (particularly unavailability of longitudinal data) is a major problem in attempting to study the sectoral transitions in Nepal's middle hills. The problem is further compounded by the uniqueness of the conditions that characterize local subsistence livelihood. As argued by Drake (1992), the local setting in the middle hills of Nepal appears to have its own unique passage through sectoral transitions. Hence, it is very difficult to make meaningful comparisons with other regions of the world. Because the local susbistence communities in Nepal's middle hills are relatively self-contained social units that are minimally influenced by global changes and trends, I will attempt to make comparisons with only other physiographic zones within Nepal (Figure 6-1), where interactions are most likely to occur.

The data analyzed in this paper have been obtained from an extensive review of published literature and government documents. My efforts to collect reliable and valid data lend support to the arguments of Ives and Messerli and Thompson and Warburton. I encountered considerable uncertainty in establishing sectoral relationships and predicting outcomes due to lack of data as well as inconsistencies and variations in reported data. However, some general trends can be observed in the data. Even though a high degree of precision and accuracy of the data can be questioned, tentative conclusions may be drawn by examining broad trends.

The nature of subsistence in the Nepalese middle hills

Nepal is a small, land-locked Himalayan country approximately 500 miles long (west to east) and 100 miles wide (north to south), bordering China on the north and India on the east, west , and south. Ecologically, Nepal can be divided into three physiographic zones running east to west: the high mountains, the middle hills, and the terai. [The Forestry Sector Master Plan of Nepal (MPFS 1988) recognizes five physiographic zones: high himal (equivalent to high mountains); high mountains, middle mountains, and siwaliks (which combinedly form the middle hills); and the terai.] The high mountains zone varies in altitude from 12000 ft. above mean sea level to the top of Mt. Everest at over 29000 ft. This zone is sparsely populated because of the high altitude and the cold. The middle hills zone lies between the altitudes of 2000 ft. to 12000 ft. and supported 47.7% of the total population in 1981 (CBS 1991). The terai zone lies between 150 ft. above mean sea level to 2000 ft. and supported 43.6% of the total population in 1981 (CBS 1991).

More than 90% of Nepal's population lives in rural societies with agriculture as its primary mode of subsistence (CBS 1991). Forests play an indispensable role in the lives of the rural farmers providing them with all the energy and biomass necessary for survival. The primary forest resources associated with the subsistence lifestyle are fuelwood, tree fodder, leaf litter, and timber and poles. Forests supply 90% of the total fuel supply in the country and more than 50% of livestock fodder (CBS 1991). There is a one-way flow of products from the forest to the farm, and the extent of this flow and the ability of the forests to sustain themselves in the long term is a subject of considerable concern (Applegate and Gilmour 1987).

The pressure upon the forest resources is particularly intense in the middle hills physiographic zone of the country where nearly 50% of the country's population subsists. Recognition of the critical importance of deforestation (in my opinion, used synonymously as forest degradation) in the deterioration of the hill farming ecosystem can be dated to the early 1970s and concern since then has increased dramatically (Seddon 1987). The middle hills are characterized by steep terrain, evergreen and deciduous forests, and intensive terrace cultivation.

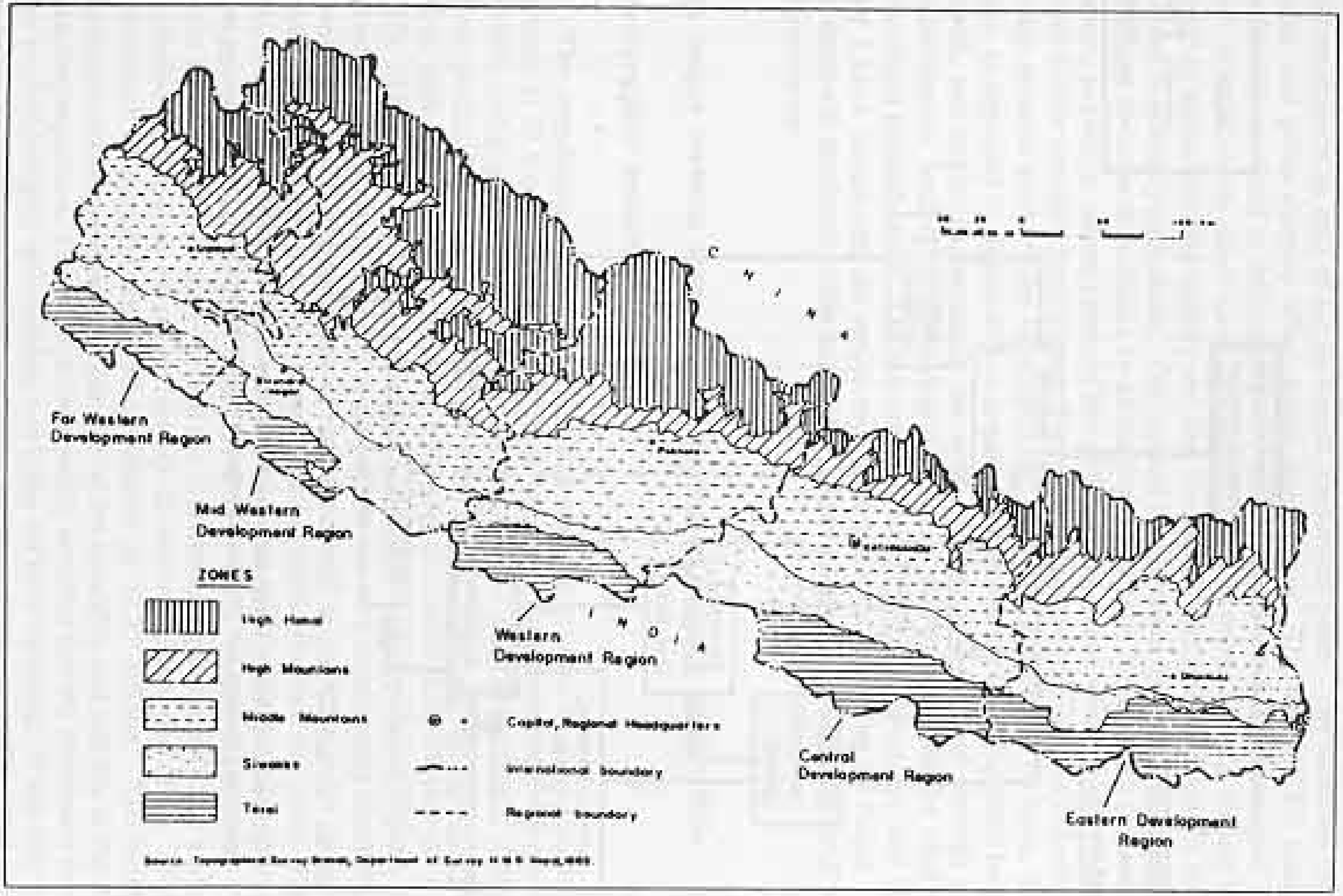


Figure 6-1. Map of Nepal showing physiographic zones and development regions. The middle hills zone in this study is considered as all of the middle mountains, the northern approximate half of the siwaliks, and the southern approximate half of the high mountains in the map.
(Source: Master Plan for the Forestry Sector Nepal, MPFS 1988)

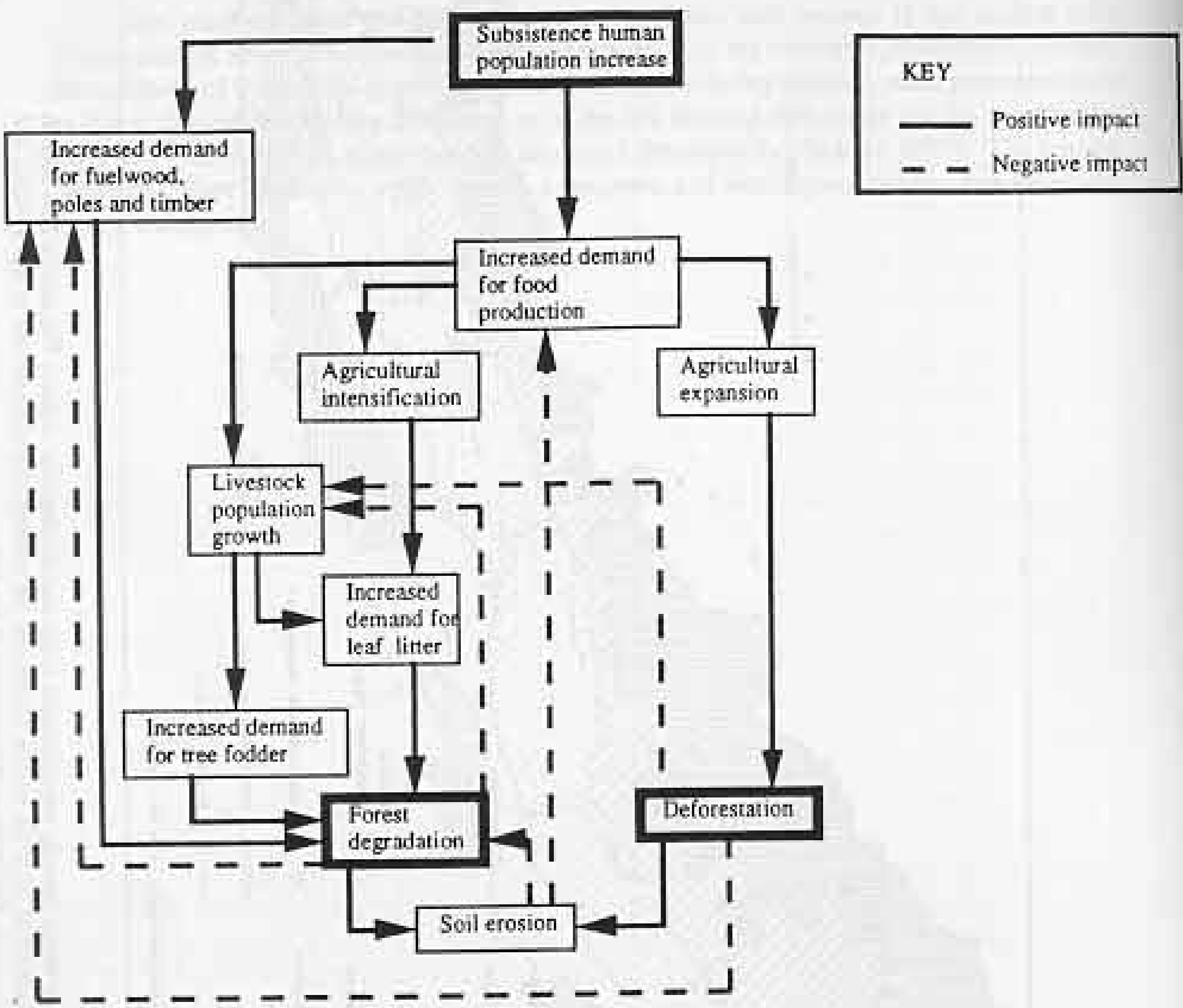


Figure 6-2. Schematic representation of the linkages between population increase, subsistence farming, and forest degradation in Nepal's middle hills.

Figure 6-2 shows the linkages between subsistence livelihood and forests in Nepal's middle hills. As the subsistence population increases, there is an increased demand for food production as well as for fuelwood, timber and poles. The demands for fuelwood, timber and poles directly affect forest degradation. The demand for increased food production may lead to deforestation by converting forested land to expand agricultural land. It may directly affect forest degradation by an increased demand for leaf litter, which is used as animal bedding initially and later composted with animal manure to fertilize crops in order to intensify agriculture. The demand for increased food production may indirectly contribute to forest degradation by increasing the demand for livestock (for animal power, manure, and edible animal products like milk and meat), and whose feed primarily consists of tree fodder obtained from forests. Forest degradation contributes to soil erosion, which in turn reduces productivity of agricultural lands and contributes to forest degradation. Thus, as depicted in Figure 6-2, a negative feed-back cycle is triggered by population growth, and begins to operate in the need to produce more food through agricultural intensification, leading to forest degradation and soil erosion, and the need for further agricultural intensification. I will discuss this relationship in more detail later in this paper after I have introduced the major sectoral transitions occurring in Nepal. Particular emphasis will be placed on the middle hills physiographic zone where data will permit such differentiation.

The major sectoral transitions occurring in Nepal's middle hills

Demographic transition

The population of the country, which was 5.6 million in 1911 (Seddon 1987) is currently at 19.4 million (CBS 1991), with an annual growth rate of 2.4% (Greenhalgh et al. 1992) and is projected to reach 23.4 million by the year 2000 (MPFS 1988). Another source places the projected annual growth rate for Nepal for the period 1985-2000 at 2.97%, with an annual growth rate of 2.78% for the middle hills (Hrabovszky and Miyan 1987). There is significant variation in the reported population figures for Nepal, depending upon sources. Population projections can vary significantly depending upon the assumptions made, and the types of equations used to project population growth. The figures (6-3a,b,c,d and 6-4a,b,c) in the following pages illustrate this point. Figures 6-3a, 6-3b, 6-3c, and 6-3d show population projections using different equations, and based upon published data for Nepal for the period 1910-1990. The results obtained by using the simple linear regression equation and the logarithmic equation are close and project the population of Nepal to be approximately 25 million in the year 2050. However, the exponential fit projects the 2050 population at 42.23 million. The validity of the projections can be questioned on grounds of the reliability and validity of the data used to make the projections. For example, it is widely accepted that the population data for Nepal prior to 1960 is highly questionable, and it has not been validated. It was only in 1961 that a nationwide population census was taken in Nepal (Shrestha 1967). Figures 6-4a, 6-4b and 6-4c show population projections with post-1960 data, and using different equations to project into the future.

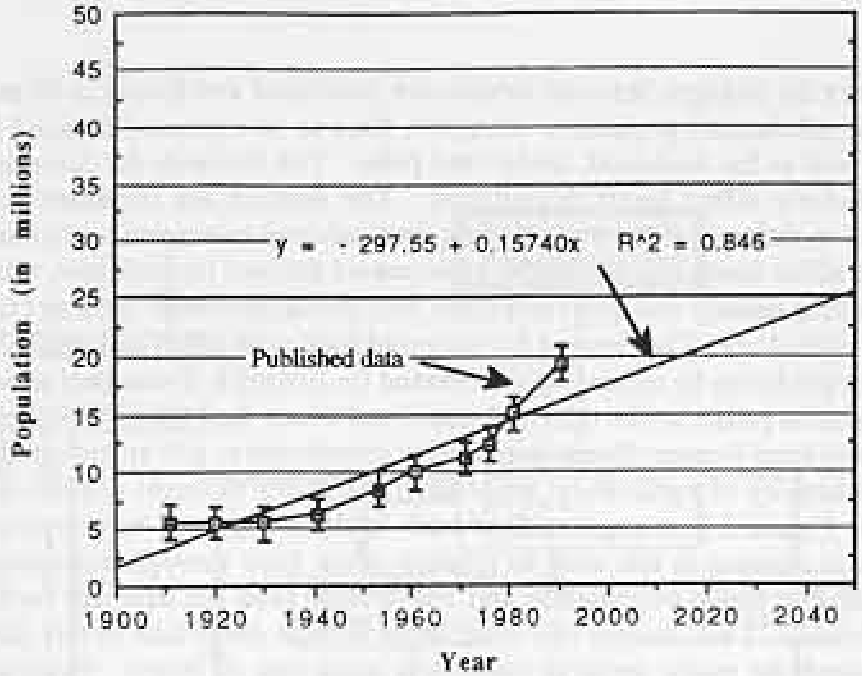


Figure 6-3a. Population trend of Nepal as indicated by published data and projection with a simple linear regression fit. Error bars show standard error of the data.
(Data Source: Seddon, 1987 and CBS, 1991)

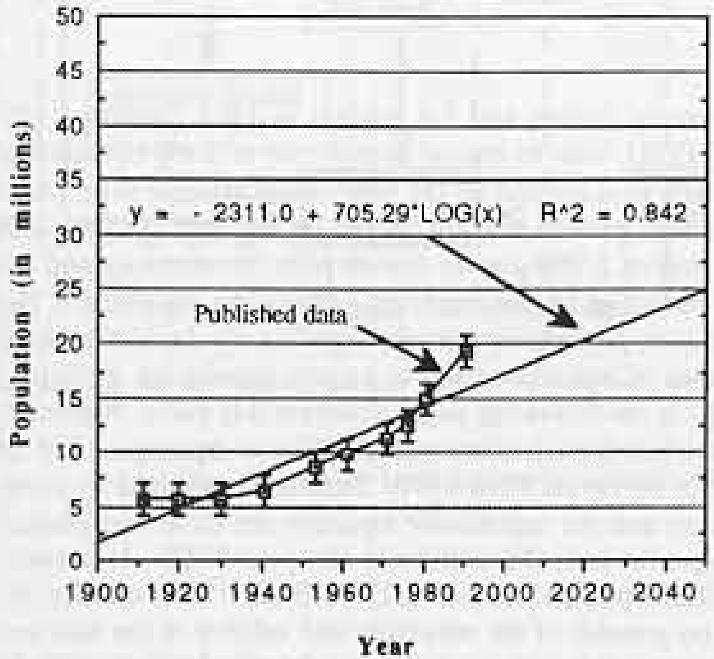


Figure 6-3b. Population trend of Nepal as indicated by published data and projection with a logarithmic function. Error bars show standard error of the data.
(Data Source: Seddon, 1987 and CBS, 1991)

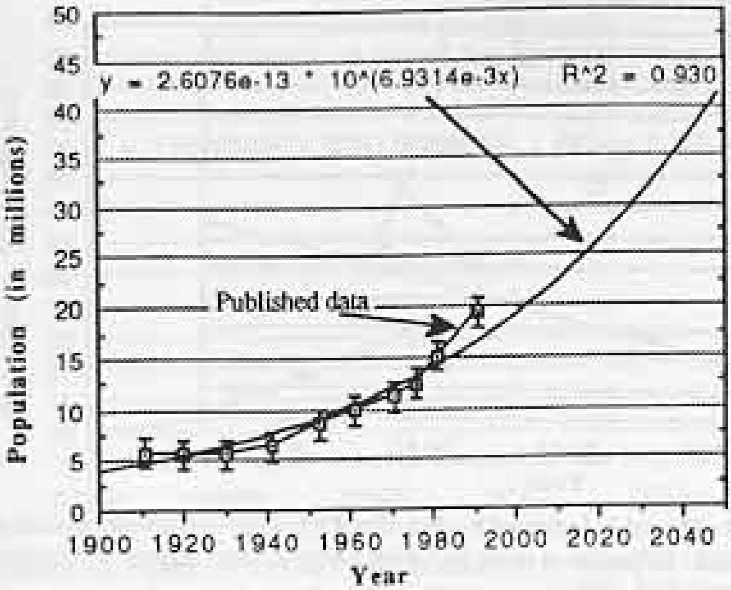
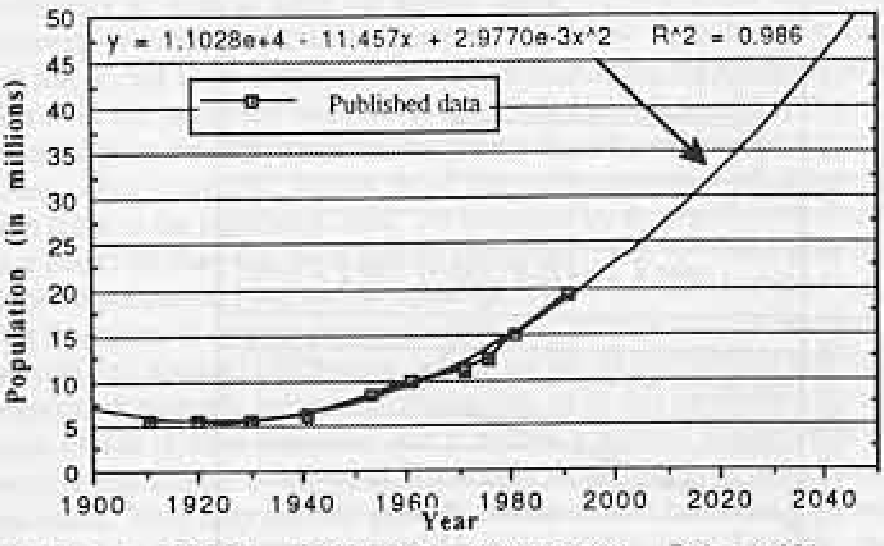


Figure 6-3c. Population trend of Nepal as indicated by published data and projection with an exponential function. Error bars show standard error of the data.
(Data Source: Seddon, 1987 and CBS, 1991)



$y = -1.6978e{+}5 + 266.57x - 0.13952x^2 + 2.4343e{-}5x^3 \quad R^2 = 0.991$

$y = 1.4920e{+}7 - 3.0670e{+}4x + 23.643x^2 - 8.1008e{-}3x^3 + 1.0409e{-}6x^4 \quad R^2 = 0.994$

$y = 8.3776e{+}6 - 1.3848e{+}4x + 6.3428x^2 + 7.9451e{-}4x^3 - 1.2458e{-}6x^4 + 2.3512e{-}10x^5 \quad R^2 = 0.994$

Figure 6-3d. Population trend of Nepal as indicated by published data and projection with a second order polynomial regression fit. Equations for third, fourth, and fifth order regressions are also shown.
(Data Source: Seddon, 1987 and CBS, 1991)

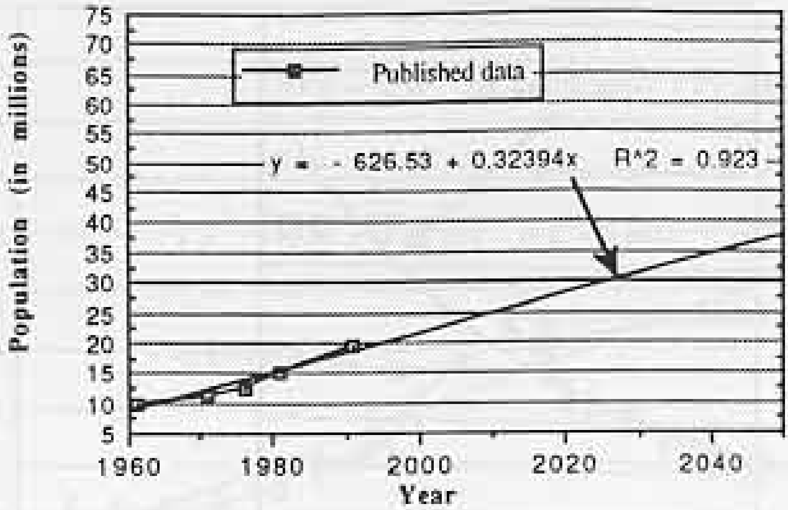


Figure 6-4a. Population trend of Nepal as indicated by data after 1960 when nationwide population census was conducted for the first time. Projection is made by fitting a simple linear regression equation. (Data Source: Seddon, 1987 and CBS, 1991)

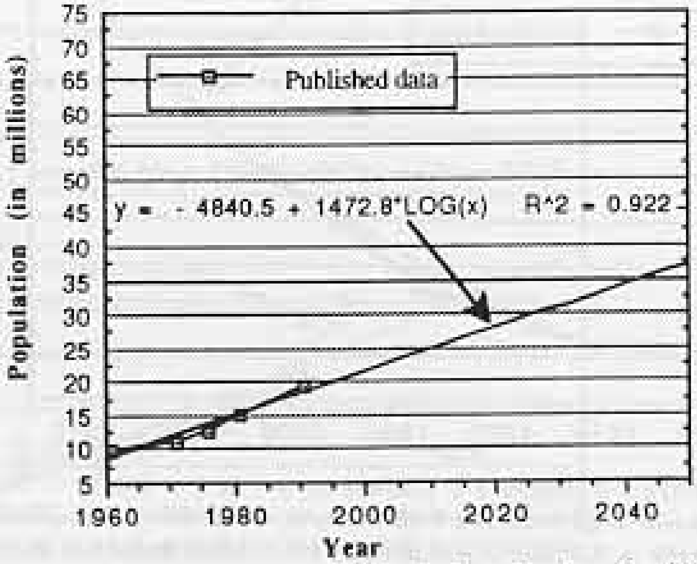


Figure 6-4b. Population trend of Nepal as indicated by data after 1960 when nationwide population census was conducted for the first time. Projection is made by fitting a logarithmic function. (Data Source: Seddon, 1987 and CBS 1991)

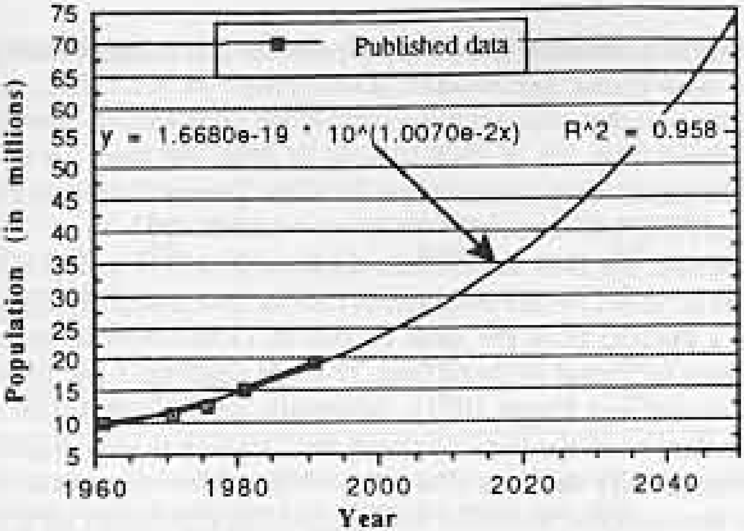


Figure 6-4c. Population trend of Nepal as indicated by data after 1960 when nationwide population census was conducted for the first time. Projection is made by fitting an exponential function. (Data Source: Seddon, 1987 and CBS, 1991)

The 2050 projected population of Nepal using only the post-1960 data increases to approximately 37 million using the simple linear regression and logarithmic equations (a 50% increase over the projected increase with the same equations, but using the published data for the period 1910-1990); and to 73.4 million using the exponential equation (a 75% increase over the projected increase of the 1910-1990 data). In addition, the projections cannot be taken at face value without assessing the rationality of the assumptions behind the equations. For example, Figure 6-3d shows a second order polynomial regression equation fitted to the population data. As indicated by the coefficient of determination (R^2), this is a better fit than the three earlier equations. The R^2 value gets better as we use a higher order polynomial regression equation. However, we need to be extremely cautious in using equations to project future changes just because they fit the data at hand. Neter, Wasserman and Kutner (1990) warn against the use of polynomial regression fits when the true response function is unknown (or complex, as in this particular case). They argue that this type of use is very common, but it entails a special danger, that of extrapolation. Polynomial regressions of all types, especially those of higher order, share this danger of extrapolation. They may provide good fit for the data at hand, but may turn in unexpected directions when extrapolated beyond the range of the data. Logistic equation, which is commonly used to denote population growth may be the way to go if we can agree upon some figure for carrying capacity. This can be problematic, especially if one argues that subsistence lifestyles may change in the future as other opportunities for livelihoods may arise leading to an increase in the land's carrying capacity. Logistic equations also need an intrinsic rate of growth, and the projections can vary depending upon the rate of growth selected for the projection.

Total fertility rates (TFR) have remained virtually unchanged in Nepal during the last 35 years at about 6.3 live births per woman (Greenhalgh et al. 1992). Although Greenhalgh et al. (1992) report that contraceptive prevalence rates among married women 15-49 years of age increased from 2% in 1976 to 15% in 1986, the rates for the hills are much lower at about 3%. According to the Nepal Fertility Survey, infant mortality rate (IMR) for Nepal declined from 140 deaths per 1000 live births in 1971-76 to 136 in 1976-81. For the same time period, the IMR for the hills declined from 134 to 110 (Gubhaju et al. 1987). Greenhalgh et al. (1992) place the current IMR at 140, a slightly higher figure, but definitely showing a decline from the IMR of 200 in 1950. According to various sources, mortality estimates for Nepal declined from 37 crude death rates per 1000 in 1952-54 to 21 in 1974-76 (Banister and Thapa 1981). Mortality, particularly infant and child mortality, is expected to decline in the years to come, thus leading to even higher rates of population growth unless fertility declines (Tuladhar 1989). These figures indicate that Nepal is at the start of a demographic transition because mortality, although quite high even by Least Developed Countries (LDC) standard, has declined; and there is every indication that fertility is quite high.

Agricultural transition

Tables 6-1 to 6-4 and Figures 6-5 to 6-8 show some of the trends occurring and projected within the agricultural sector in Nepal. As population has increased in the middle hills, agricultural production has not only not kept pace but actually declined in the case of some crops, for example, maize. According to Seddon (1987), between 1964 and 1972 maize production registered an 11% decrease in Nepal. There was a 70, 697 metric ton food deficit in the middle hills in 1971, which increased to 123, 755 tons in 1981 (Seddon, 1987). Population growth has forced people to farm marginal lands on steep terraces. Since land for expanding the cultivated area is in short supply, farmers have been forced to intensify their cropping.

Table 6-1. Expansion of cultivated and cropped land (in 1000 ha)

Years	Cultivated land	Cropped area	Cropping intensity**
1965/66	1,840	1,995	108
1970/71	2,030	2,231	110
1975/76	2,161	2,410	112
1980/81*	2,272	2,459	108
1985/86	2,410	4,002	166

*Drought year
**(Cropping intensity = annually cropped area/cultivated area X 100)
(Source: Hrabovszky and Miyan, 1987)

Table 6-2. Changes in land-use intensity and in yields per hactare of cropped area

	1985		2005	
	Cropping intensity (%)	Yield (mt/ha of cropped area)	Cropping intensity (%)	Yield (mt/ha of cropped area)
Mountain	135	1.07	140	1.62
Hills	170	1.30	175	2.33
Terai	163	2.00	190	3.02
Nepal total	163	1.62	182	2.86

Note: Yields represent weighted average of main cereals (paddy, maize, wheat, millet, barley) and potato. Yield of potato has been adjusted to cereal equivalent.
(Source: Hrabovszky and Miyan, 1987)

Table 6-3. Changes in per capita availability of cultivated and cropped area 1985-2005 by ecological zones

Particulars	1985				2005			
	Mountain	Hills	Terai	Nepal	Mountain	Hills	Terai	Nepal
Population (millions)	1.4	7.8	7.5	16.7	2.4	13.5	14.1	30.0
Cultivated area (millions/ha)	0.21	0.90	1.3	2.41	0.19	0.82	1.61	2.62
Cropped area (millions/ha)	0.28	1.53	2.12	3.93	0.27	1.44	3.06	4.77
Cultivated area (ha/cap)	0.15	0.12	0.17	0.14	0.08	0.06	0.11	0.09
Cropped area (ha/cap)	0.25	0.20	0.28	0.24	0.11	0.11	0.22	0.16

(Source: Hrabovszky and Miyan, 1987)

Table 6-4. Livestock population projections for Nepal ('000 LU)*

Year	1985-86	1990-91	1995-96	2000-01	2005-06	2010-11
Physiographic Zone						
High Himal	55	61	70	82	96	115
High Mountains	1048	1031	1037	1065	1119	1200
Middle Mountains	4940	5383	5910	6537	7281	8163
Siwaliks	770	838	917	1010	1119	1246
Terai	2408	2542	2705	2901	3135	3411
Nepal Total	9211	9855	10639	11595	12750	14135

*An adult female buffalo is counted as 1 LU (Livestock Unit), an adult male buffalo as 0.76, a young buffalo as 0.66, a cow as 0.69, an ox as 0.89, a young cattle as 0.37, an adult male sheep or goat as 0.23, an adult female sheep or goat as 0.20, and a young sheep or goat as 0.11

(Source: Master Plan for the Forestry Sector Nepal, 1988)

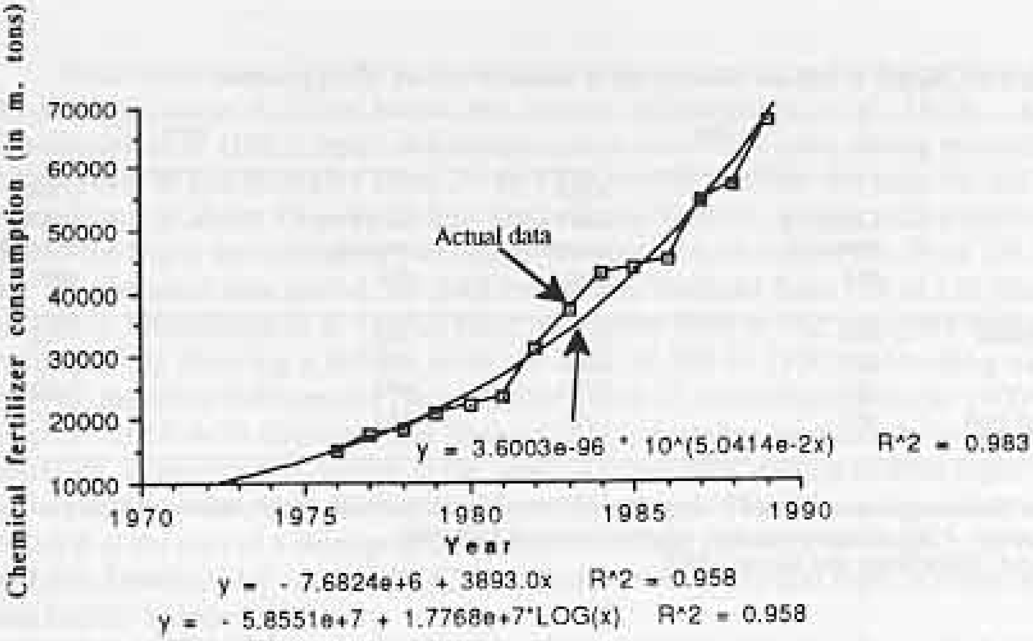


Figure 6-5a. Total chemical (N,P,K) fertilizer consumption data for Nepal.
An exponential function appears to give the best fit.
Equations for simple linear and logarithmic regression curves are also presented.
(Data Source: CBS 1987, 1991)

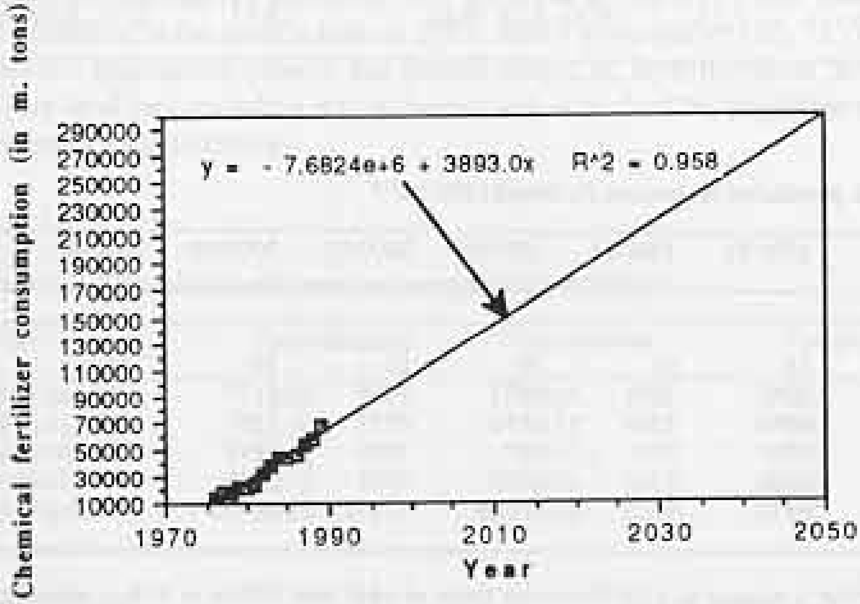


Figure 6-5b. Total chemical (N,P,K) fertilizer consumption data for Nepal.
Projection with a simple linear regression fit.
(Data Source: CBS 1987, 1991)

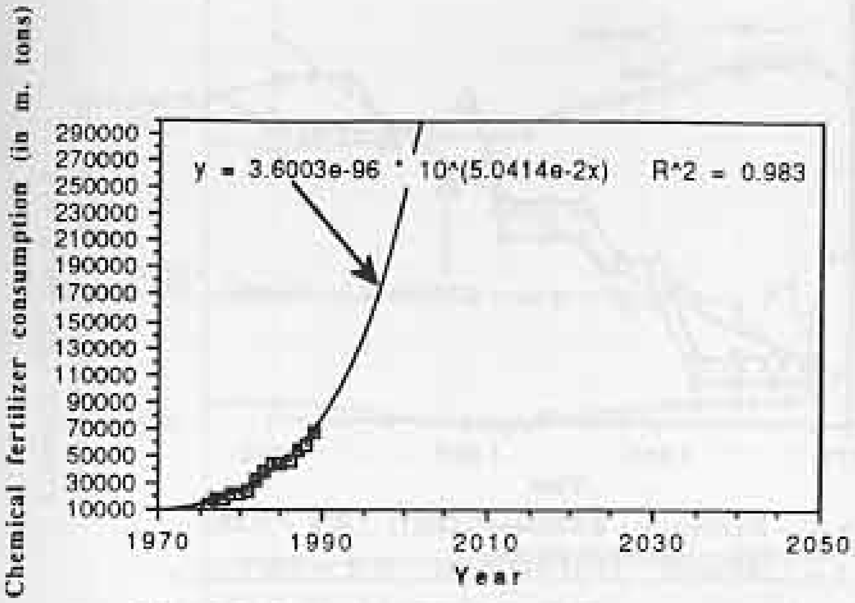


Figure 6-5c. Total chemical (N,P,K) fertilizer consumption data for Nepal. Projection with an exponential function.
(Data Source: CBS 1987, 1991)

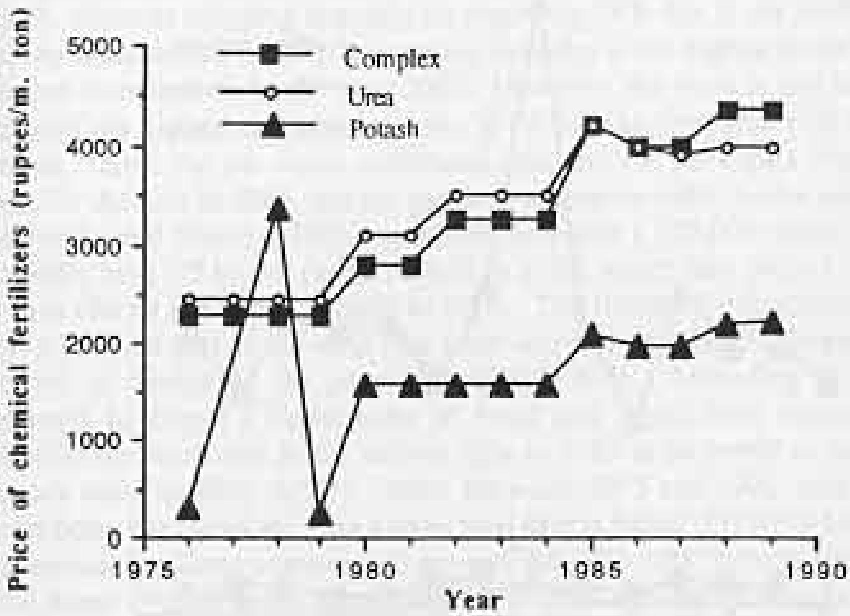
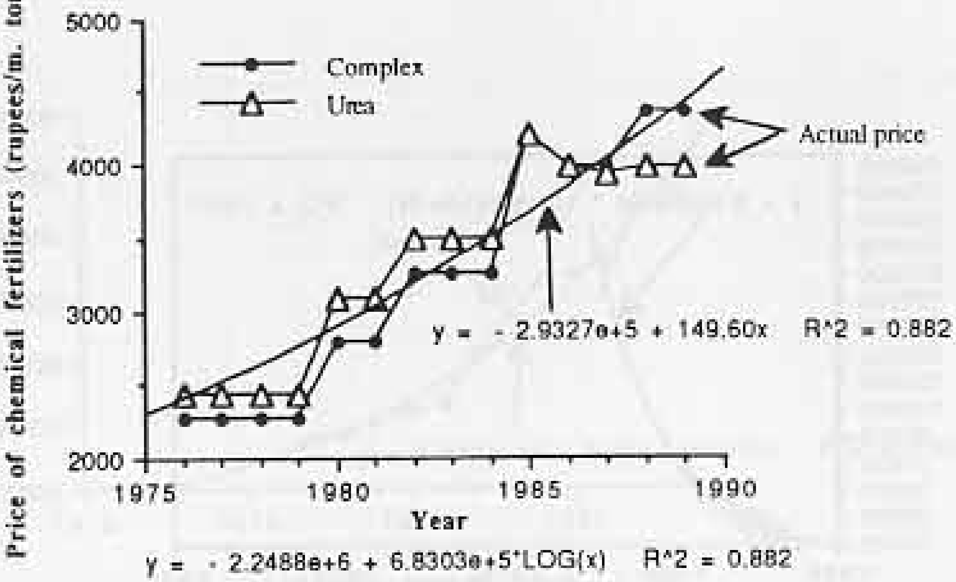


Figure 6-6a. Changes in price of some common chemical fertilizers in Nepal between 19'6-1989.
(Data Source: CBS 1987, 1991)



y = - 2.2488e+6 + 6.8303e+5*LOG(x) R^2 = 0.882

y = 1.0663e-37 * 10^(2.0421e-2x) R^2 = 0.872

Figure 6-6b. A simple linear regression equation curve fitted to the actual price of two commonly used chemical fertilizers in Nepal.
Equations for logarithmic and exponential regression fits are also given.
(Data Source: CBS 1987, 1991)

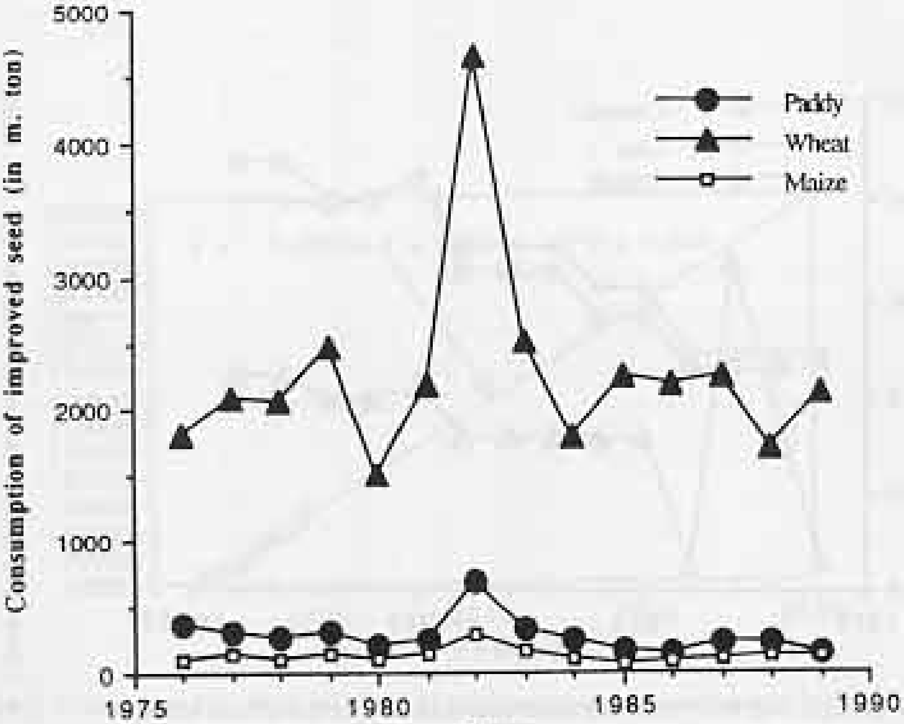


Figure 6-7. Consumption of improved seeds in Nepal.
(Data Source: CBS 1987, 1991)

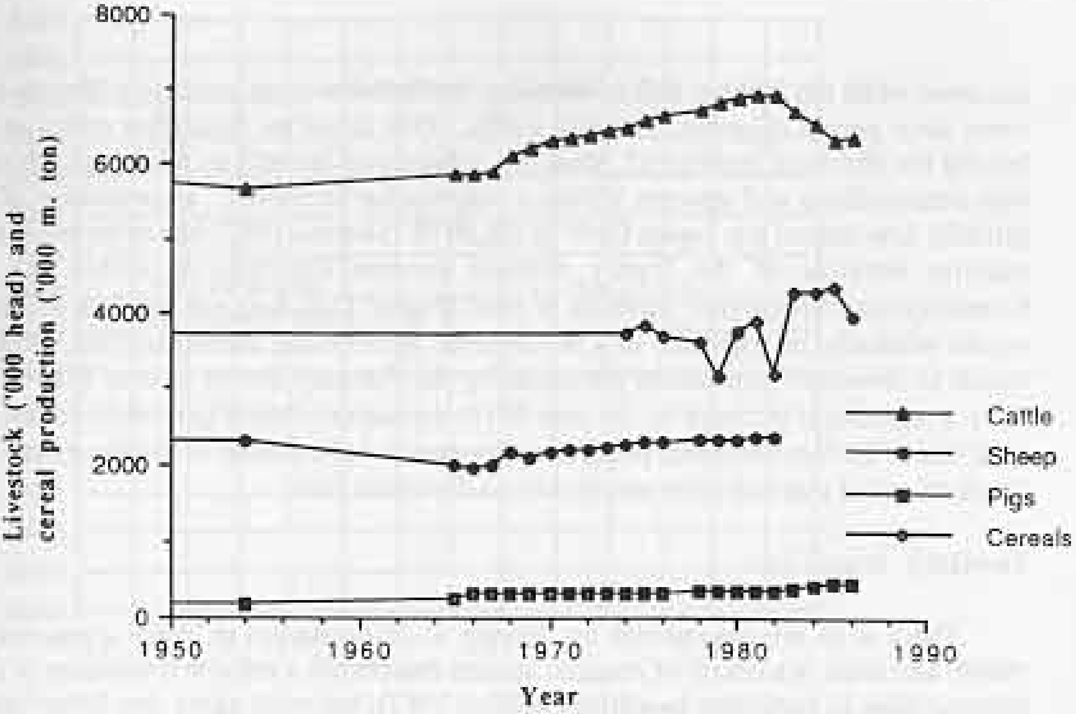


Figure 6-8. Trends in livestock raising and cereal production in Nepal.
(Data Source: UN Statistical Yearbook 1985/86-1970)

As indicated in Table 6-1, between 1965 and 1985, cultivated land in Nepal increased by 30%, whereas cropping intensity increased by 54% due to the doubling of the cropped area. As indicated in Table 6-2, cropping intensity is the highest in the middle hills, and is projected to remain so by the year 2005. However, the yield is less than that of the terai. In spite of the highest cropping intensity in the hills as compared with other physiographic zones in Nepal, the per capita cultivated area and the per capita cropped area were the lowest for the hills in 1985, and the gap is projected to widen by the year 2005 (Table 6-3). Hrabovszky and Miyan (1987) report that there was a 269,000 metric tons food deficit in the middle hills (35 kg per capita deficit) in 1985, which they project to a deficit of 1,091, 000 tons (80 kg per capita deficit) in 2005. The livestock population of the hills, which already is twice that of the terai (the zone with the next largest livestock population), is expected to double by the year 2010 (Table 6-4). According to a livestock survey conducted by Nepal's Department of Food and Agriculture Marketing Services, the 4,940,000 livestock unit in the middle hills in 1985 is projected to increase to 8,163,000 livestock units in 2010 (MPFS 1988). Between 1975 and 1990, total chemical fertilizer consumption has increased at an exponential rate in Nepal (Figure 6-5a), and if the demand for chemical fertilizers continues to grow at the 1975-1990 growth rate, whether projected by the linear (Figure 6-5b) or exponential (Figure 6-5c) growth rates, the country would have to invest tremendous amounts of foreign currency in importing chemical fertilizers. If the data on chemical fertilizer consumption is to be relied upon, it can be argued that the growth in consumption has been to support agricultural intensification to meet the demand of higher food production. The rapid increase in consumption of chemical fertilizer has occurred while the cost per unit of chemical fertilizer has been increasing linearly during the same time period (Figures 6-6a and 6-6b). This raises an important question. Who is buying the chemical fertilizers? Most hill subsistence farmers do not have cash on hand to buy commodities and operate within a non-market economy. Expenditure of even the pitifully low annual per capita GNP of US $179 (Sharma 1992) has to be interpreted with caution because of the highly skewed income distribution within the country. Consumption of improved varieties of seed (Figure 6-7) does not indicate any growth, as would normally be expected in a modernized agricultural intensification. Although the trends in livestock population projected by the Forestry Sector Master Plan (Table 6-4) show a significant increase by the year 2010, the current data (Figure 6-8) do not show any such trend. In fact, the cattle population appears to have started to decline after 1982. The implications of this and other trends will be discussed later.

Forestry transition

There is an ongoing debate on the rate of deforestation in Nepal (Ives and Messerli 1989), and there is a dearth of detailed studies that permit a reliable evaluation of the rate of deforestation in particular localities (Seddon 1987), but most agree that forest degradation has been increasing rapidly. According to Nepal's forestry sector master plan (MPFS 1988), 41% of the total land area is covered with forests (37% forested lands and plantations and 5% shrublands and degraded forests), and the annual rate of deforestation is 0.4% . The latest estimates of the World Bank indicate a much lower figure for forest cover (18%) and a 4% annual rate of deforestation (Sharma 1992). Figures 6-9 a-c show some projections for forest area based upon the different reported annual deforestation rates. If there is no reforestation or afforestation, Nepal is expected to be devoid of any forests by the year 2017 according to the projections of the World Bank and others (Figure 6-9b). This projection is based upon the Nepal government's figure for 1988 forest cover (37% of total land area). The World Bank contends that the 1988 forest cover in Nepal is only 18% of the total land area. If the annual deforestation rate of 0.4% (as given by the Nepalese government) is assumed to be correct, the projected forest cover in the year 2050 will be 4.2 million hectares, or 28.5% of the total land area. Clearly, the magnitude of the problem portrayed by these two reported figures is very different. Tables 6-5 to 6-10 show the Nepalese government's statistics and projections for the different physiographic zones for population, land use, changes in natural forest area, and projected balance for biomass fuel, fodder, and timber. MPFS (1988) estimates that there was a 10,000 ha decrease in area of natural and enriched forests between 1978/79 to 1985/86. The report identifies the main causes of forest degradation in the hills to be overcutting of wood for fuel and heavy lopping of trees for fodder. According to the current trend, the MPFS (1988) report projects the biomass fuel balance for the middle mountains to increase from a 343,000 metric tons deficit in 1985 to 1,530,000 tons in 2000. In the same period, the report projects a timber deficit for the middle mountains to increase from 8,000 cu m to 479,000 cu m. The fodder deficit is projected to increase from 163,000 tons in 1985 to 586,000 tons in 2000, and then nearly double to a deficit of 1,067,000 tons in 2010. These trends paint an alarming picture of forest resources crisis in the middle hills, where the entire subsistence population is dependent upon forest resources for survival.

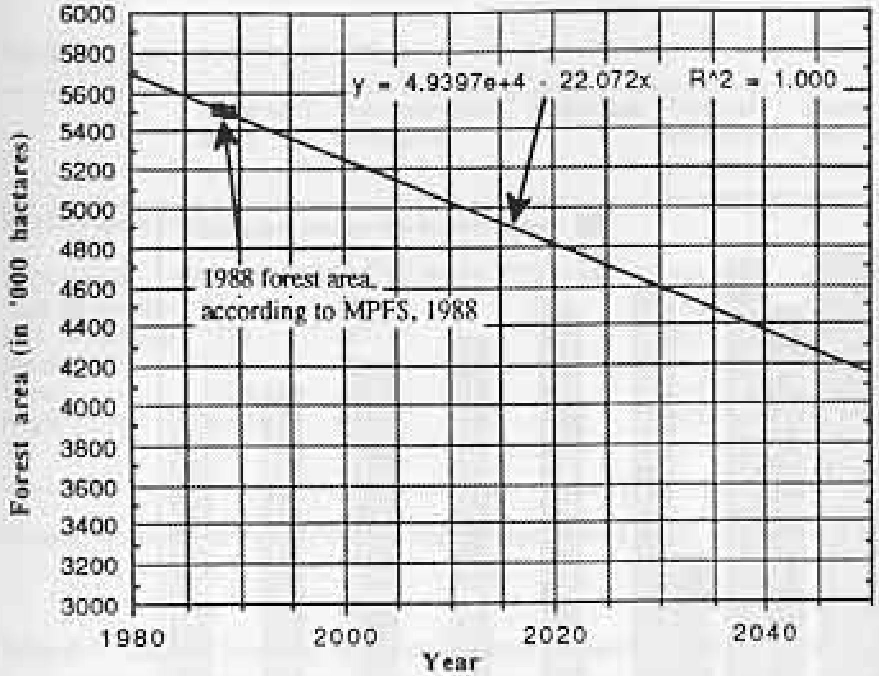


Figure 6-9a. Projected decline in Nepal's forest area at an annual deforestation rate of 0.4% (as reported by MPFS, 1988).

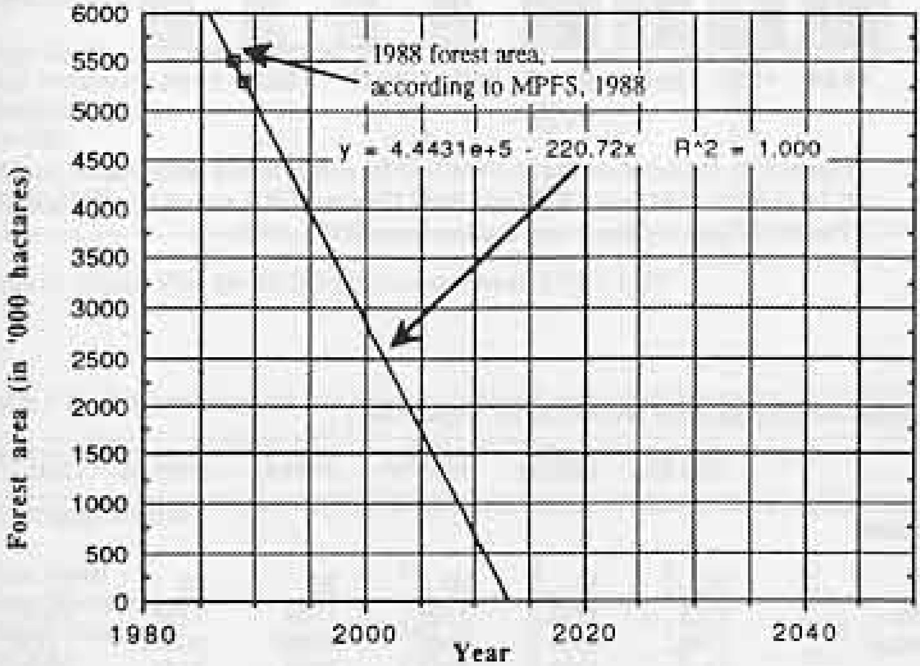


Figure 6-9b. Projected decline in Nepal's forest area at an annual deforestation rate of 4% (as reported by the World Bank, (Sharma, 1992) and other publications).

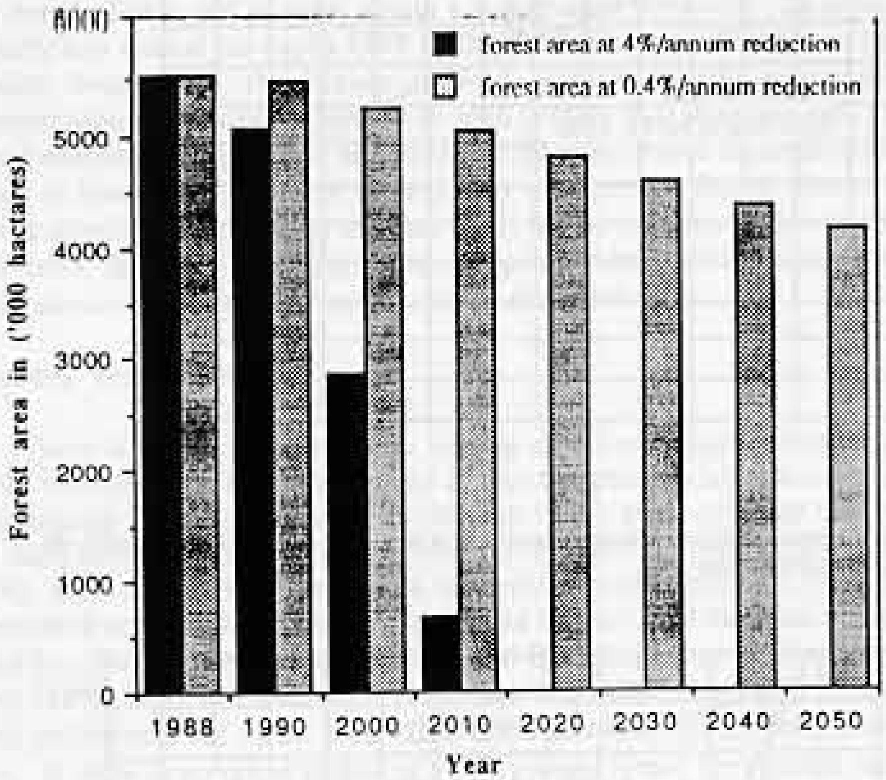


Figure 6-9c. Projected decline in Nepal's forest area at annual deforestation rates of 0.4% (MPFS, 1988) and 4% (World Bank (Sharma 1992) and other publications). The 1988 figure for forest area is taken from MPFS, 1988.

Table 6-5. Medium-variant population projections for Nepal ('000)

Year	1985-86	1990-91	1995-96	2000-01	2005-06	2010-11
Physiographic zone						
High Himal	30	30	30	30	28	25
High Mountains	1275	1307	1306	1269	1188	1068
Middle Mountains	7740	8579	9369	10087	10691	11150
Siwaliks	1374	1594	1822	2052	2276	2484
Terai	6490	7598	8758	9948	11119	12224
Nepal Total	16909	19108	21285	23386	25302	26951

(Source: Master Plan for the Forestry Sector Nepal, MPFS 1988)

Table 6-6. Land use in Nepal ('000 ha)

	Cultivated lands	Non-cultivated inclusions	Grasslands	Forested lands/forest plantations	Shrub lands/degraded forests	Other lands	Total
Physiographic zone							
High Himal	8	1	885	155	67	2234	3350
High Mountains	244	148	508	1639	176	245	2960
Mid. Mountains	1223	667	278	1811	404	59	4442
Siwaliks	269	59	16	1438	29	75	1886
Terai	1308	123	58	475	30	116	2110
Nepal Total	3052	998	1745	5518	706	2729	14748
%	21	7	12	37	5	18	100

(Source: Master Plan for the Forestry Sector Nepal, MPFS 1988)

Table 6-7. Changes in area of natural and enriched forests in Nepal, 1978-79 to 1985-86 ('000 ha).

	1978-79	1985-86	Difference	% Change	
				1978-85	Annual
Physiographic zone					
High Himal	154	155	+ 1	0.6	0.0
High Mountains	1628	1634	+ 6	0.4	0.0
Middle Mountains	1791	1781	- 10	- 0.6	0.0
Siwaliks	1445	1434	- 11	- 0.8	- 0.1
Terai	587	445	- 142	- 24.1	- 3.9
Nepal Total	5605	5449	- 156	- 2.8	- 0.4

(Source: Master Plan for the Forestry Sector Nepal, MPFS 1988)

Table 6-8. Projected biomass fuel balance for Nepal, current trend assumptions ('000 t).

Year	1985-86	1990-91	2000-01	2010-11
Physiographic zone				
High Himal	3	3	8	15
High Mountains	352	387	558	878
Middle Mountains	- 343	- 937	- 1530	- 1336
Siwaliks	108	6	- 79	181
Terai	- 2224	- 2423	- 2008	- 1166
Nepal Total	2104	- 2964	- 3051	- 1428

(Source: Master Plan for the Forestry Sector Nepal, MPFS 1988)

Table 6-9. Projected fodder balance for Nepal, current trend assumptions ('000 t).

Year	1985-86	1990-91	2000-01	2010-11
Physiographic zone				
High Himal	36	37	37	33
High Mountains	502	551	622	666
Middle Mountains	- 163	- 316	- 586	- 1067
Siwaliks	203	175	155	247
Terai	- 81	- 86	- 23	- 97
Nepal Total	497	361	205	- 218

(Source: Master Plan for the Forestry Sector Nepal, MPFS 1988)

Table 6-10. Projected timber balance for Nepal, current trend assumptions ('000 m^3).

Year	1985-86	1990-91	2000-01	2010-11
Physiographic zone				
High Himal	1	0	0	1
High Mountains	45	37	24	58
Middle Mountains	- 8	- 106	- 479	- 459
Siwaliks	39	30	- 6	42
Terai	- 325	- 457	- 690	- 680
Nepal Total	- 248	- 496	- 1151	- 1038

(Source: Master Plan for the Forestry Sector Nepal, MPFS 1988)

Epidemiologic transition

According to Greenhalgh et al. (1992), life expectancies since the 1950s have improved some, but are still relatively low. Although infant mortality rate (IMR) has declined from about 200 in 1950 to about 140, it is still relatively high. Patterns of diseases are still heavily weighted towards infant/child deaths--especially caused by acute infectious diseases (e.g. diarrhoea and acute respiratory infections (ARI), which account for a vast majority of deaths) along with immunizable diseases like measles and other leading causes of childhood mortality in LDCs (Wright 1986). Overall mortality by cause does not show a shift from infectious disease causes toward chronic diseases as Abdel Omran's classic theory of epidemiologic transition (Omran 1982) predicts. As far as I am aware, there is no national level data on causes of death because of lack of a vital events monitoring system; however, I would think it is safe to say that the overwhelming cause of death is infectious disease.

Urbanization transition

Although urbanization in the middle hills (excluding Kathmandu valley) is low compared to the terai region, nevertheless, some hill urban areas have grown significantly. Kathmandu valley, which lies in the middle hills, has the highest urbanization level in the country. There is a dearth of studies looking at urbanization in Nepal. The most authoritative study has been carried out by Sharma (1989), and my figures below have been obtained from that study. The average annual growth rates (in %) during the period 1952/54 to 1981 for the major hill towns were 9.71 for Pokhara, 3.87 for Tansen, 6.72 for Dhankuta, and 8.49 for Ilam. The growth rates during the same period for Bhaktapur, Kathmandu, and Lalitpur (the three urban areas in Kathmandu valley) were 1.51, 2.97, and 2.39 respectively. The growth of the hill towns can be attributed largely to their administrative and governmental investment functions. Those that have had the benefit of permanent road links have evidenced rapid growth. For example, Pokhara, which had a population of 5,413 in 1961, grew to 20,611 in 1971 and 46,642 in 1981. Dhankuta's population grew from 4,137 in 1971 to 13,836 in 1981. Of the 7 hill districts with significant urban population (including the Kathmandu valley urban area), all except Bhaktapur (which showed a slight decline) showed significant increases in the percentage of urban population during the decade of 1971-81. However, although there has been large growth around a few key urban areas, limited infrastructure and the limited production potential of the immediate hinterland have largely inhibited the growth of urban areas in the hills in general.

Discussion

Any conclusions drawn from the data in this paper have to be only tentative ones. The published data on Nepal lend themselves to considerable uncertainty. An excellent example of the unreliability of the published data on Nepal is illustrated by two recent papers published in different journals by the same authors using the same data source (Table 6-11).

Table 6-11. Overall food, feed, and fuelwood sufficiency status in Nepal -- 1981 and 2000, as published in two journals by the same authors.

	Journal 1*		Journal 2**	
	1981	2000	1981	2000
Food deficit	11%	44%	6%	36%
Feed deficit	74%	84%	57%	74%
Fuelwood deficit	20%	35%	10%	21%

*Mountain Research and Development, Vol. 10, No. 2, 1990, pp. 155.
**Environmental Management, Vol. 15, No. 6, 1991, pp. 819.
(Source: Schreier, Shah and Kennedy 1990 and Schreier, Brown, Kennedy and Shah 1991)

The figures in Table 6-11 were reportedly obtained by the authors from the 1986 Land Resources Mapping Project data (supposedly the most reliable data on land use in Nepal), which they digitized by districts, and used a GIS-based land evaluation model to determine the food, feed, and fuelwood sufficiency of all districts in Nepal. In neither of their published papers do they explain why their figures and projections differ in the two published papers. However, even though the data and projections in the two journals differ a great deal, the broad trend and overall pattern are similar. Hence, as argued earlier, some tentative conclusions may be drawn, and we can say that although food, feed and fuelwood deficit in Nepal is expected to widen by 2000, the feed situation appears to be the most critical.

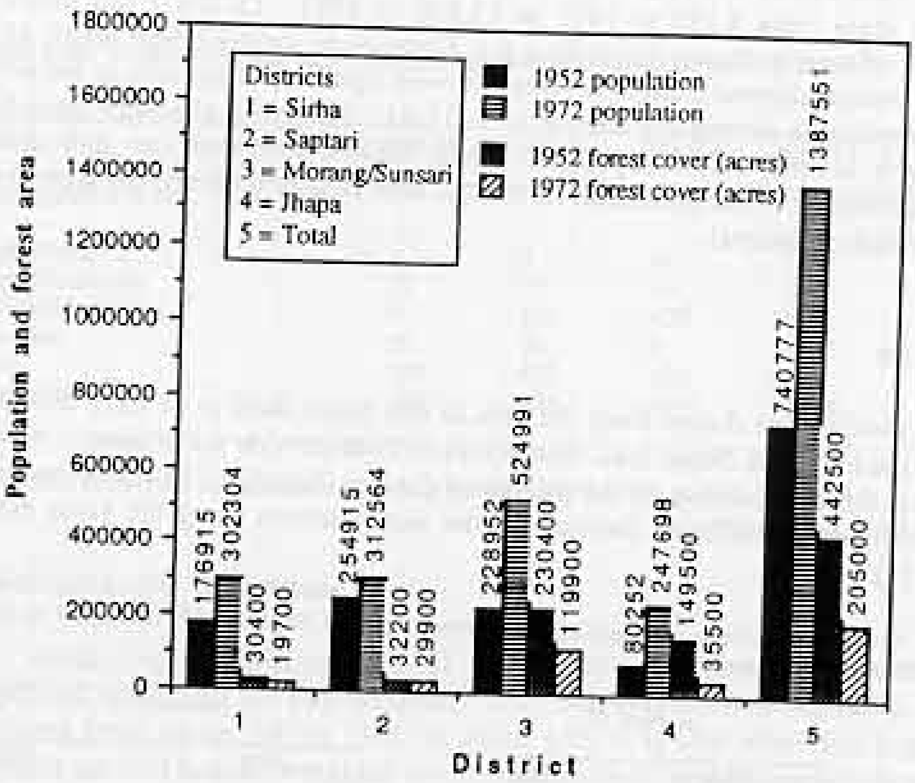


Figure 6-10. Changes in population and forest area in some Terai districts of eastern Nepal between 1952-1972. (Data Source: Seddon, 1987)

Although the terai region was a safety valve for accomodating the growing population in the hills in the past, it can be argued that the safety valve has now been closed. After the eradication of malaria in the tropical forests of the terai in the late 1950s and early 1960s and as a result of the active policy of the government to export timber from the zone and settle the hill migrants in the newly-cleared land, the terai was heavily deforested. Figure 6-10 shows the rise in the population of some terai districts and the corresponding decline in forest cover during 1952-1972. The forests in the terai now have disappeared altogether except within the protected areas of national parks.

The current demographic transition relates directly to forest degradation in the hills. Even in the past when the terai was being deforested, deforestation was never a major occurrence in the hill zone. As the hill population continues to grow, the demand for forest resources will increase, and so it seems will forest degradation. Due to the built-in momentum in population growth because the population age structure is heavily weighted toward children, even if fertility could be reduced to zero today, the younger birth cohorts would move into reproductive age within the next 20 years, guaranteeing population growth into the future. The population projection of 25 million by the year 2010, used by the Forestry Master Plan, is a medium-variant projection made by the government's Central Bureau of Statistics (Table 6-5). It appears this projection was made using a simple linear regression fit to the post-1960 population data (Figure 6-4a). The population projection of Hrabovszky and Miyan (1987), is slightly higher at 30 million in the year 2005 (Table 6-3). It is not apparent how they projected the data. Depending upon whether we use a linear projection or an exponential projection, the projected population at some time in the future can be quite different. It also depends a great deal upon what data we use to make projections. A linear population projection using the published data between 1911 and 1991 would estimate the population in the year 2050 to be 25 million, whereas an exponential projection estimates it to be 42 million. Using only the more reliable, post-1960 data, a linear projection estimates the population at 2050 to be 37 million, whereas an exponential projection estimates it to be 73 million. If we can come up with a figure for a population carrying capacity limit, a logistic equation would be the preferred projection mechanism. However, estimating the carrying capacity would be highly subjective, and many highly debateable assumptions would have to be made.

The epidemiologic transition can indirectly affect forest degradation by affecting the demographic transition. Reduction in mortality through disease control, albeit small, while fertility remains high and life expectancy has increased, will accelerate the demographic transition.

The urbanization transition, although not significant at the entire hills region, is nevertheless important at some localized areas in contributing to forest degradation. An example is Dhankuta, where urban population grew threefold in 1971-81. Seddon (1987) writes, "Thus, in Dhankuta area, the disappearance of forest is now almost total: forest covers only 0.2% of the total land area, with 42.3% poor marginal land under cultivation."

The agricultural transition, which exhibits cropping intensification, affects forest degradation by increasing the demand for fodder to feed the livestock growth, and leaf litter for composting. As forests get more degraded, farmers will be unable to maintain their livestock herds due to difficulty in obtaining tree fodder. Hill subsistent farming is dependent upon livestock for both draft power and manure, which is also supplemented by composting litter to fertilize fields. Although the consumption of chemical fertilizer, an indicant of agricultural intensification, has increased sharply in recent years, it can be argued that its use has primarily been in the terai and not in the hills. First of all, hill farmers do not have the money to buy chemical fertilizers. Secondly, the terai seems to be the most likely zone for the consumption of chemical fertilizers not only because of the purchasing power of the bigger landowners in the terai (some of who even practice mechanized agriculture), but also because of the irrigational facility there. Hill agriculture is mostly dependent upon rain, and thus not conducive to chemical fertilization. The higher yield in the terai (Table 6-2), despite the lower intensification than in the hills, supports this argument.

Thus, hill farmers will continue to rely upon traditional farming practices that employ livestock and forest biomass to meet the food demand of the growing population. This will create tremendous pressure upon the existing forests. The relationship between the agricultural transition and forestry transition appears to be circular. As forest degradation increases, it will be more difficult to get fodder for livestock. Deforestation also increases topsoil erosion, especially on steep slopes, affecting agricultural production. As fuelwood becomes more scare, farmers may resort to burning dung cakes (as currently practised in the terai), which would deprive crop fertilization, and again affect agriculture. Reduced agricultural production will require further agricultural intensification, which will lead to further pressure on existing forests.

The policymakers and administrators need to be aware of this vicious cycle tightening in the hills of Nepal. The problem of forest degradation and negative balance of forest resources can be viewed from two policy perspectives: the demand side, and the supply side. The demand side policy options will be to reduce the overall consumption of forest resources either by reducing the number of people using those resources, or by reducing the per capita consumption of these resources. It can be argued that the per capita consumption of forest resources in Nepal cannot be reduced significantly. Recent data from the World Bank shows that the Nepalese people are already living on the edge, when it comes to energy consumption. The annual per capita energy consumption in Nepal (where biomass fuels are predominant, especially in the rural areas) was reported to be 23 kg of oil equivalent, the lowest in Asia after Bangladesh (46 kg of oil equivalent), and lower in the world than only four African countries -- Chad, Burundi, Burkina Faso, and Ethiopia (World Bank estimates, cited in Sharma 1992). One way to reduce the overall consumption of forest resources will be to reduce the number of people depending upon it. This avenue needs to be seriously pursued by launching vigorous family planning programs. Although the Nepalese government has been promoting family planning programs, the results have not been significant. Total fertility rate still remains high at 6.3, and the contraceptive prevalence rate is extremely low at about 3% in the hills. The family planning program, hence, needs to be greatly expanded in both intensity as well as coverage.

The supply side policy options should aim at finding substitutes for biomass energy and increasing biomass production. Active research, demonstration, and promotion of alternative sources of energy such as solar and hydro-power, which both appear to be feasible in Nepal, need to be pursued. Biomass production can be increased by bringing new land into afforestation as well as reforesting degraded forests. The local communities should be brought into this process, as success of any plantation will depend upon protection and management by the local people. Allan (1991), Exo (1990), Metz (1990), and Zurick (1990) have documented success stories where local communities have taken active part in forest resource protection and management. An active policy to promote biomass self-sufficiency should be pursued by encouraging and assisting farmers to grow more trees on their land and thereby reducing pressure on natural forests. Carter and Gilmour (1989), Gilmour and Nurse (1991), and Carter (1992) have reported that as forest resources get more difficult to obtain, farmers in the hills of Nepal have resorted to growing more private trees. This indicates that the practice and knowledge of growing private trees already seems to be in place in the hills. The government needs to actively encourage farmers and support them in growing a large number of private trees before the remaining forests get too degraded, and not after extensive damage has already been done.

Although most data on Nepal are arguably questionable, the data do exhibit broad trends. Even these broad trends paint a scary picture. The decision-makers must not wait for reliable data to appear before they begin to formulate plans. Programs to reduce the population, maintain existing forests, and promote afforestation, reforestation, and private biomass production are urgently needed. It is also imperative that data collection systems be established urgently to document reliable inventories of present conditions and to monitor program impacts as well as future sectoral changes and trends.

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Chapter 7: Catherine MacFarlane

THE INTERRELATIONSHIP BETWEEN THE FORESTRY SECTOR AND POPULATION/ENVIRONMENT DYNAMICS IN HAITI

Brief Historical Background

In just over a decade, the Republic of Haiti will celebrate its 200th anniversary of independence. After nearly 13 years of slave uprisings and revolt, in 1804, Haiti became the second oldest independent state in the western world (after the United States,) the first free black republic in the world, and the only country to stage a successful slave rebellion in world history.

Although the French rulers left two centuries ago, French colonialism has directed the path that Haitian society and government has taken since independence: an elite, light-skinned, rich, and repressive minority ruling violently and coercively over an oppressed and impoverished black peasant majority. Perhaps as a result of the French influence and the legacy of slavery, Haiti has not experienced any periods of time without violence, economic hardship, racial injustice, and repression in its entire 200 year history as a nation.

An Introduction to the Problems and Issues Facing Haiti Today

The unrest Haiti has experienced has caused a lack of development and an underdevelopment of basic human services (child and maternal health care, general health care, education, transportation, and communications to name a few) in comparison to Haiti's island neighbor, the Dominican Republic, and other Caribbean and Central American countries. In some cases, the unrest has caused a worsening of the services, or a lessening in the availability of those services.

The following statistics, reported in World Resources, A Guide to the Global Environment 1992-1993 will illustrate Haiti's comparative lack of development. *(Unless otherwise indicated, statistics pertain to countries in South, Central, and North America and the Caribbean.)*

Haiti

- has the 2nd lowest per capita GNP behind Guyana.
- has the lowest per capita GNP in North and Central America and the Caribbean.
- has the 2nd lowest life expectancy behind Bolivia.
- is tied with Bolivia for the highest death rate.
- has the 2nd highest highest infant birth rate behind Bolivia.
- has the highest child death rate.
- has the 3rd highest maternal death rate behind Bolivia and Paraguay.
- has the highest rate of wasting in children.

- is tied with Bolivia for having the 2nd highest rate of stunting of children (behind Guatemala.)
- has the 2nd lowest per capita calories available behind Bolivia.
- has the 2nd lowest per capita protein consumption behind the Dominican Republic.
- has the lowest access to safe water in urban areas.
- is tied with Guatemala for the lowest female literacy rate.
- has the lowest male literacy rate.
- has the lowest usage of birth control.
- has the 3rd highest population density behind El Salvador and Trinidad/Tobago.
- has the 2nd highest deforestation rate within the past 10 years behind El Salvador.
- has the highest percentage of households without electricity.

This is just a sampling of the hardships with which the people of Haiti, mainly the peasants, live on a day-to-day basis.

Haiti's population was measured in 1990 at 6.51 million with an anticipated growth rate of 2.07% from 1990-1995.[1] Although Haiti has a fairly low percentage of urban dwellers (28%,) the population growth rate in Port-au-Prince was 3.5% between 1971 and 1982 - far higher than the 1.4% national population growth rate for those same years. It is safe to assume that the growth rate in Port-au-Prince has stayed as high as 3.5%, or has increased since 1982.[2] In addition, the total fertility rate in Haiti is currently 4.8 children per adult female, an exceptionally high number among the Caribbean nations, and the contraceptive prevalence rate is an exceptionally low 10%.[3]

Haiti's estimated population doubling time, based on the 1990 population of 6.51 million is 34 years.[4] This is not an unusually short doubling time compared, for instance, to countries on the African continent where every country has a shorter doubling time (except Tunisia which is tied with Haiti.) Some examples of doubling times in African nations include: Egypt, 32 years; Zimbabwe, 23 years; Nigeria, 22 years; Kenya, 19 years; and Cote d'Ivoire, 18 years.[5] Similar to many African nations, Haiti's infrastructure, welfare system, and human services are having a difficult time serving the needs of the current populations. What havoc and poverty will a doubled population cause in the year 2026?

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[1] Allen L. Hammond, Ed., et al, World Resources 1992-1993, A Report by The World Resources Institute, (New York: Oxford University Press), 1992, p 246.
[2] Richard A Haggerty, Ed., Dominican Republic and Haiti Country Studies, (Washington DC:US Government Printing Office), 1991, p 245.
[3] Andrew Steer, Ed., et al, World Development Report, 1992: Development and the Environment, (New York: Oxford University Press), 1992, p 270.
[4] "Population and the Environment: The Challenges Ahead," UNFPA, 1992.
[5] Ibid.

To some degree, citizens of all countries depend on government-organized health care to keep them healthy and government-organized education to make them literate. These are man-made institutions. The natural resources of a country like Haiti need to be taken into consideration in a population study as well. It is estimated, for example, that less than 2% of Haiti's original forest cover is left today.[6] Mountainsides have been deforested completely to make way for cultivation to grow food, to sell as firewood, and to make charcoal. Haiti was once considered one of the most fertile countries in the New World; now only 11.3% of its land is suitable for agriculture use.[7] The lush, tropical countryside has evolved into arid, barren, inhospitable land.

Problems beyond an increase in population are causing the deforestation: the US's recent embargo on importing most goods to Haiti has halted the delivery of propane gas, the most commonly used cooking fuel. This has caused an increased demand for charcoal and in order to meet this demand and to make much needed money, farmers are felling live fruit trees. Chopping the trees not only further degrades the poor top soil, it takes away vitally necessary food for Haiti's population.[8]

Overview

Comprehensive data on the various sectors in Haiti are difficult to locate. Much longitudinal data exists on the demographic transition in Haiti from 1950 to the present, but data in most other sectors is limited to one year's findings. For that reason, I will concentrate on the demographic transition and discuss how Haiti's projected exponential population growth rate has affected and will continue to affect the forestry sector. For the purpose of comparison, I will include data on Haiti's neighbor on the island of Hispaniola, the Dominican Republic.

Much of the data and the graphs presented originate from the World Resources Data Base. In this data base, World Resources Institute has compiled data from many sources. To give credit to the institutions, I have indicated on each graph from which of the many sources the data arose. Other data comes from a number of other books, journals, World Bank documents, and reports.

One final note: Haiti's recent history has been one of extreme despair: the tenuous and violent political situation has forced many citizens to seek asylum in the United States (only 5% are allowed to stay,) and the AIDs epidemic has placed severe strains on the health care system. Because I am concentrating on the population transition in this paper and not the recent and bleak history, I have not specifically analyzed the effects of the political violence and reprisals and the AIDs epidemic.

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[6]Charles E. Cobb, Jr., "Haiti: Against All Odds," National Geographic, Vol 172, No 5, November, 1987, p 648.
[7]Haggerty, 1991, p 293,
[8]Lee Hockstader, "Embargo Translates into Ecological Disaster for Haiti," Washington Post, May 31, 1992.

The Demographic Transition

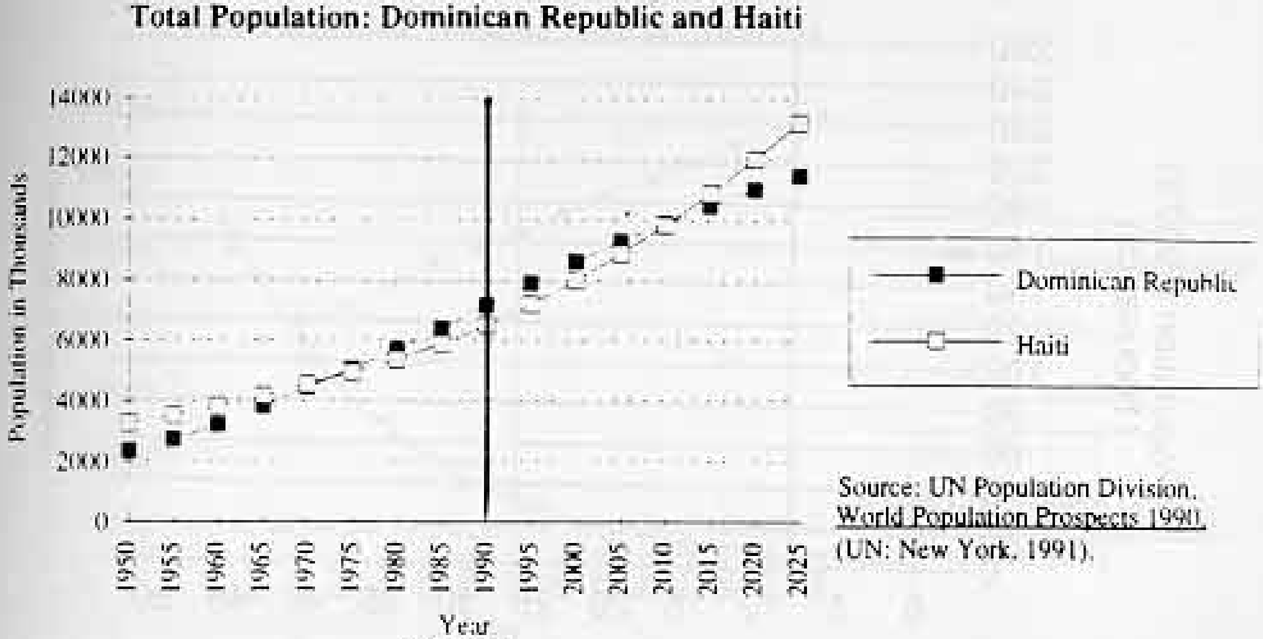
The demographic transition analyzes changes in population over time. The transition begins with relatively high birth and death rates that are in fairly close equilibrium with each other. The birth rate tends to be slightly higher than the death rate which results in a slow, steady increase in population. During the transition, the death rate takes a sudden downward turn, usually because of improved health standards, but also because of a variety of other life-improving situations. If the birth rate follows the death rate in its downward turn and remains in equilibrium with the death rate, the population continues to increase steadily. If, however, the birth rate remains high while the death rate drops, a population explosion will occur.

The end of the demographic transition is the downturn of the birth rate until equilibrium with the death rate has been established again. While many, if not most, of the industrialized nations have reached this end point of the demographic transition, the majority of developing nations have not.

If the population projections cited by World Resources Institute (and other sources I located) are to be believed, both Haiti and the Dominican Republic appear to be in the midsection of the transition, although at slightly different points, and both countries are feeling the pressures currently of rapid population growth. To give the reader an understanding of how world population growth and the growth in Central and North America and the Caribbean compares with Haiti's and the Dominican Republic's growth, I have included the data for all these areas in some of the graphs.

In 1950, Haiti's population of 3.25 million exceeded Dominican Republic's population by nearly 1 million. By 1970, only twenty years later, the Dominican Republic (4.4 million) had almost caught up with Haiti (4.5 million) and in only five more years, the Dominican Republic's population exceeded Haiti's. Currently, the Dominican Republic's population is about .6 million higher than Haiti's[9], but the following graph seems to indicate that Haiti will surpass the Dominican Republic by 2015 and continue growing exponentially, while it appears that the Dominican Republic population will level off and grow linearly (please see Figure 7.1 on next page):

[9]Allen L. Hammond, et al, World Resources - A guide to the Global Environment 1992-1993, (New York: Oxford University Press, 1992), p 246.



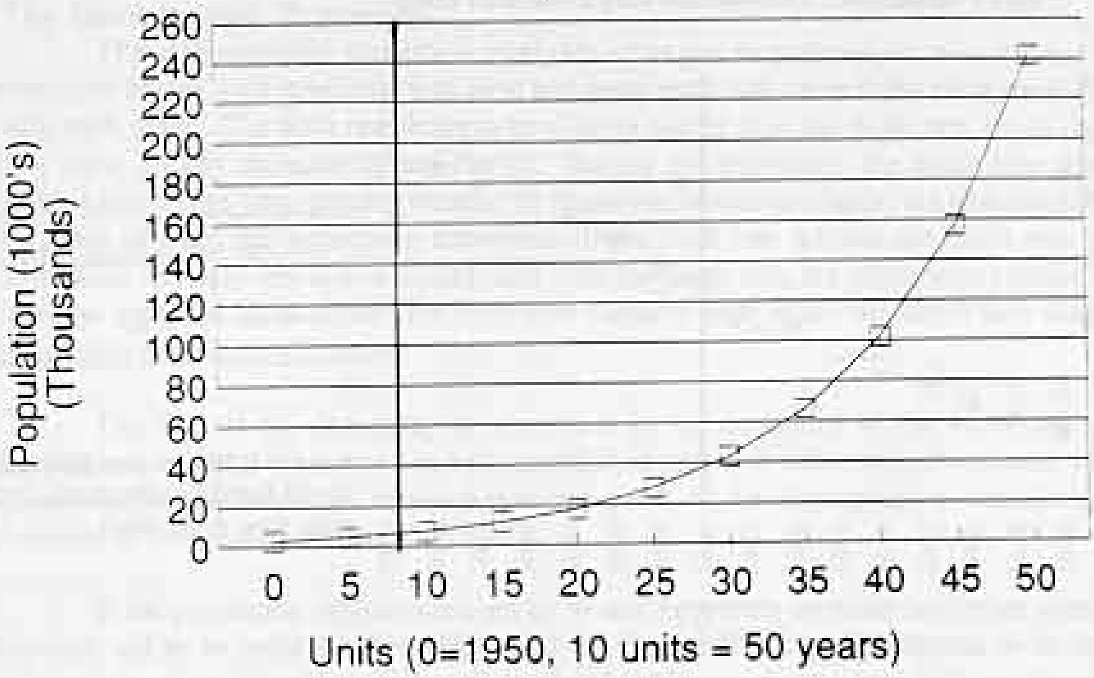
Source: UN Population Division, World Population Prospects 1990 (UN: New York, 1991).

Figure 7.1

It is extremely important to differentiate between actual data and projected data. The data from UN's Population Division (the source of most of the population graphs in this paper) are actual data until 1990; to assist the reader in differentiating between actual and projected data, I have demarcated the actual/projection cut-off points with vertical lines. UN's Population Division, in extrapolating projected future population data, has chosen specific curve fits for specific data. The reader must be aware that different information sources may choose different curve fits - this could lead to widely varying projected data. The first example of biased curve fitting is evident in the above graph, Figure 7.1: the Population Division at UN chose to have the Dominican Republic's population level off into a linear curve and Haiti's population to continue to grow exponentially.

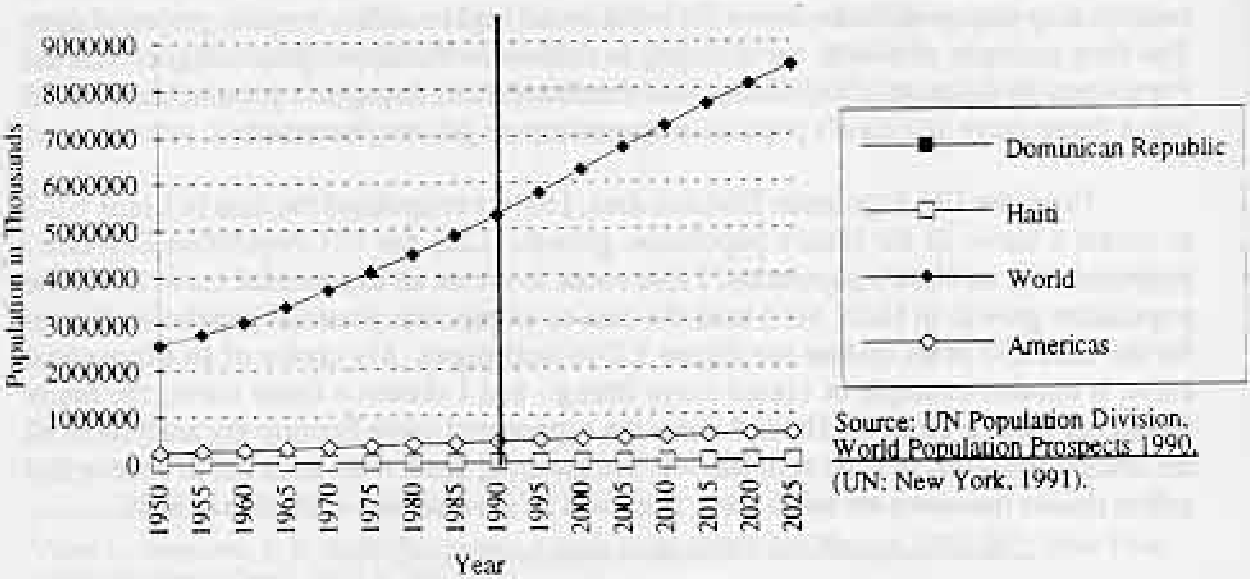
From the UN Population Division data, I have extrapolated the data in Lotus 1-2-3 to create a curve fit for Haiti's population growth. Like the UN Population Division's projected data on Haiti's population, I also chose to create an exponential curve fit for the population growth in Haiti, but I used the data to extrapolate potential population figures for the next 250 years (please see Figure 7.2 on next page). My choice of an exponential curve is another example of biased curve fitting - had I chosen a linear curve, the future would not look so bleak for Haiti. I chose the exponential curve because my analysis of all the linking problems in Haiti coupled with the lowering death rates leads me to believe that unless drastic measures are taken soon, there will be a population explosion in Haiti.

Figure 7.2
Total Population of Haiti



The following graphs (Figure 7.3 on this page and 7.4 on the next page) show total population in the world and in the Americas and are included mainly to show the similarities and differences in curve shapes between these graphs and the previous graph:

Total Population



Source: UN Population Division, World Population Prospects 1990, (UN: New York, 1991).

Figure 7.3

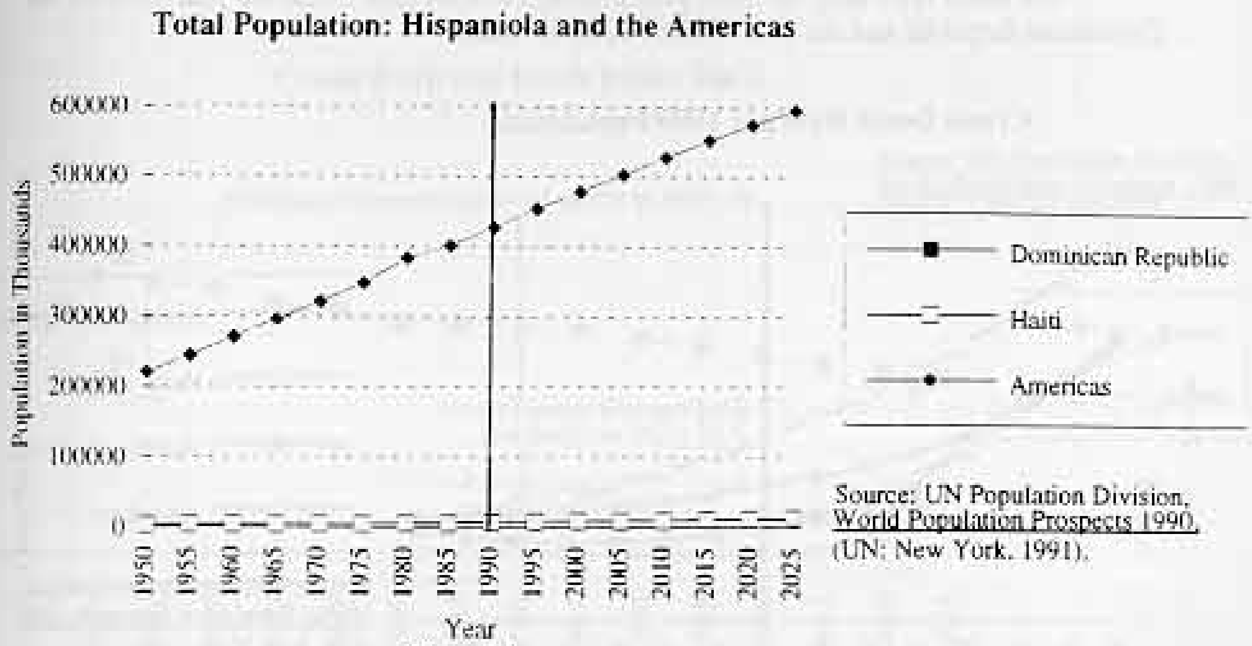


Figure 7.4

In examining the birth rate graph, the drops in birth rates are fairly slow, with the Dominican Republic showing a steeper drop than Haiti. This graph shows a far lower projected birth rate in 2025 in the Dominican Republic (16.8) than in Haiti (28.2).

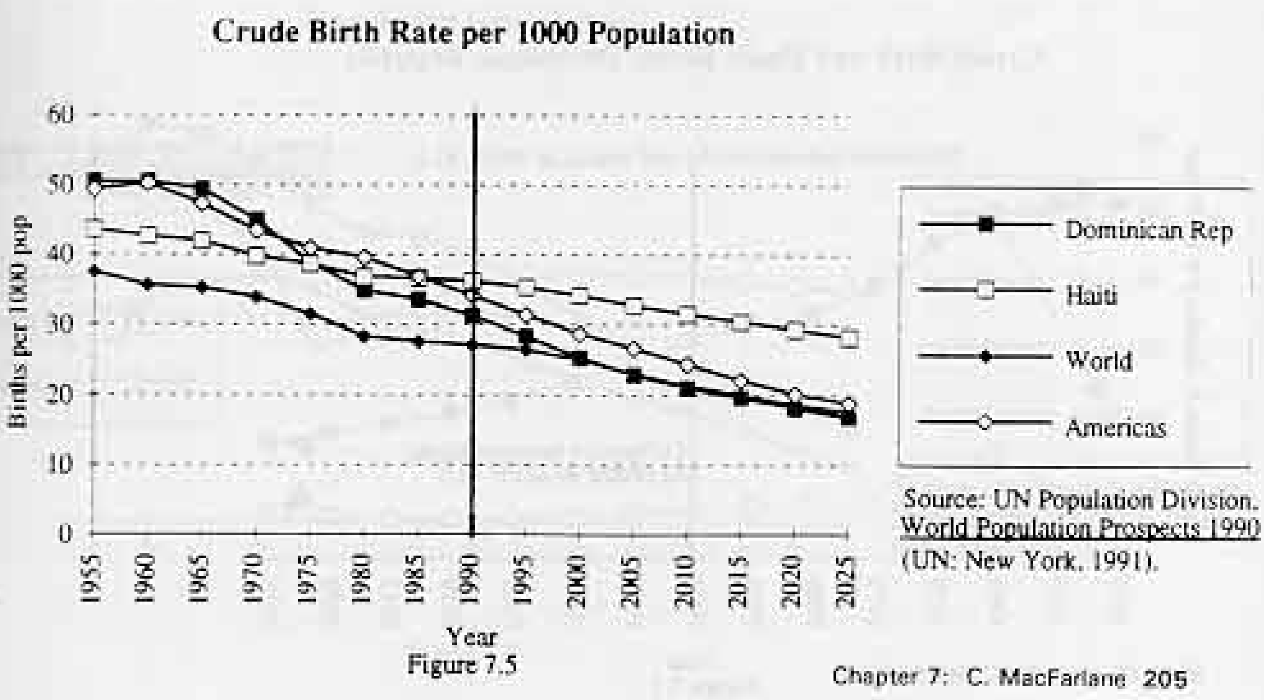


Figure 7.5

The death rates drop far more precipitously, at least until about the year 1990 for the Dominican Republic and the year 2010 or 2015 for Haiti:

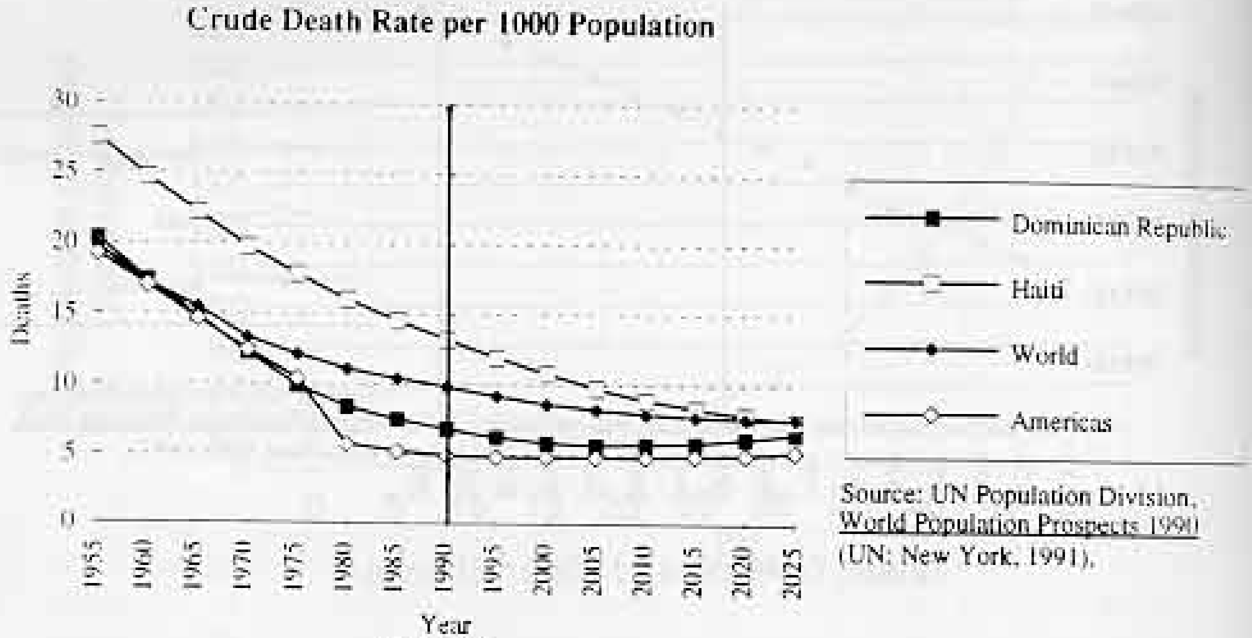


Figure 7.6

By examining the birth and death rates together on the same graph, one can more easily see the differences between births and deaths. The first graph (Figure 7.7) shows the Dominican Republic's birth and death rates. The actual data from 1955 shows a very high difference between births and deaths and as the years pass, the birth and death rates draw closer and closer to each other:

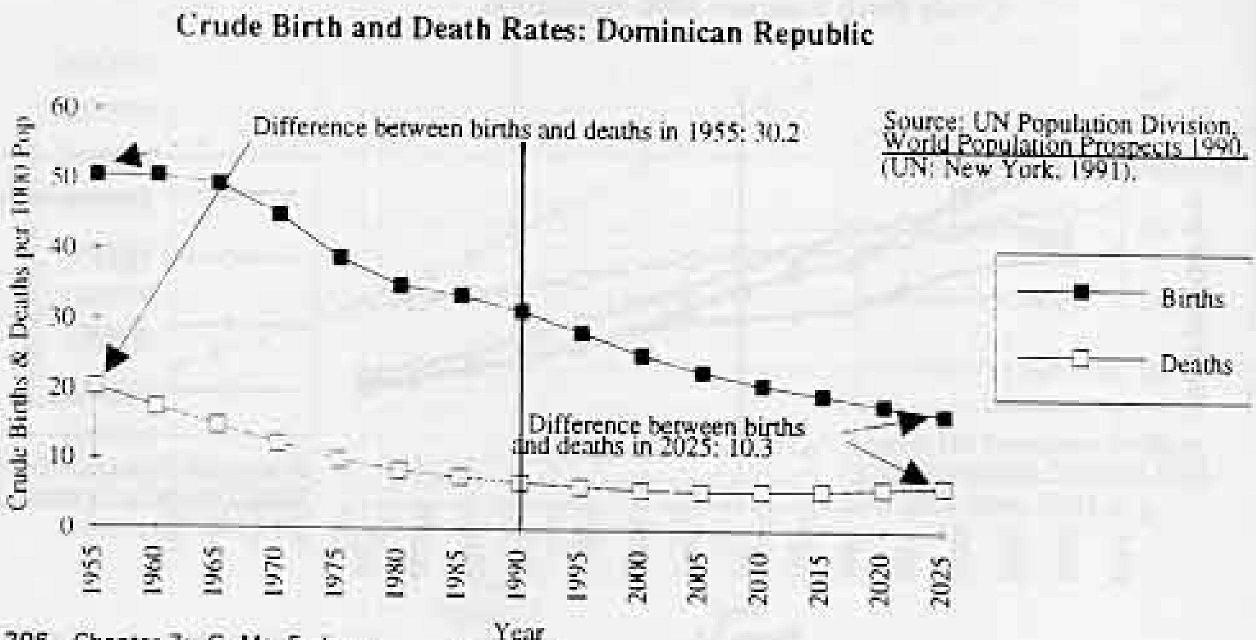


Figure 7.7

Compare data from the Dominican Republic with data from Haiti:

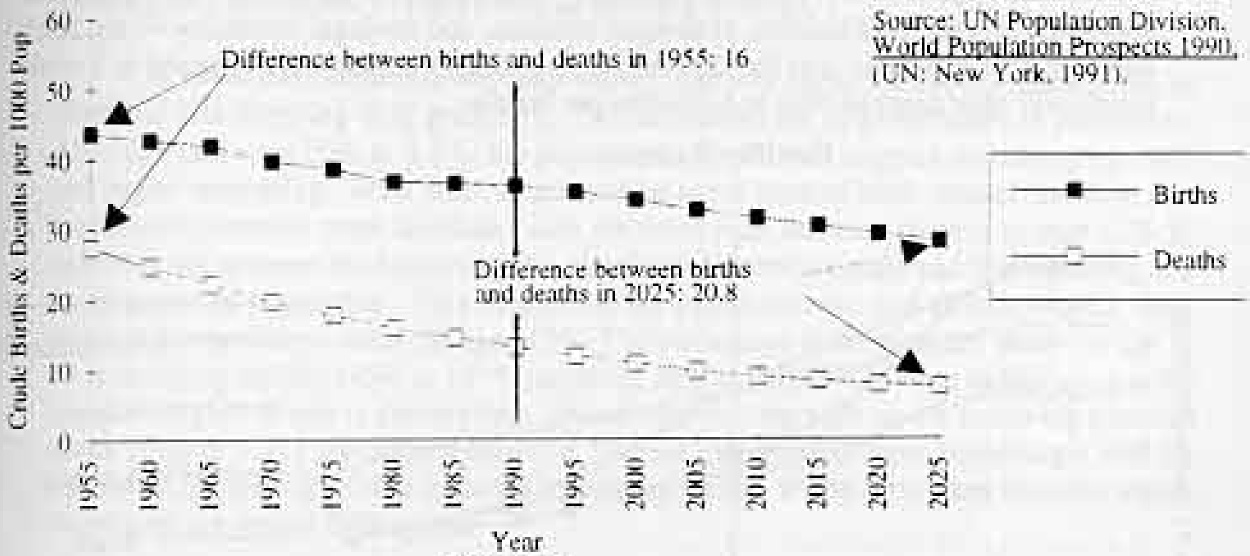


Figure 7.8

While not as dramatically far apart as the Dominican Republic's birth and death rates from 1955-1970, Haiti's rates grow further apart over time. If the projected data from UN's Population Division turns out to be correct, this wide separation between birth and death rates can only signal one thing: comparatively higher population growth rates for Haiti than for the Dominican Republic:

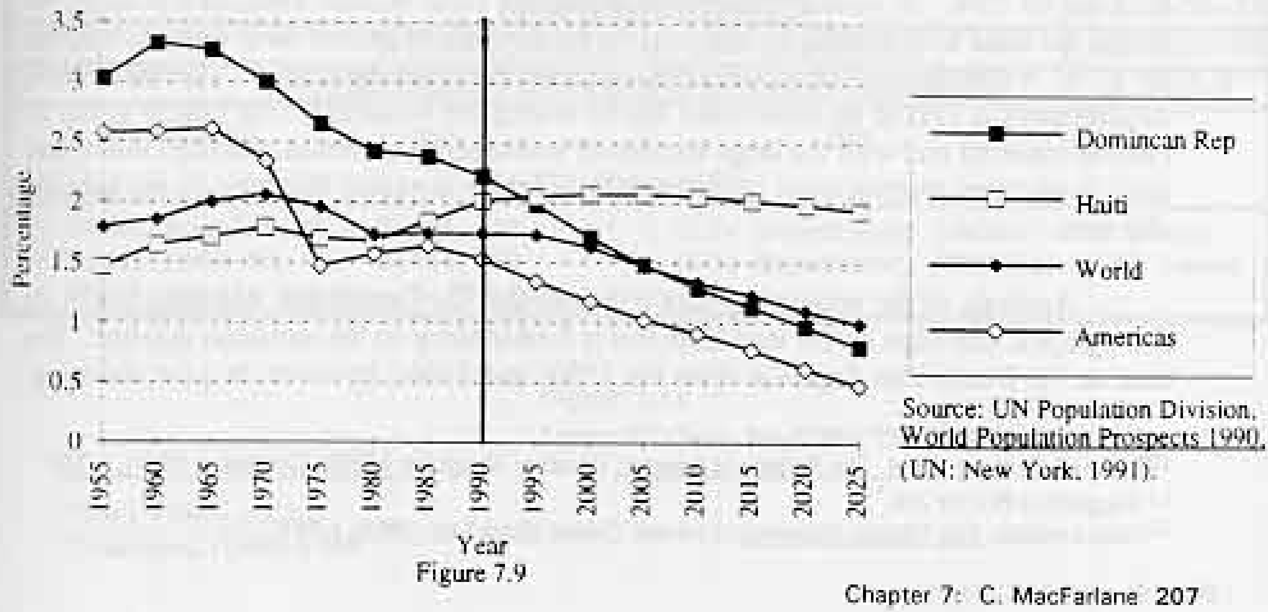


Figure 7.9

Besides the large gaps between birth and death rates, fertility rates also play a role in population growth. In 1955, the Dominican Republic's fertility rate (average number of children per mature female) was a very high 7.4, while Haiti's rate was 6.3. Haiti's fertility rate in the 1950s and early 1960s was low compared to other Caribbean nations, not because of government policy, but because of unhealthy living conditions, spontaneous abortions, delayed cohabitation, prolonged lactation, and conjugal instability.[10] By 2025, however, it is estimated that the Dominican Republic's rate will have dropped to 2 while Haiti's will have dropped only to 4 children per female:

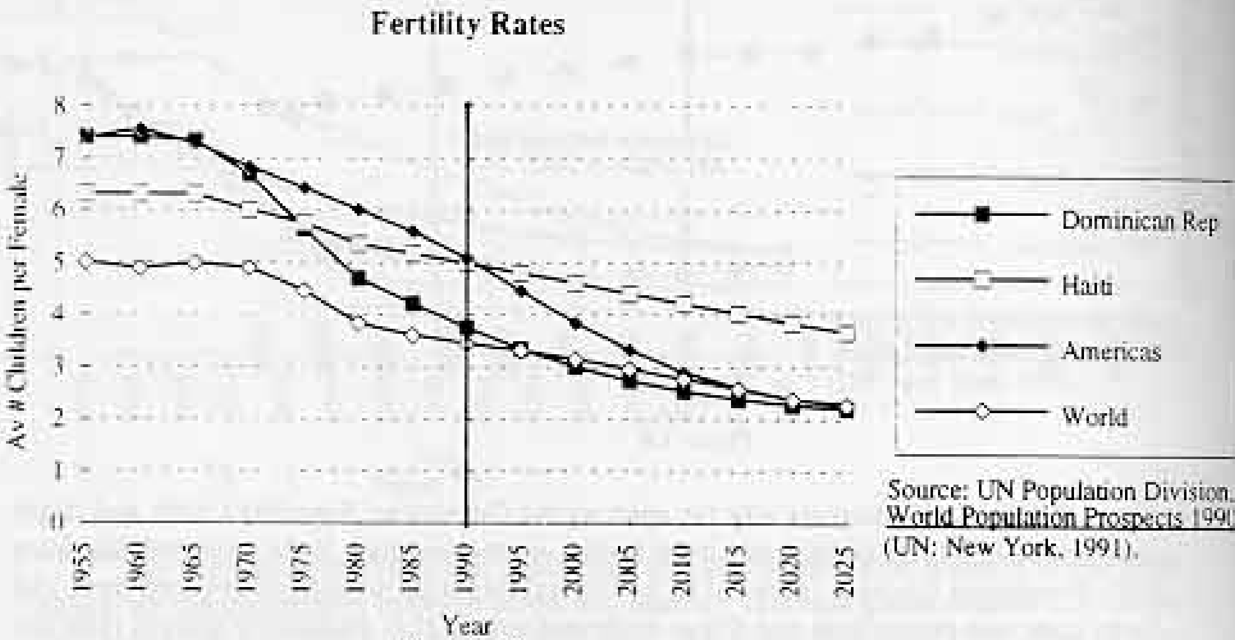


Figure 7.10

As in other countries around the world, there seems to be a strong correlation between fertility rates, urban residency, and literacy. The 1977 "Haitian Fertility Study" found that between the years 1962 and 1977, the fertility rate of literate urban women declined by 33%. In contrast, the rate for illiterate rural women declined by only 7 % during the same time period. In addition, the fertility rate of literate rural women declined by 27%, while that of illiterate urban women declined by 15%.[11] Nevertheless, childlessness is said to be universally feared among the peasants[12] (the largest group of Haitian citizens) and with the large number of spontaneous abortions and high infant and child death rates, women must continue to have babies to ensure that they do not become childless.

Analysis of the population data indicates that the Dominican Republic began its demographic transition earlier than Haiti and is further along on the transition timeline. The data on the Dominican Republic from the 1950s and 1960s, however, is quite alarming:

[10] Robert I. Rotberg, Haiti, The Politics of Squalor, (Boston: Houghton Mifflin Company, 1971), p 264.
[11] Haggerty,(1991,) p 248.
[12] Mats Lundahl, The Haitian Economy, (London: Croom Helm Ltd., 1983), p 241.

high fertility rates, high birth rates, high population growth rates and relatively low death rates. Beginning in the 1960s and 1970s, the government began supporting family planning and the use of contraceptives and although family planning took a while to become widely available, officially, about 50% of all couples currently use some form of contraception (compared to Haiti's official estimate of 10%).[13]

In 1955, the Dominican Republic's death rate was already dropping quickly, but its birth rate was dropping only gradually. This accounted for large increases in population. Although still very high at 3.3%, the population growth rate stopped increasing by 1960 and began decreasing. With more couples using some form of birth control, the birth rate continues to become more stabilized with the death rate, however there is at least a 20-30 year time lag between the beginning of a population control program and the beginning of a stabilization of population. This means that the population has had an inordinately large percentage of children under the age of 15. The percentage of Dominicans under the age of 15 is dropping rapidly (45% in 1975, projected 36% in 1995)[14], another indication that the population growth rate is diminishing. Please note that the ages on the following pyramid graph (Figure 7.11) are broken down in 10-year increments: these percentages will be somewhat different than data included in this paper from World Resources Institute whose increments are spaced differently:

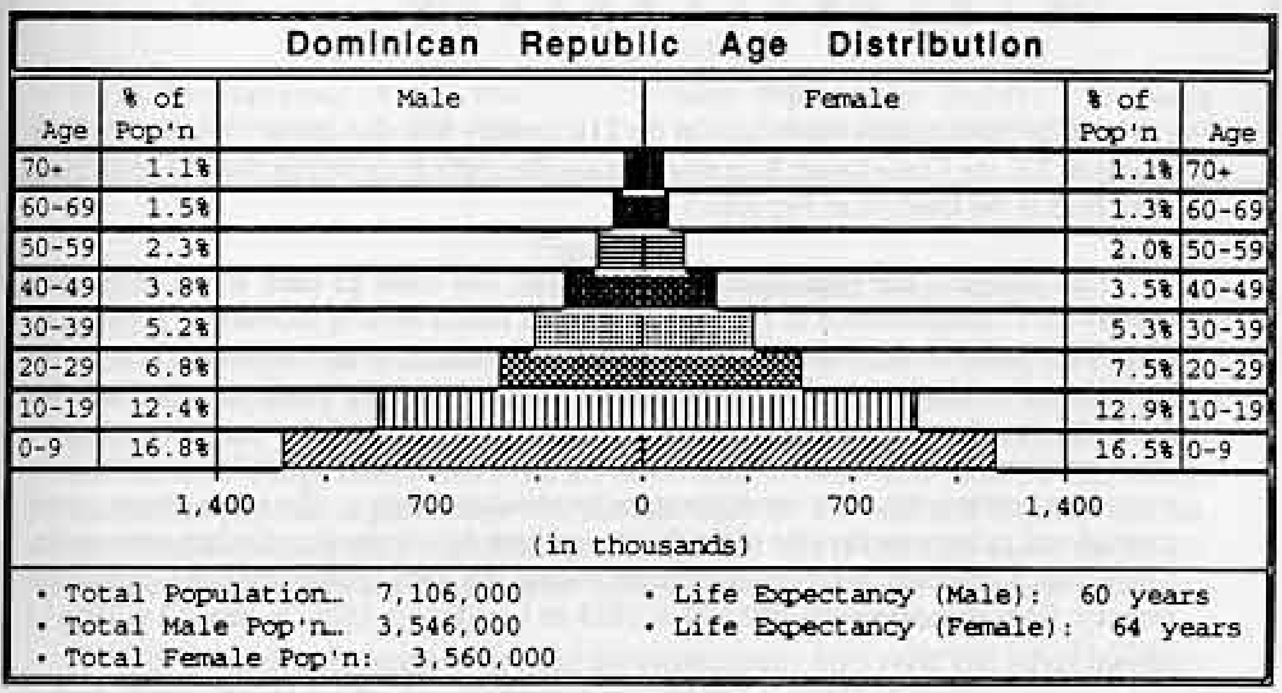
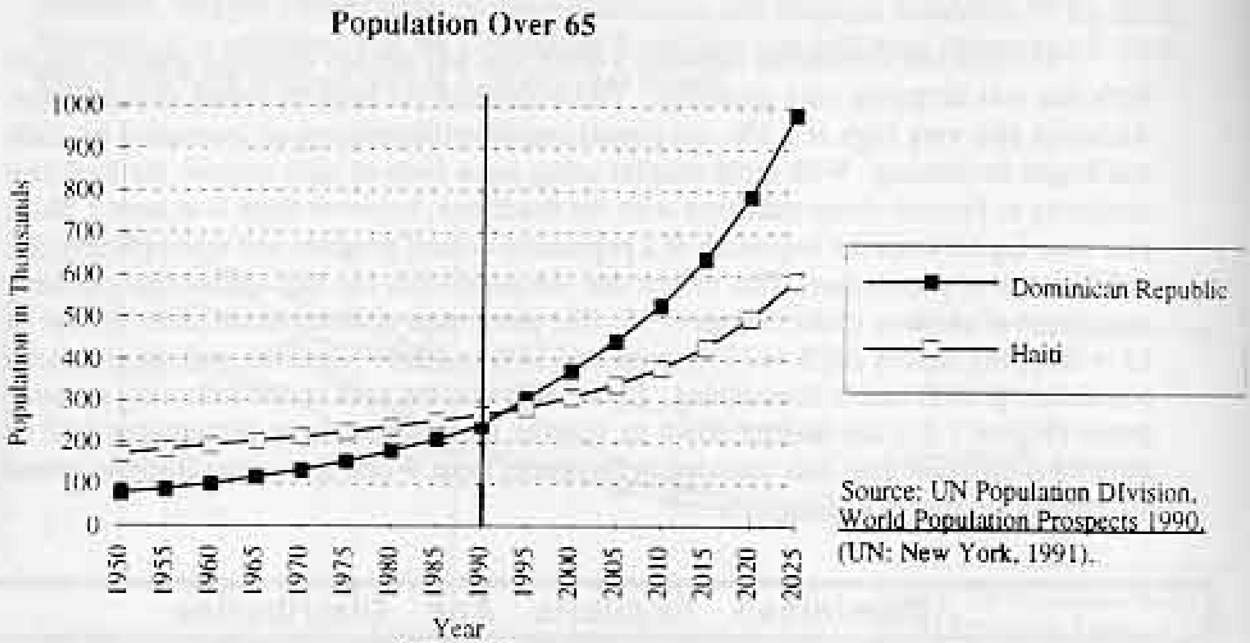


Figure 7.11
Source: PC Globe, MacGlobe, Tempe, Arizona, 1991.

[13] Steer, (1992), p 270.
[14] Hammond, (1992), p 248.

Large numbers of children having been born in the past three to six decades means that the number of senior citizens will grow rapidly in the 21st century putting pressure on social services and health services in the Dominican Republic to care for these citizens.



Source: UN Population Division, World Population Prospects 1990, (UN: New York, 1991).

Figure 7.12

Correspondingly, death rates in the 21st century will also grow. (Please turn back to Figure 7.6, the Crude Death Rate graph, to see the slight projected increase in death rates after 2015 in the Dominican Republic.)

In studying the population trends in Haiti, one must go back to the early 19th century (after independence in 1804) to understand Haiti's need to increase its population. In order to survive, the peasant class of Haiti (the majority class) depended heavily on agricultural productivity. To increase their productivity, the peasants relied on two methods, one short-range and the other long-range. The first was to create cooperative labor practices where peasants who lived in the same community banded together to help each other perform the labor-intensive tasks involved in farming. The other, longer-range method was to increase the size of the family unit and the community through procreation. There was a dramatic population increase during the 19th century into the early 20th century: from approximately 500,000 in 1818 to 1 million in 1860, to about 2 million in 1922.[15]

The population data on Haiti since 1955 appears deceptively steady: a low fertility rate, compared to other Caribbean nations, and a slower rate of total population increase than the Dominican Republic (see Figure 7.1). Haiti's death rate appears to drop very

[15] Alex Dupuy, Haiti in the World Economy: Class, Race, and Underdevelopment Since 1700, (Boulder: Westview Press, 1989), p 108.

steeply after 1955 signaling the beginning stages of the demographic transition. At the same time, however, the graphs seem to indicate that Haiti lags behind the Dominican Republic in the transition by at least 30-40 years and the severe population problem arises in Haiti because the birth rate drops far more slowly than the death rate. Another indication that Haiti lags behind the Dominican Republic in the transition is the difference in age distribution as indicated by Haiti's pyramid:[16]

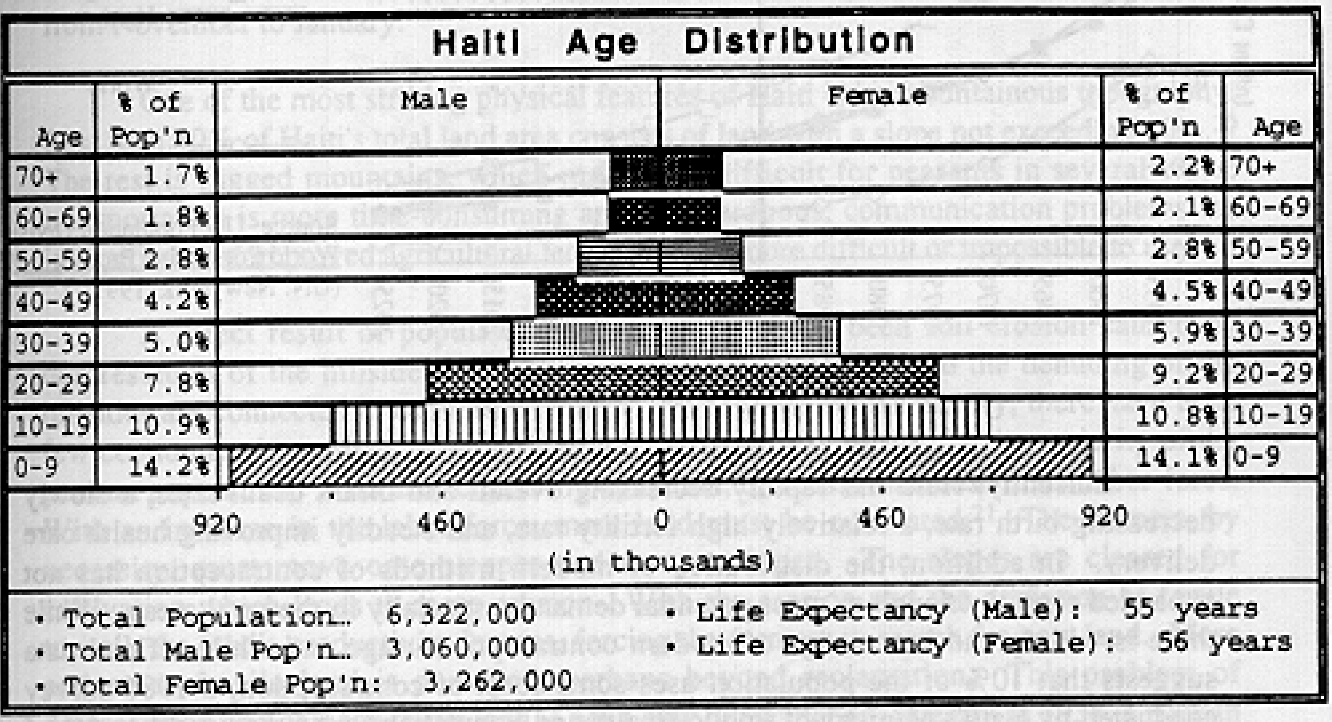


Figure 7.13
Source: PC Globe, MacGlobe, Tempe, Arizona, 1991.

The percentage of children under the age of 19 in Haiti is about 25%; in the Dominican Republic, that percentage is higher at 29.5% (see Dominican Republic's age pyramid, Figure 7.11). I would estimate that in the near future, because Haiti's women continue to have high fertility rates and the infant and child mortality rates are decreasing, Haiti's child population percentage will increase rapidly. I would also estimate that the Dominican Republic's child population percentage will slowly decrease due to the slowly decreasing fertility rates and the increased use of contraceptives in the Dominican Republic.

In the past, poor medical care and the consequently high child and infant mortality rates in Haiti have kept the population increase somewhat steady. Improved primary health care delivery beginning in the 1960s has led to rapid decreases in infant mortality (please see Figure 7.14 on the following page):

[16]PC Globe, 1991.

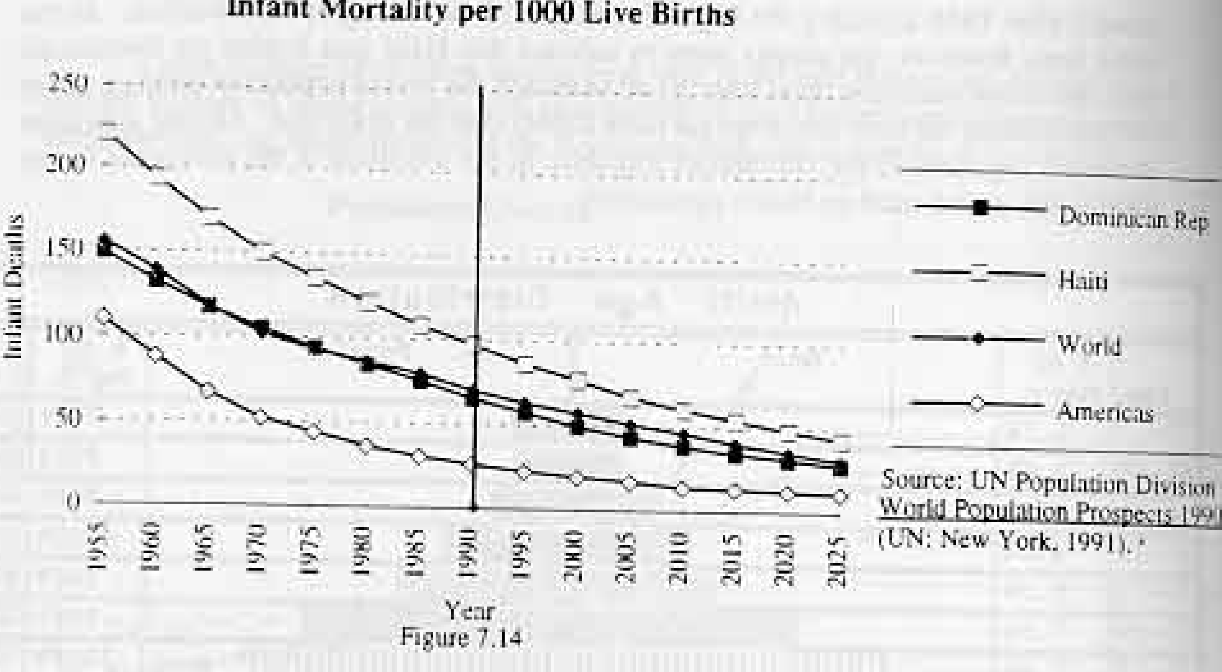


Figure 7.14

Currently, Haiti has rapidly decreasing overall and infant death rates, a slowly decreasing birth rate, a relatively high fertility rate, and steadily improving health care delivery. In addition, the distribution of modern methods of contraception has not expanded rapidly enough to meet potential demand, especially in the rural areas. While there is widespread knowledge of modern contraceptive usage and while official data suggests that 10% of the population uses some form of contraception, a 1986 survey conducted by Haiti's Ministry of Public Health and Population found that less than 5% of married women use contraceptives.[17] Due to the indicators listed above, Haiti's population seems destined to grow rapidly, unlike the Dominican Republic whose population may level off in 50-100 years.

An outline of a population policy, the Ministry of Public Health and Population's "New Orientation," was drawn up in 1982. This plan set as goals for the year 2000 a crude birth rate of 20 per 1,000; a fertility rate of 3 children per woman; a crude death rate of 8 per 1,000; an infant mortality rate of 50 per 1,000; and a life expectancy of 65 years.[18] UN's Population Division estimates for the year 2000 a crude birth rate of 34.1, a fertility rate of 4.6, a crude death rate of 10.8, an infant mortality rate of 77, and a life expectancy of 58.5. While the Ministry's plans may seem ambitious, they will come fairly close to the UN's estimates in one area: in the crude death rate figure. Unfortunately, a lower death rate without a corresponding lower birth rate means more people and higher population.

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[17] A. David Knox, et al, Haiti, Public Expenditure Review, (Washington DC: The World Bank, 1987), p 104.

[18] Ibid.

The Forestry Transition in Haiti

Haiti's land area of 28,000 square kilometers is defined by five mountain ranges which divide the country into three regions: Northern, Central, and Southern. The highest peak, Morne de la Selle, located in the Southern Region, reaches an altitude of 2,715 meters.[19] Because of the mountainous topography, the rainfall patterns tend to be irregular, but the wet season generally lasts from February through May and the dry season from November to January.

One of the most striking physical features of Haiti is its mountainous topography. Less than 30% of Haiti's total land area consists of land with a slope not exceeding 10%.[20] The rest is rugged mountains, which makes life difficult for peasants in several ways: transportation is more time-consuming and more arduous; communication problems are intensified, and improved agricultural techniques are more difficult or impossible to use.

A direct result of population growth in Haiti has been soil erosion caused by deforestation of the hillsides. The mechanisms which have led to the denuding of the hillsides are connected to economic factors. Throughout Haiti's history, there have been few economic alternatives to an agricultural, agrarian way of life for the majority of the peasant population. With an increase in population, there is an increase in the labor-force. With an increase in the labor-force, more land must be cultivated.[21] The farmers, by necessity, must move onto steeper and steeper slopes. The slopes are cleared for cultivation which leads to more erosion. With the erosion and the depletion of fertile topsoil, the land's productivity lessens, forcing the farmers to search for new land. More and more fragile land is damaged, perhaps beyond reclamation. This problem of deforestation and damage to the land is not a new phenomenon: as early as 1938, a Haitian agronomist estimated that 210,000 hectares, or 7.8% of the total land area, that was once cultivated had been abandoned due to loss of productivity.[22]

Haiti's population density is exceptionally high at 2,500 people per 1,000 hectares (the Dominican Republic's population density is 1,500 people per 1,000 hectares).[23] According to estimates from international agencies, only about 29% of the land is suitable for planting. Because of increasing population and increasing demand for land, 43% of the land is cultivated.[24] (This data was collected in 1982; the percentage of cultivated land has most certainly increased in the past decade.) This means that farmers are being forced to cultivate the steeper hillsides. As a result of the severe deforestation, only 1/70, or less than 2%, of the land remains forested. (Please see Figure 7.15 on the next page):

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[19] Haggerty, (1991), p 196.
[20] Lundahl, The Haitian Economy, (1983), p 240.
[21] Charles R. Foster and Albert Valdman, eds., Haiti: Today and Tomorrow, (Lanham, MD: University Press of America, 1984), p 183.
[22] Rotberg, (1971), p 292.
[23] Hammond, (1992), p 264.
[24] Rod Prince, Haiti Family Business, (London: Latin America Bureau, 1985), p 45.

Forest and Woodland Area: Dominican Republic and Haiti

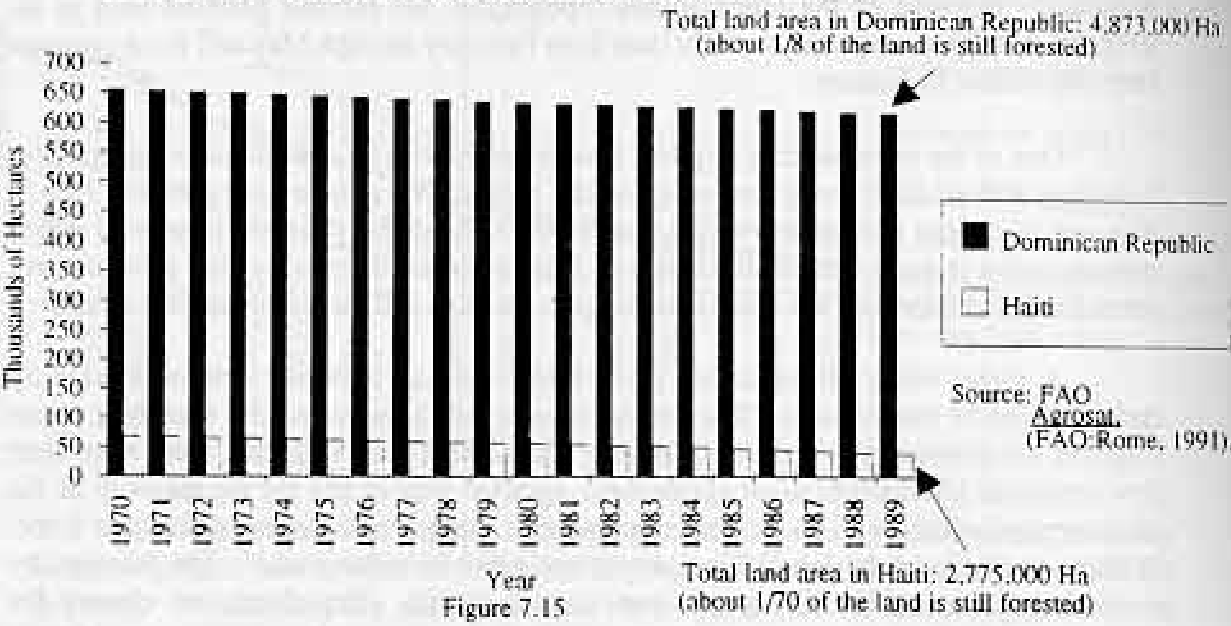
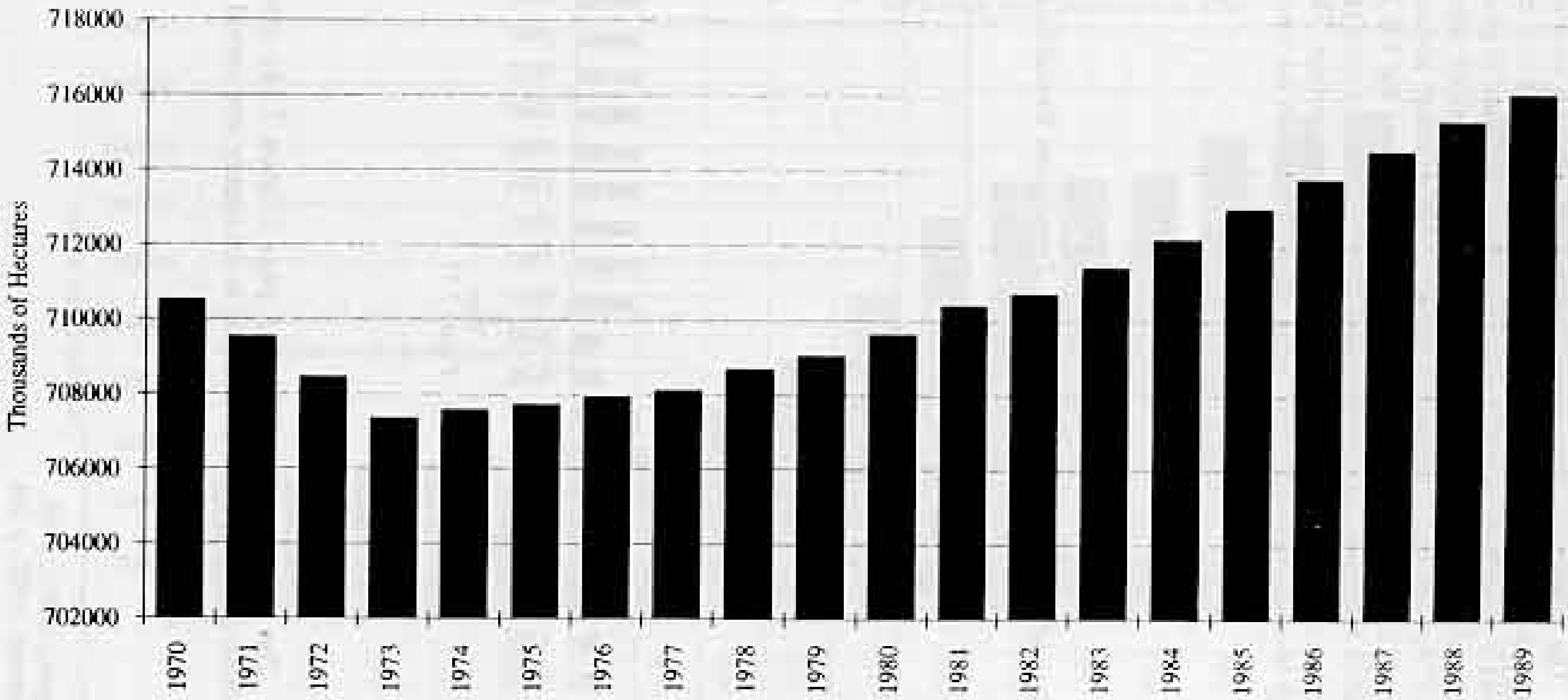


Figure 7.15

As a comparison, please see the graph on the following page depicting forest and woodland cover of the Americas. This graph proves that in some parts of the Americas, reforestation is occurring at a rate higher than deforestation. The graph above proves that this is not the case on the island of Hispaniola.

Forest and Woodland: The Americas



Year

Source: FAO, Agrosat, (FAO: Rome, 1991).

Figure 7.16

The deforestation of Haiti is caused not only by increasing numbers of farmers needing land; it is also caused by an increased population's need for raw materials to construct dwellings, to produce wood for exportation, and to produce charcoal for energy. Haiti has no petroleum resources and little hydroelectricity potential: wood accounts for 75% of the nation's energy consumption (petroleum accounts for 15%, bagasse - sugarcane residue - for 5%, and hydroelectric power for 5%.)[25] With only 4% of the population having access to electricity[26], Haiti's peasants must rely on felling trees for the production of charcoal to use as their primary energy source. The following graph shows the high level of charcoal production in Haiti compared to the Dominican Republic:

Fuelwood and Charcoal Production: Dominican Republic and Haiti

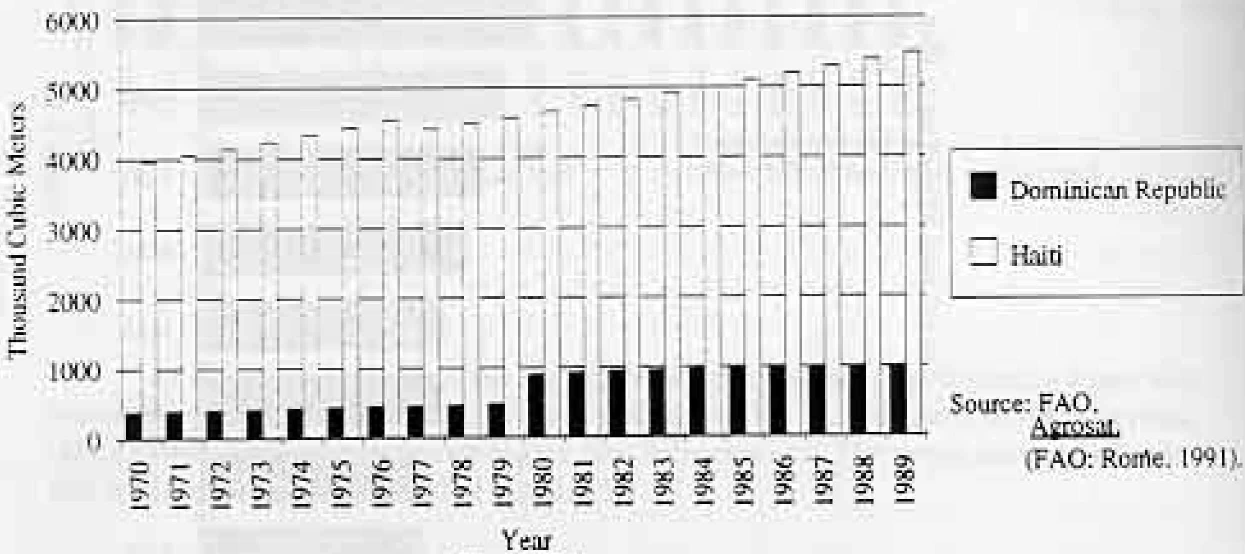


Figure 7.17

The graph on the following page (Figure 7.18) shows the large increase in production of charcoal in the Americas in the twenty-year period between 1970 and 1990.

[25]Haggerty, (1991), p 308.
[26]Hammond, (1992), p 264.

Fuelwood and Charcoal Production: The Americas

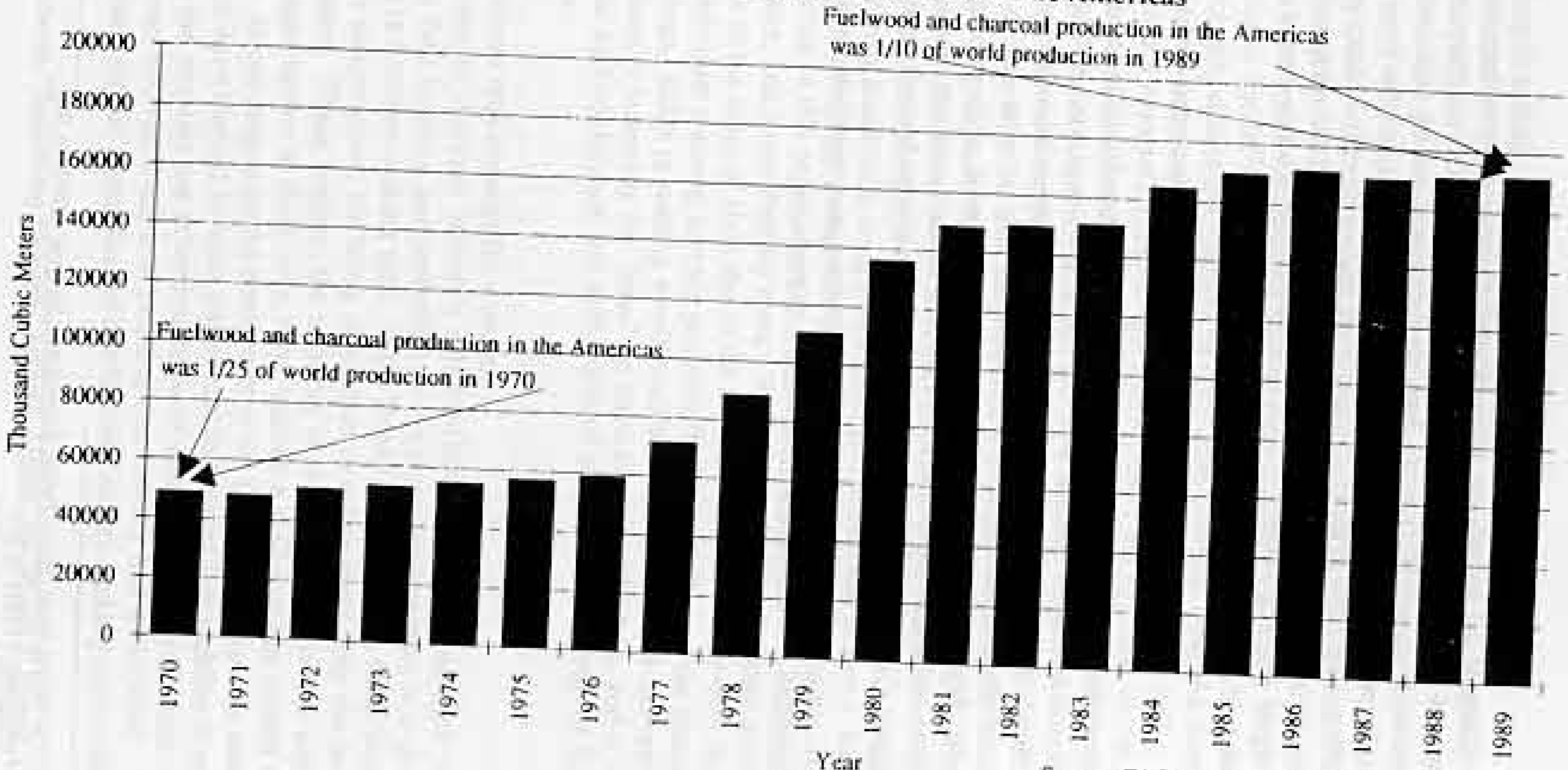


Figure 7.18

Source: FAO. Agrostat. (FAO: Rome, 1991).

Despite the seriousness of Haiti's deforestation and resultant erosion problems, the Ministry of Agriculture, Natural Resources and Rural Development has not developed a replicable or cost-effective mechanism for implementing soil conservation projects. Promising pilot programs are being tried in various localities, but few, if any, are attractive to farmers unless the farmers are subsidized or paid directly to carry out soil conservation works. A replicable strategy integrating soil conservation and reforestation into hillside farming is urgently needed. Such a strategy must provide direct economic benefit to farmers and it must be linked to watershed management.[27]

The main impetus to initiate reforestation projects has come from outside donors such as US AID. In the 1980s, AID's Agroforestry Outreach Program was the country's major reforestation effort. Peasants planted more than 25 million trees during the program, but as many as seven trees were cut for every new tree planted.[28] Data from 1985 indicates that Haiti's deforestation rate was 3.7% while its reforestation rate was .2%. Compare this with the Dominican Republic's deforestation rate of .64% and its reforestation rate of .6%.[29] Figures like this make it apparent why looking at photographs of the frontier between Haiti and the Dominican Republic (such as the one included in a March, 1987 National Geographic story) show lush green on one side and harsh brown on the other. Indeed, it makes one realize that when the original inhabitants gave their country the name Haiti, which means "green island" in the native patois[30], they had no idea of the unfortunate fate that would befall Haiti's lush forests.

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[27]The World Bank, Haiti: Public Expenditure Review, (1987), p 34.

[28]Haggerty, (1991), p 301.

[29]Hammond, (1992), p 286.

[30]Clive Ponting, A Green History of the World, (New York: St. Martin's Press, 1991), p 255.

Conclusions, Implications, and Suggestions for Haiti's Future

The main factor in Haiti's inability to improve conditions for its citizens is the continuing unstable political climate. Moreover, it is possible that one of the reasons for the political instability could be the environmental degradation. It seems to be a catch-22 situation: until a ruler who is popular with the peasant class as well as the elite class is chosen, the misery could continue and escalate, but unless Haiti is reforested, Haiti may never be politically stable. While many of the Haitian people who fled to the United States left because of the brutality of the Duvalier regimes, it is probable that many Haitians have been forced to leave by the impossible task of farming on degraded, nutrient-poor mountainsides. Not only should the Haitians be considered political refugees, they should also be thought of as environmental refugees.[31]

With or without a stable leader, it is vital to the health, the lives, and the well-being of the Haitian people that community development programs be instituted immediately. Among others, the programs I consider perhaps the most important to the future of the Haitian nation are: improved education for women, increased business opportunities for women, birth control education, reforestation efforts, and bi- and multi-lateral agreements with neighboring nations to assist Haiti in its efforts to return to a healthy and productive existence. Short descriptions of my vision of these programs are as follows:

1. Improved education for women, particularly literacy education:

As stated earlier in this paper, there is a direct correlation between literacy levels, urban living situations, and lower fertility rates. While I would not advocate an exodus from the countryside to the cities of Haiti due to the rampant and extreme poverty found in the cities, I would advocate a strong literacy program for women all over the country, in urban and rural settings. Skills in reading would enable women to seek job opportunities outside the home thereby lessening the "need" to have as many children, and it would greatly improve the self-confidence and self-worth of an oppressed group of Haitian citizens - the women.

2. Increased business opportunities for women:

Another avenue to increase women's self-confidence, to improve their living conditions by raising their incomes, and potentially to lower the fertility rates is to provide women with training in a money-making skill. In the Dominican Republic, small business enterprises, women's cooperatives, are being developed in urban areas with the help of Peace Corps Volunteers. These women, the majority of whom were illiterate and had never worked for wages before in their lives, have learned a skill that has earned them much needed money. In one project on the north coast of the Dominican Republic near the tourist resorts, women have learned to make papier mache tropical fish mobiles to sell to the tourists. While the mobiles are labor-intensive to create, the start-up costs were minimal and the women showed a talent in painting that nobody had anticipated. This revelation of the women's artistic talents has led to additional money-making opportunities.

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[31]Jessica Tuchman Mathews, "Redefining Security," Foreign Affairs, Vol 68, No 2, Spring, 1989, p 168.

Through this project, the women have been given the skills to earn money, the self-confidence that comes from earning your own wages, and the comraderie of other women in similar circumstances. Projects such as this should be undertaken in Haiti after appropriate money-making ventures have been located. (For the time being, because tourism is not a big business in Haiti due to political upheavals, a project similar to the one in the Dominican Republic would not be successful, but other opportunities must exist.)

3. Birth Control Education:

As part of the literacy and small business enterprise projects described above, women should be given the opportunity to learn about methods of birth control. While the main target of these programs is women, the husbands should be invited for the birth control as well for some of the sessions. Men's cooperation will be vital in the effort to lower birth rates. The birth control education program should train local women as practitioners in the use of the different methods so that they can visit women and families in their homes and advise them on contraceptives in private. A large scale advertising effort using pictures and billboards of happy-looking smaller families and using radio programs should be launched to get the message out to the general public that having smaller families is better and will lead to better living conditions. There must be a monitoring capacity built into the program to determine its effectiveness. If, after 10 years or so, it does not appear to be working (that is, fertility rates are not lowering,) a more drastic form of fertility control must be enforced in order to keep a population explosion from dessimating Haiti.

4. Reforestation Efforts:

As described in this paper, previous reforestation efforts in Haiti have failed. Any future efforts should include the training of men, women, and children on agroforestry techniques and the massive planting of nitrogen fixing, fast-growing trees, such as the neem tree. Because of the destruction of the soil, it will be impossible to grow the original species of trees on Haiti. In the place of those species, besides the neem tree, other hardy tree and shrub species should be planted and a drought resistance ground cover should be introduced to keep the hillsides from eroding further. The fertile topsoil in Haiti has eroded away leaving nutrient-poor soil in which to grow trees and crops. The neem tree, whose roots slough off nodules of nitrogen into the soil under the surface, will start to fertilize the soil naturally. The fast-growing properties of the neem tree will enable peasants to cut the tree after just two to three years of growth. In the time that it will take to grow the trees and for a period of time after the beginning of harvesting, peasants will need to be subsidized with an alternative source of energy besides charcoal.

As with the birth control efforts, a wide-reaching campaign to educate the general public on the hazards of deforestation should be launched. School children should be taught about the worth of trees and forests in school and efforts to reach school-leavers and the community in general should be made. Until wide-scale education and reforestation efforts are begun and until a donor agency has the perseverance and monetary means to continue this project (which will most likely take many years of hard work), the devastating deforestation situation in Haiti will continue.

5. Role of the United States and other Nations:

First and foremost, the US must immediately cease any embargo on goods to Haiti. While the embargo described in this paper was meant to show Haiti that the US will not tolerate political atrocities, it only served to make life more difficult for the peasants in Haiti. Secondly, where possible, the US and other nations should initiate bi- and multi-lateral agreements promising funding and trained personnel to work with the Haitian people to make their living situations better. It is important that any workers going to Haiti must learn the cultural norms and the language and they must have some altruistic sentiments. In past efforts to help Haiti and other needy nations, the US (mainly government agencies) has often sent culturally insensitive people who went to these countries more to make money than to help the people. Not only have projects in the past introduced technology that is inappropriate to the locale, they have also gone about completing the projects in such a way that the local people feel no ownership and no reason to continue the project after the donor agency has gone. The Haitian people must be a part of the planning process of the projects I have suggested above and they must be major players throughout the life of the projects if the projects are to be successful.

♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦♦

> All farmers know that to grow crops you have to have trees. The roots of trees retain topsoil, the nutrient-filled layer of dirt that nourishes whatever you plant in it. Trees keep that good earth in place. And trees keep the cycle of rainfall going. They absorb the rain from the skies, and then the sun heats it back out of them, creating the humidity that again forms the clouds that will bring the rain once more, and water for the seed. Haitian peasants know this, too. *Si oui gen youn sous k ap ba-w dlo, ou pa koupe pyebwa kote-l.* If you have a stream that gives you water, the proverb says, you don't cut the trees around it. Peasants use this proverb all the time; it means "Don't bite the hand that feeds you."[32]

Were it not for a possible exponential increase in population and a tentative and precarious political system, I believe the majority of farmers in Haiti would try to adhere to the proverb written above. If the political situation does not improve and suggestions similar to the ones described on the previous pages are not undertaken soon, I feel that Haiti will slip further and further into the abyss of severe poverty and misery and improved standards of living will be impossible to attain.

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[32] Amy Wilenz, The Rainy Season, (New York: Simon and Schuster, 1989), p 244.

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This paper was written in memory of my father, Douglas MacFarlane, a scholar and an aficionado of all things Haitian.

Chapter 8: Gary Stahl

TRANSITION TO PEACE: ENVIRONMENTAL IMPACT OF DOWNSIZING THE UNITED STATES NUCLEAR WEAPONS COMPLEX

I. Transitions in the U.S. Nuclear Weapons Complex

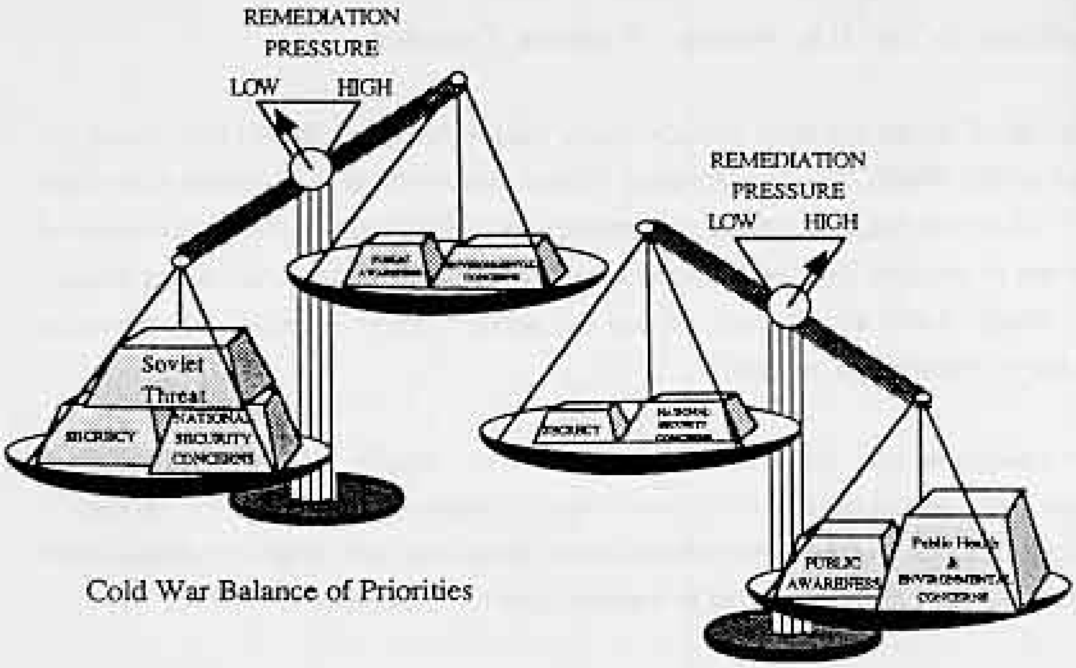
The United States has been manufacturing nuclear weapons since 1945. Since the early years of the World War II Manhattan Project, nearly 30,000 warheads have been produced.[1] There are fourteen primary plants and processing facilities that have developed over the years to produce the materials and components required for constructing nuclear weapons. Much of this activity was carried out under extreme secrecy and with scant regard for the environmental impacts.

The environmental impacts have been severe. Nearly all the facilities have documented some degree of soil and ground water contamination. Except for the sites in arid locations all have contaminated surface water. Most sites have large accumulations of hazardous or radioactive wastes stored in various types of containers.

The agencies that oversaw the production activities were completely "self-policing". There was always the imperative of "national security" and very little environmental concern. In the words of former department of Energy (DoE) Secretary James Watkins; ". . . the waste management and environmental problems have resulted from a 40 year culture, cloaked in secrecy and imbued with a dedication to the production of nuclear weapons without a real sensitivity for protecting the environment."[2]

The transition to peace has brought a change in pressure for remediation of the environmental impacts of nuclear arms production. During most of the cold war, national security concerns outweighed concerns for environmental concerns and even public health. Public awareness of the extent of the environmental impacts was limited by the high level of secrecy that was assigned to nuclear weapons production. These forces combined to keep remediation pressures low. Now, with the end of the cold war and the evaporation of the Soviet threat, the national security concerns and secrecy have been reduced.

People have long feared the use of nuclear weapons. There is now a desire to reduce nuclear weapons stockpiles and ban future testing. With reduced secrecy, public awareness has grown, and with it a growing concern over the environmental impacts of nuclear weapons production and the public health implications. Because of this, the remediation pressures are much greater. Figure 8-1 depicts this transition.



Cold War Balance of Priorities

Post-Cold War Balance of Priorities

Figure 8-1: Changing Pressures on the Nuclear Weapons Complex

The Nuclear Weapons Chain

The key ingredient to any nuclear weapon is a fissionable material. Fission occurs when radioactive material is brought together in a high enough concentration and in sufficient mass to produce a nuclear chain reaction. The path for obtaining this material is essentially the same for nuclear weapons or for nuclear power generation. The "Nuclear Weapons Chain" is outlined in figure 8-2.

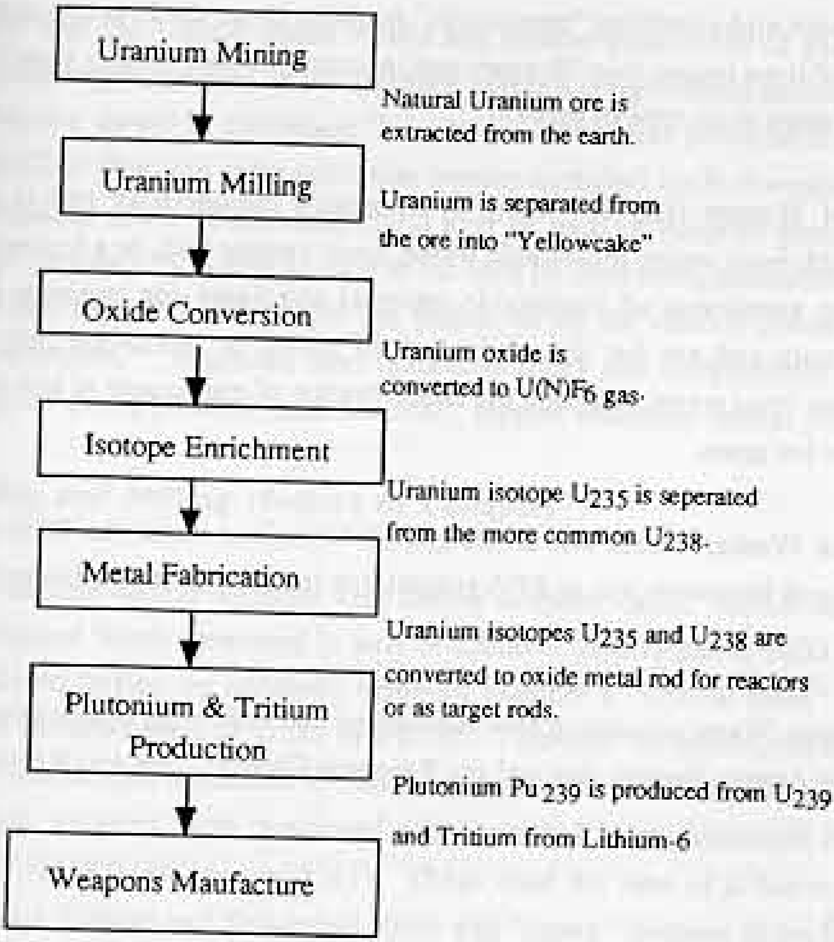


Figure 8-2: Nuclear Weapons Chain

Wastes Along the Way

Each stage of the nuclear weapons chain produces wastes. The specific types of wastes produced at each stage will be discussed in greater detail later. There currently are five classifications of wastes produced at by the nuclear weapons complex:[3]

1. **High Level Wastes (HLW)** The highly radioactive waste material that results from the reprocessing of spent nuclear fuel, including liquid waste produced directly in reprocessing and any solid waste derived from the liquid that contains a combination of transuranic waste and fission waste products in concentrations requiring permanent isolation.

2. **Transuranic (TRU) Waste:** Waste, without regard to source or form, that is

contaminated with alpha-emitting "transuranic" nuclides (from the Uranium decay series) with half lives longer than 20 years and in concentrations greater than 100 nanocuries per gram at the time of assay.

3. **Low Level Wastes (LLW)**: Waste that contains radioactivity and is not classified as high-level waste, transuranic waste, spent nuclear fuel, or a byproduct material. Test specimens of fissionable material irradiated for research and development only and not for the production of power or plutonium may be classified as low level waste, provided the concentration of transuranic is less than 100 nanocuries per gram.

4. **Hazardous Waste:** Waste that is designated hazardous under the Resource Conservation and Recovery Act or EPA regulations (such as paints, solvents and acids).

5. **Mixed Waste**: Waste containing both radioactive and hazardous components as defined by the Atomic Energy Act and the Resource Conservation and Recovery Act.

Wastes in the End

Plutonium (Pu239)[4] was once a primary product of the nuclear weapons complex. Plutonium does not occur in nature. It may be produced by bombarding U238 with neutrons or as a byproduct of fission reactions by U235. In the early years of nuclear weapons production tremendous effort was expended to produce plutonium. Commercial nuclear power plants, using U235 fission began to proliferate. The U.S. Navy also began to employ nuclear power plants in submarines and warships. All of these reactors produce plutonium as a by product. While there are possible applications for plutonium in electric power generation, no such reactors have ever been put to commercial or military use. The plutonium is essentially a highly radioactive, extremely toxic, and long lived waste product (its half life is 24,400 years).[5]

The DoE recognized that there was no longer any need to make any special effort to produce plutonium but did not officially cease production until 1988 (and then only because of safety consideration at the production plants). In 1989 the Soviet Union announced that it would cease Plutonium production by 1991.[6] In January 1992 the Bush administration announced that the United States would not resume production of plutonium.[7] DoE Secretary Harrington testified on the stockpile before a congressional subcommittee in 1988 saying; "we are awash in plutonium."[8] The overshoot was predictable even before the end of the Cold War and arms reduction treaties curtailed nuclear weapons production. More plutonium was available than could ever be used in weapons production. When looking for reasons why it took so long to cut back on plutonium production it is important to realize that over 100,000 people are employed by the various plants in the nuclear weapons complex.[9] Scattered over numerous states and congressiona districts, these plants enjoyed strong political, (and financial), support within the federal government.

II. Mining and Milling (Sectors in Collapse)

The earliest nuclear weapons were fission weapons, called "atomic bombs". Fission bombs produced blasts measured in tens of kilotons (equivalent to 1000 tons of TNT). They produced fission by suddenly bringing together a "critical mass" of fissionable radioactive material such as U235 or Pu239. This may be accomplished by bringing together to sub-critical masses or by compressing a sufficient mass into a critical density. Later, fusion weapons were developed which yielded blasts measured in hundreds of "megatons" (1,000,000 tons of TNT). These used the heat of a fission weapon as a trigger to fuse Tritium and Deuterium (rare and "heavy" isotopes of hydrogen). These were called "thermonuclear bombs", hydrogen bombs, or simply "H-Bombs."[10]

The key raw material to both types of weapon was Uranium. The nuclear weapons chain begins with Uranium ore. Figure 8-3 illustrates the mining and milling process.

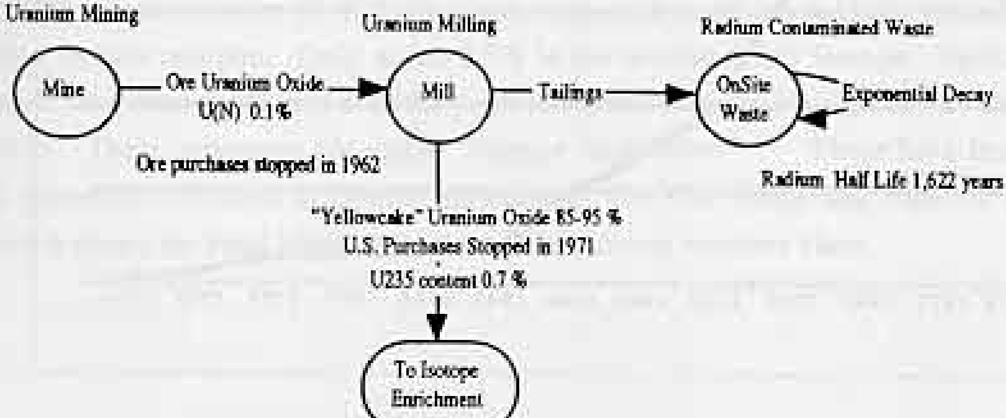


Figure 8-3: Mining and Milling

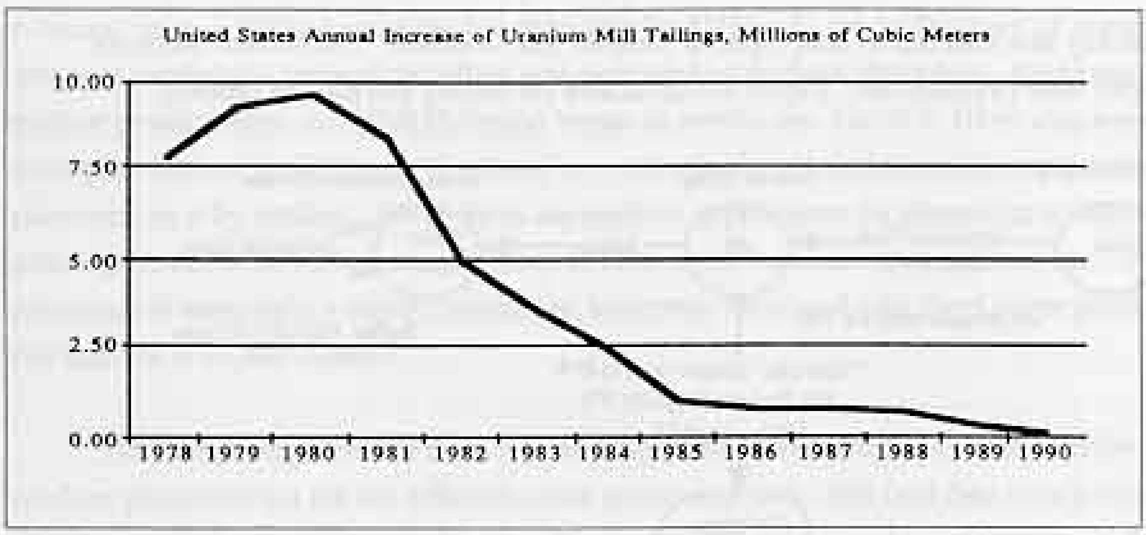
Mining

In 1948 the Atomic Energy Commission initiated a program of incentives to spur exploration and mining of Uranium. The incentives included price guarantees and bonuses. The program was very successful. By 1962 the U.S. government had sufficient Uranium stockpiles on hand and stopped all purchase of Uranium ore.[11] Since the ore occurs naturally, it is not classified as a hazardous material. Uranium ore typically contains 1-2 % Uranium. Even at such low concentrations, it is radioactive. The natural Uranium is separated from the ore in a process called "milling.

Milling

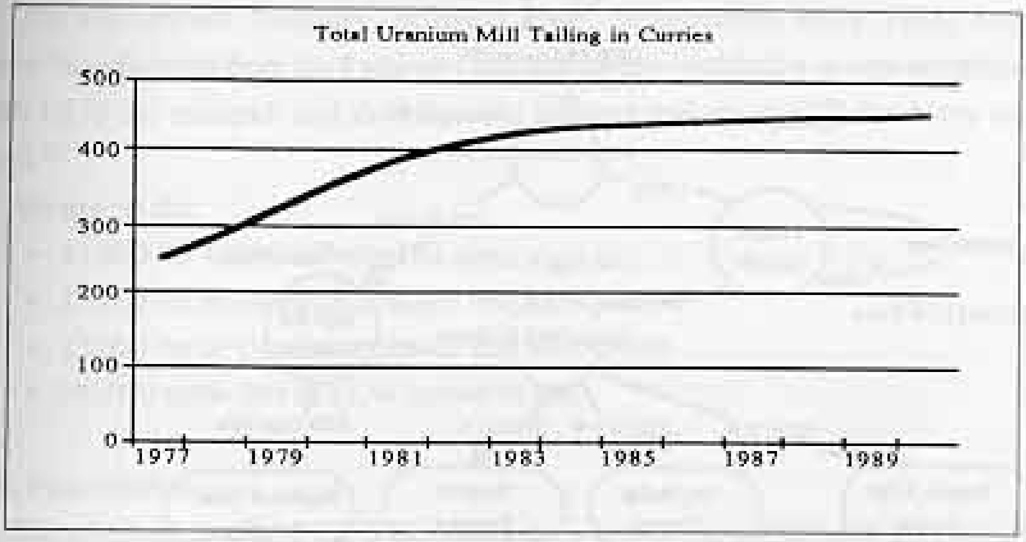
Milling is a mechanical and chemical process. The ore is crushed, ground into powder and then leached to dissolve the uranium which is then precipitated out of solution.[12] Milling produces a material called "Yellow Cake" that contains 85-95% Uranium Oxide. It also produces milling wastes called "tailings". The tailings contain Radium which is radioactive.

The United States government stopped purchasing yellowcake in 1971.[13] Uranium mill tailings have continued to accumulate at a very slow rate. Uranium mining in the United States has virtually ceased. Milling is also declining rapidly as the few remaining mills work off the back log of Uranium ore. A graph of annual Uranium mill tailings since 1977 clearly shows an industry in collapse.[14]



Graph 8-1: Uranium Mill Tailings 1977 to 1990

The total radioactivity from the accumulated tailings is on the order of 450 curies. Considering the fact that the tailings are largely confined to the mill sites they are not a great threat to the environment. Radium decays into Radon gas which dissapates quickly. Graph 8-2 shows the accumulating radioactivity (derived from the cumulative data used to produce chart 1 multiplied by of $4.165x10^{-6}$ curries per cubic meter.[15]



Graph 8-2: Radioactivity of Uranium Mill Tailings

Once milled, yellowcake moves on to the next stage in the nuclear weapons chain, "Feed Materials Production".

III. Feed Materials Production (Sectors in Decline)

Yellowcake contains 85-95% Uranium oxide. About 99.3% is U238 which cannot sustain a fission reaction. Only about 0.7% is the desired U235 isotope. Specialized processes have been developed over the years to separate the two isotopes and concentrate the U235. These processes are called "Isotope Enrichment".[16] There have been two plants primarily dedicated to isotope enrichment; The Oak Ridge and Paducah plants. Figure 8-4 shows the Feed Materials section of the nuclear weapons chain.

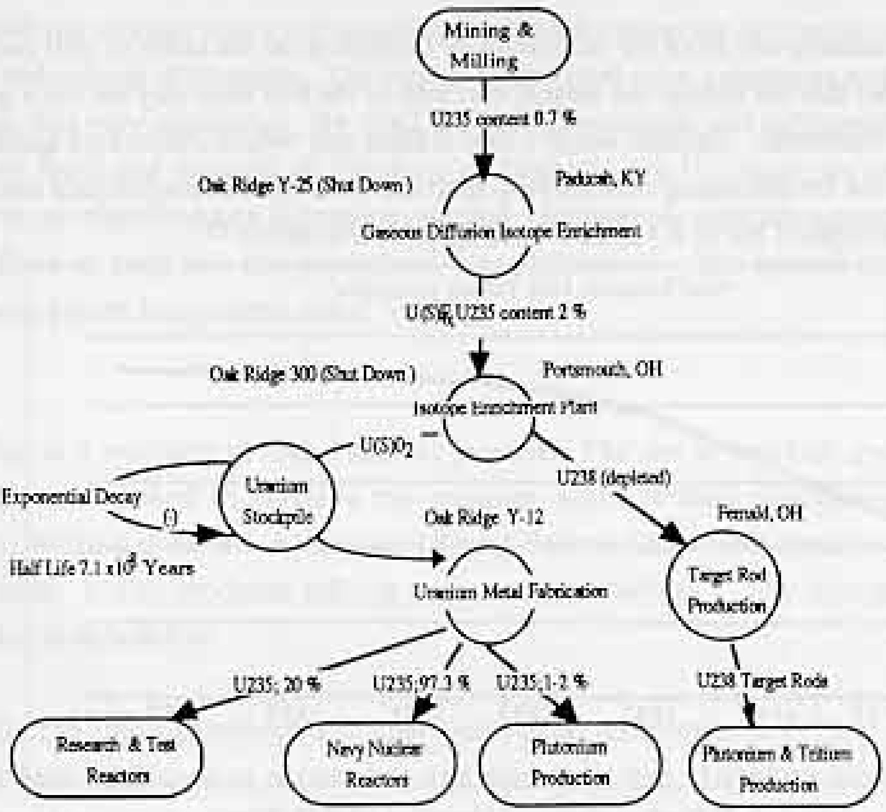


Figure 8-4: Feed Materials Chain

The Oak Ridge Plant, Oak Ridge Reservation, TN

The Oak Ridge Gaseous Diffusion plant produced the Uranium U235 for the first atomic bomb. It began operations in 1945 and was shut down in 1985. It now serves as a waste dump for the Y-12 plant, also located on the Oak Ridge Reservation.[17]

Wastes on site:

- 2.7 million cubic feet of LLW buried
- 36,000 lbs of Uranium U238 released into local water table.
- 23,000 lbs of Uranium U238 released into the air.
- 124,000 lbs of Uranium in holding ponds.[18]

The Paducah Plant, Paducah, KY

The Paducah Gaseous Diffusion Plant began operations in 1952 and is still in operation, although at reduced capacity. The plant converts Uranium Oxide into Uranium Hexaflouride and then separates the U235 isotope to a concentration of 2%.[19]

Wastes on site:

- 270,000 cubic feet of LLW buried
- 7 million lbs of Uranium U238 buried on site.
- 130,000 lbs of Uranium U238 released into the air.
- 60,000 lbs of Uranium into local creeks.[20]

Portsmouth Plant, Piketon, OH

The Portsmouth Gaseous Diffusion Plant, in operation since 1954, accepted Uranium Hexaflouride from the Paducah Plant and further enriched it to concentrations of 4 to 20% U235 for research and development reactors and up to 97% for Navy nuclear reactors.[21]

Wastes on site:

- 11,000 lbs Uranium buried on site
- 17,000 lbs of Uranium dumped into local streams
- 23,000 lbs of Uranium released into atmosphere
- 350,000 cubic feet of LLW buried on site

Metal Fabrication

The enriched Uranium U235 Hexaflouride is further concentrated to between 20 and 97.3% and converted into metal pellets for use in reactors. These processes are carried out at the Y-12 plant. Uranium U238 is collected and turned into metal target rods which can later be converted into plutonium by bombarding them with neutrons.

The Oak Ridge Y-12 Plant, Oak Ridge, TN

The Oak Ridge Y-12 Plant produces uranium metal for use in Navy Nuclear reactors and in the Hanford plutonium production reactor. The Y-12 also has a chemical processing plant for recovering Uranium from expended fuel assemblies.[22]

Wastes on site:

- 50 million lbs of Uranium within 3.9 cubic feet of LLW.
- Local creeks contaminated with Uranium.[23]

Fernald Plant, Fernald, OH

The Fernald Plant processed uranium into metal from 1951 to 1985.[24] Using U328 from the Portsmouth Plant, it produced U238 target rods for use in the Savannah River Plant.[25] The plant is now inactive due to lack of demand for its materials.

Wastes on site:

- 50 million lbs on Uranium within 3.9 cubic feet of LLW.
- 520,000 lbs of Uranium released into the air.
- 12.7 million lbs of Uranium in settling ponds
- 167,000 lbs of Uranium released in Miami River.[26]
- Local creeks contaminated with Uranium.

The feed materials are passed along the nuclear weapons chain to the plants which produce "weapons grade" materials, the Hanford and Savannah River plants.

IV. Weapons Material Manufacture and Recycling

The principle nuclear weapons materials are Plutonium and Tritium. As with feed materials these materials are no longer in production. Figure 8-5 illustrates the weapons material manufacture and recycling section of the nuclear weapons chain.

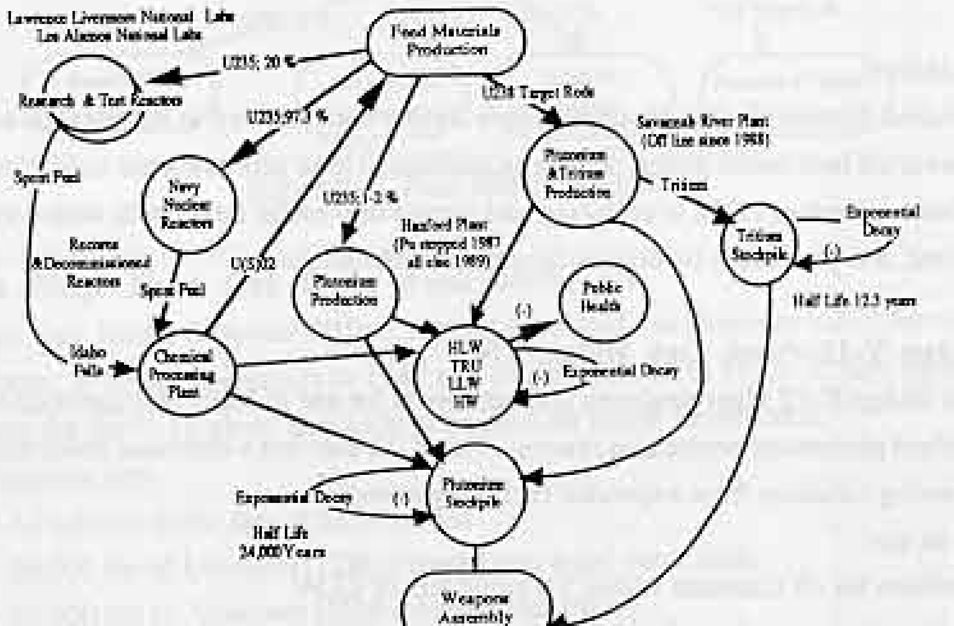


Figure 8-5: Weapons Material Production

Hanford Plant, Richland, WA

The Hanford Plant has been in operation since 1943. Its primary function was Plutonium and Uranium Extraction. Plutonium was produced in a reactor. Plutonium and Uranium were extracted in a chemical plant known by the acronym "PUREX". Its product was weapons grade plutonium and an enormous amount of HLW, TRU and mixed wastes.[27] The Plutonium production reactor was shut down in 1987 and the PUREX plant in 1989.[28]

The original Plutonium production reactors at Hanford had no secondary cooling systems. The first began operations in 1944. By 1954 there were nine reactors. They were cooled with water drawn directly from the Columbus River and returned directly to it. This resulted in a discharge of approximately 1000 curies of radioactive cooling water per day from 1954 to 1964, directly into the river.[29]

Wastes on site:

- 210 billion gallons of LLW
- 8 million cubic feet of HLW slurry is underground tanks (5000,000 gallons have leaked)
- 18 million cubic feet of solid LLW buried
- 3.9 million cubic feet of Plutonium contaminated soil buried
- ground water contaminated with Tritium and Strontium plume in contact with Columbia River[30]

Savannah River Plant, Aiken, SC

The Savannah River Plant began operations in 1952 producing Plutonium and Tritium. Tritium is a heavy isotope of Hydrogen which is fused in a thermonuclear warhead detonation. Plutonium was produced by bombarding U238 with neutrons. Likewise Tritium was produced by bombarding Lithium-6 with neutrons.[31] Savannah River contains three reactors and two chemical processing plants. All have been shut down since 1988.[32]

Wastes on site:

- 18 million cubic feet of LLW
- 4.5 million cubic feet of HLW in 51 underground storage tanks
- 190,000 of Plutonium contaminated wastes
- 30 million gallon of LLW effluent in seepage basins
- Severe ground water contamination.

R&D and Naval Reactors and Materials Recycling

DoE and the military operate reactors for research and development, for training and as naval power plants. Nuclear materials are recycled from operational reactors.

Lawrence Livermore National Laboratories (LLNL), Livermore, CA

The LLNL operates a research and development reactor. Activities at LLNL include design and development of nuclear weapons and directed energy weapons.

Wastes on site:

- 320,000 cubic feet of LLW
- 81,000 lbs of Uranium buried on site
- Tritium leaking into ground water[33]

Los Alamos National Laboratories (LANL), Albuquerque, NM

Like the LLNL, LANL is a design center for nuclear weapons and directed energy research.

Wastes on site:

- 6.7 million cubic feet of LLW buried on site
- 5000,000 cubic feet of plutonium contaminated waste is buried on site

Naval Reactors

The U.S. Navy operates nearly 200 nuclear power plants. Most of them serve as propulsion plants for submarines and surface ships. Each power plant produces plutonium as a byproduct. Plutonium and Uranium from naval reactors are recycled though the chemical processing plant at Idaho Falls.

Idaho National Engineering Lab, Idaho Falls,ID

The Idaho National Engineering Lab (INEL) reprocesses depleted fuel rods from naval nuclear reactors, when they are refueled, recovering U235 for reuse. The INEL also recycles material from retired reactors.[34]

On site wastes:

- 16 billion gallons of LLW released into ground water. (70,000 curies)
- 350,000 cubic feet of HLW ((61 million curies)
- 5 million cubic feet of LLW
- 2 million cubic feet of plutonium contaminated soil (TRU)
- 2.2 million cubic feet of plutonium contaminated soil (TRU) from Rocky Flats[35]

V. Weapons Manufacture & Test

Weapons materials from the Hanford and Savannah River plants and other components from at least four other plants are brought together for assembly into complete nuclear weapons. Nuclear weapons materials from disassembled weapons are recycled back into the weapons material stockpile. Figure 8-6 illustrates the weapons assembly section of the nuclear weapons chain.

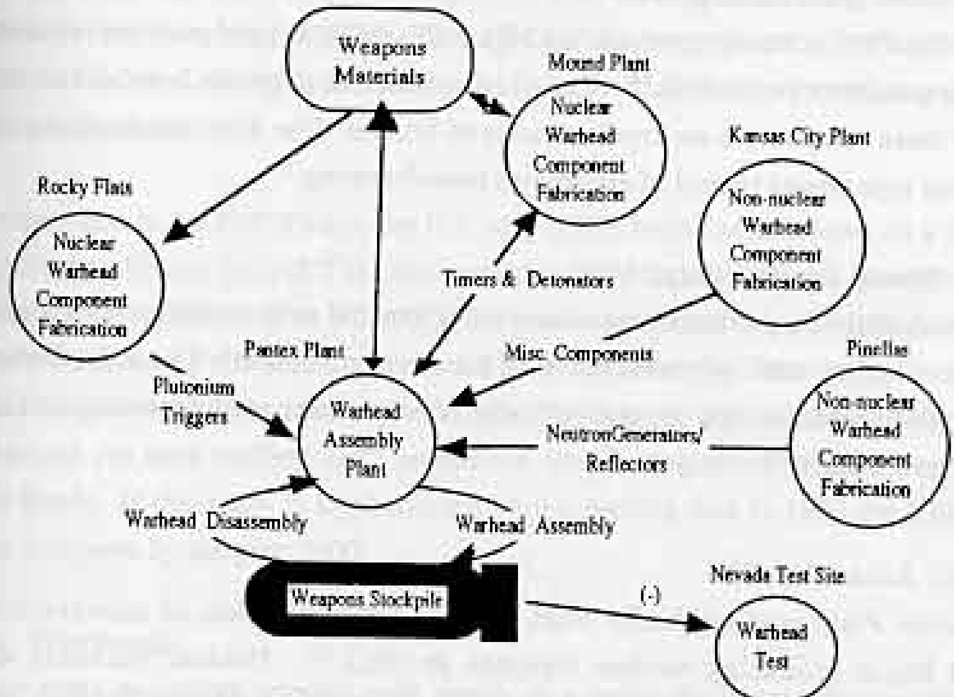


Figure 8-6: Weapons Assembly

Rocky Flats Plant, Golden, CO

Rock Flats produces Plutonium triggers for thermonuclear warheads using plutonium from either Hanford or Savannah River or recycled from old warheads. It has been operating since 1952. There was a fire at the plant in 1988 which resulted in a release of a sizable amount of Plutonium and Beryllium into the local air, soil and ground water. Most other on site wastes are classified as hazardous wastes.[36]

Mound Plant, Miamisburg, OH

The Mound Plant has been in operation since 1952 producing detonators for nuclear weapons, recovering Tritium from old weapons and constructing plutonium heat generators for satellites. Although there is no on site storage, there has been some Tritium and Plutonium contamination to local soil and water.[37]

Non-nuclear Components

Nuclear weapons also require some non-nuclear components. Among these are extremely accurate timing devices and neutron reflectors.

Pinellas Plant, St. Petersburg, FL

The Pinellas Plant primarily produces the high precision timers and switches required for for initiating nuclear explosions.[38] The only radioactive materials involved in the manufacture of these components are small amounts of Tritium. The main wastes produced are the hazardous type wastes typical of electronics manufacturing.[39]

Kansas City Plant, Kansas City, MO

The Kansas City Plant primarily produces reflectors and neutron sources.[40] Small amounts of Uranium are used in manufacture of the neutron sources. The main wastes produced are the hazardous type wastes typically of electronics manufacturing (acids, solvents and heavy metals).[41]

Pantex Plant, Amarillo, TX

The Pantex Plant was originally built in 1942 for production of conventional explosive. It began producing nuclear weapons in 1952.[42] Nuclear warheads are assembled at Pantex from components produced at the Rocky Flats, Mound, Pinellas and Kansas City Plants.

Nevada Test Site

The Nevada Test Site covers over 1,350 square miles of desert. Weapons are assembled and tested on site. Since testing began here in 1951 there have been 100 atmospheric tests and more than 600 underground tests. The last test was conducted in 1988. The tests have released huge quantities of radioactivity into the the soil and ground water. Wastes from other sites have also been stored here.

Wastes on site:

- 8 million cubic feet of LLW
- 3.8 million lbs of buried Uranium [43]

VI. Arms Reduction Impacts

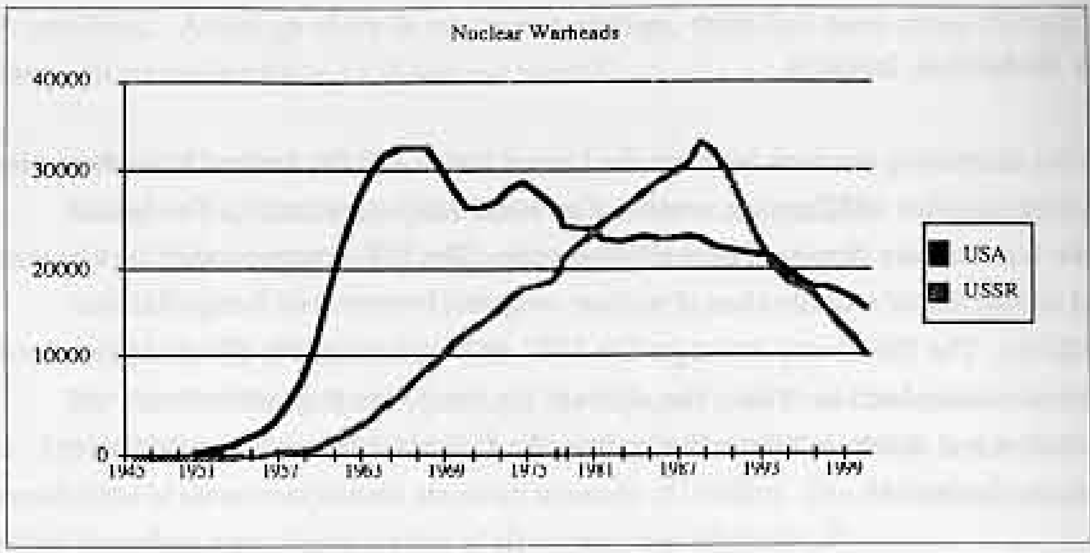
With the decreasing tensions between the United States and the Soviet Union that occurred in the mid to late 1980's came a series of arms reduction agreements. The first of these was the Intermediate Nuclear Force (INF) Treaty. The INF Treaty resulted in the removal and destruction of a whole class of nuclear weapons, Intermediate Range Ballistic Missiles (IRBMs). The INF Treaty was signed in 1987 and the dismantling of the missiles and warheads was completed in 1989. The effect of the treaty was to eliminate over one thousand missiles, and nearly 3,000 warheads, from the U.S. inventory and a comparable number from the Soviet's.[44]

Subsequent to the INF Treaty, the U.S. and USSR began negotiations on a Strategic Arms Reduction Treaty (START-II) that would reduce the numbers of Intercontinental Ballistic Missiles (ICBMs). The START Treaty was completed July 1991, and signed by President's Bush and Yeltsin in June. It calls for drastic reductions in both countries' weapons stockpile over a seven year period from the date of ratification.[45] Although the Treaty has not yet been ratified, both parties are already beginning to build down to the specified levels. If the treaty is implemented with a starting date in 1993 the build down should be complete by the year 2000.

Retiring Warheads

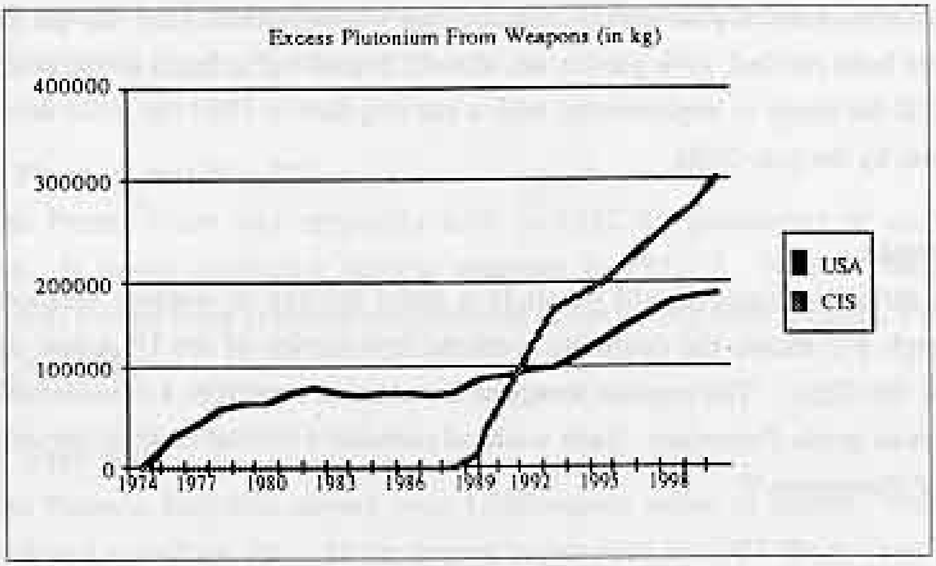
The arms reduction treaties will result in a rapid decline in nuclear weapons inventories. Graph 8-3 shows the declining warhead inventories of the USA and the USSR, (and now the CIS). The nuclear weapons inventories represent a considerable stockpile of weapons grade Plutonium. Each warhead contains a critical mass of between 13.2 and 11 kg of Plutonium.[46]

The material from the dismantled warheads will pose a significant radiological storage problem. If the peak number of warheads is used to estimate the peak amount of Plutonium contained in the weapons stockpile the amount of excess Plutonium, (which will have to be stored) can be estimated by multiplying the number of retired warheads (from graph 8-3) by the critical mass. The results are shown in graph 8-4.



Graph 8-3: USA and USSR Nuclear Weapons Stockpiles

Derived from: U.S. , Soviet Nuclear Weapons Stockpile: 1945-1989, (Bulletin of the Atomic Scientists, November 1989 p. 53. Post 1989 estimates based on; "USA and Soviets Agree to START Cuts", Jane's Defense Weekly, 27 July 1991, p. 131



Graph 8-4: Excess Plutonium USA and USSR

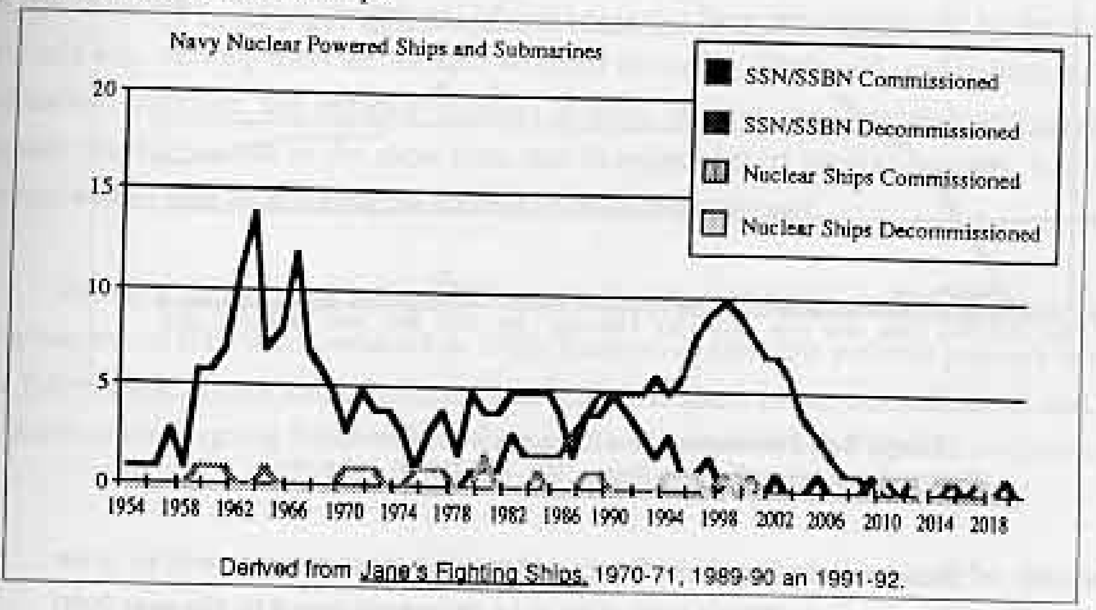
Based on Graph 8-3. Warhead decline from peak stockpile times 13.2 kg per warhead.

Retiring Naval Nuclear Reactors

Another result of the post Cold War arms reductions is a decline in the fleets of both the USA and the former Soviet Union. Both countries possess a large number of nuclear powered submarines and surface ships. The United States first began operating nuclear powered submarines in 1954 with the USS Nautilus. The Nautilus was retired in 1979 (after 25 years of service)[47] Since then a number of the early nuclear submarines that followed the Nautilus have also been retired.

Graph 8-5 shows the number of U.S. Naval nuclear submarines or surface ships commissioned and decommissioned each year since 1954. The numbers are based on nuclear powered submarine and ship commissioning dates and number of reactors aboard each type.[48] It also shows estimates of the numbers retired naval reactors based on decommissionings through 1992 and a Navy goal of a 100 submarine force by the year 2000 and an expected force of 60 by 2020.[49]

The spikes in submarine production rates represent the peak production of specific classes of submarines. The first five to ten submarines were basically prototypes. Navy designers tried out a number of ideas, built submarines with the various features then selected the beat features for inclusion in submarines for series production. The first spike represents the series of "Polaris" submarines (which deployed long range nuclear missiles at sea). The second spike represents the "Sturgeon" class of hunter killer submarines (which were intended to hunt Russian subs). The the smaller humps represent later classes of submarines and surface ships.

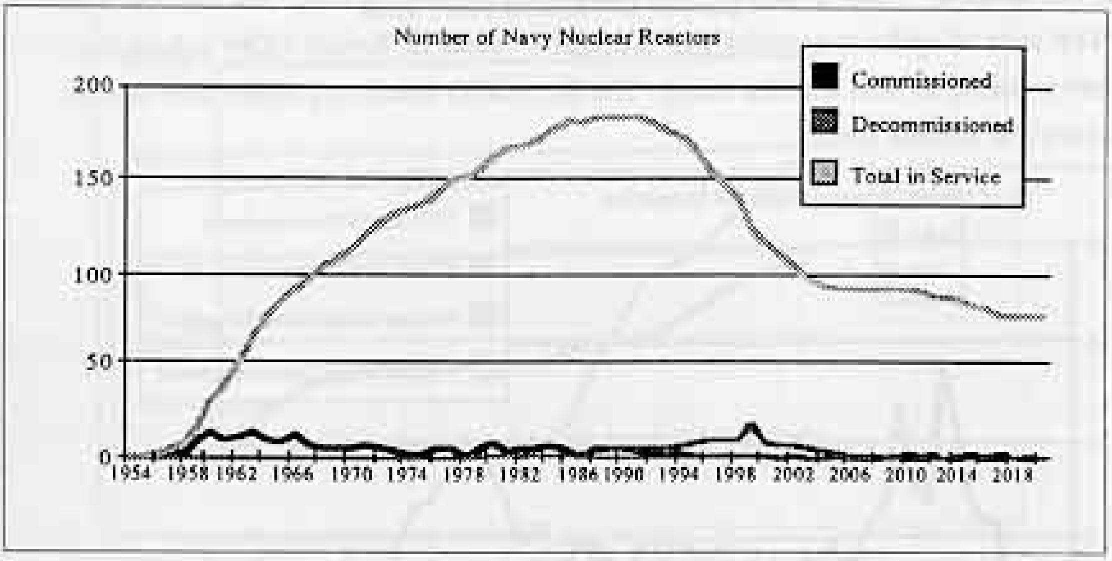


Graph 8-5: U.S. Nuclear Powered Ships and Submarines by Year

The later submarines have longer service lives. While the Nautilus and her immediate successors only served for 25 years or so, the later, improved versions, have service lives of 30 to 35 years. In demographic terms they can be thought of as cohorts. The Navy even refers to the groups as first, second and third "generation" submarines.

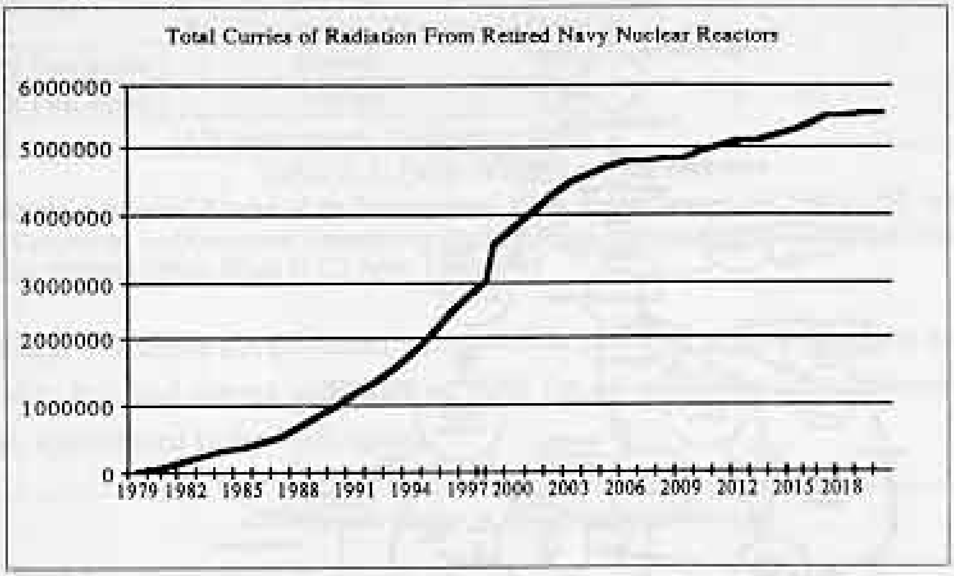
Despite their greater longevity the second generation and even some of the third generation are nearing the end of their operational lives. Large numbers are growing old at the same time (a problem the Navy calls "block obsolescence"). The Navy also has built five nuclear powered aircraft carriers (with plans for two more) and a nine of cruisers. Building rates for submarines have declined to one every two years, just enough to keep the shipyards in business.

The nuclear fleet is undergoing a transition much like the demographic transition of an aging population. Commissioning rates are declining (due to a changing political and economic environment). Decommissioning rates are increasing due to age and a lack of financial support for a large fleet. The net result is a rapidly declining population. This is shown in graph 8-6.



Graph 8-6: Number of Naval Reactors In Service
(Derived from: Jane's Fighting Ships, 1971-72;1989-90, 1991-92)

The cost of decommissioning these forces and retiring these reactors will be in on the order of $40 million per unit. With a total of 94 to be decommissioned by the year 2000 units the effort comes to $3.76 Billion.[50] The environmental impact of decommissioning these reactors will be great. Each reactor represents a radioactive waste disposal problem of about 33,000 curies.[51] Graph 8-7 shows the growth rate of waste from retiring naval reactors through the year 2020.



Graph 8-7: Cumulative Radioactivity from Retired Naval Reactors
Derived from Graph 8-5 & 8-6. Cumulative Number of Retired Naval Reactors times 33,000 curries per reactor.

Figure 8-7 shows the complete nuclear weapons chain for the United States nuclear weapons complex. It includes several key elements that have been introduced by the end of the cold war. Among these are reduced weapons stockpiles which will tend to increase the plutonium stockpile, and reduced numbers of naval nuclear reactors which will result in greater nuclear wastes in the short term due to retirement of nuclear reactors, but may reduce wastes later by reducing the number of units being recored.

Along with weapons reductions is the reduced need for nuclear weapons testing. The last test at NTS was conducted in 1988. There is considerable political pressure to halt all future tests. Since each test results in large increases in on site soil water and air contamination, forgoing future nuclear represents a considerable benefit to the environment.

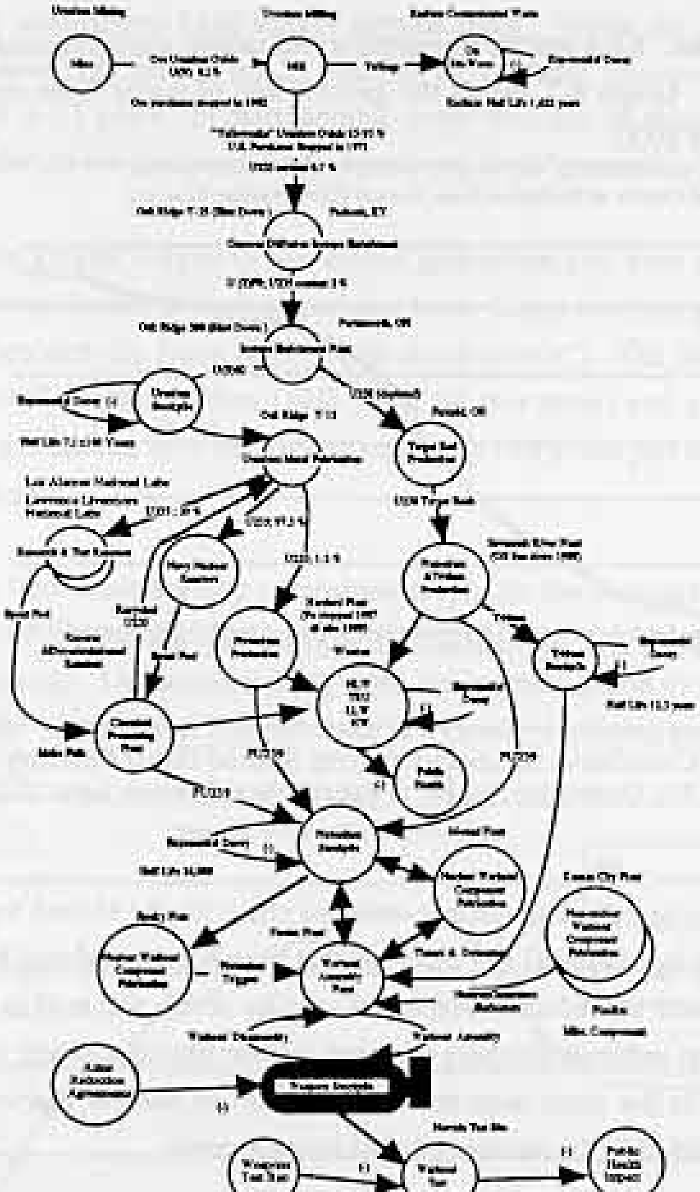


Figure 8-7: Nuclear Weapons Chain in the United States

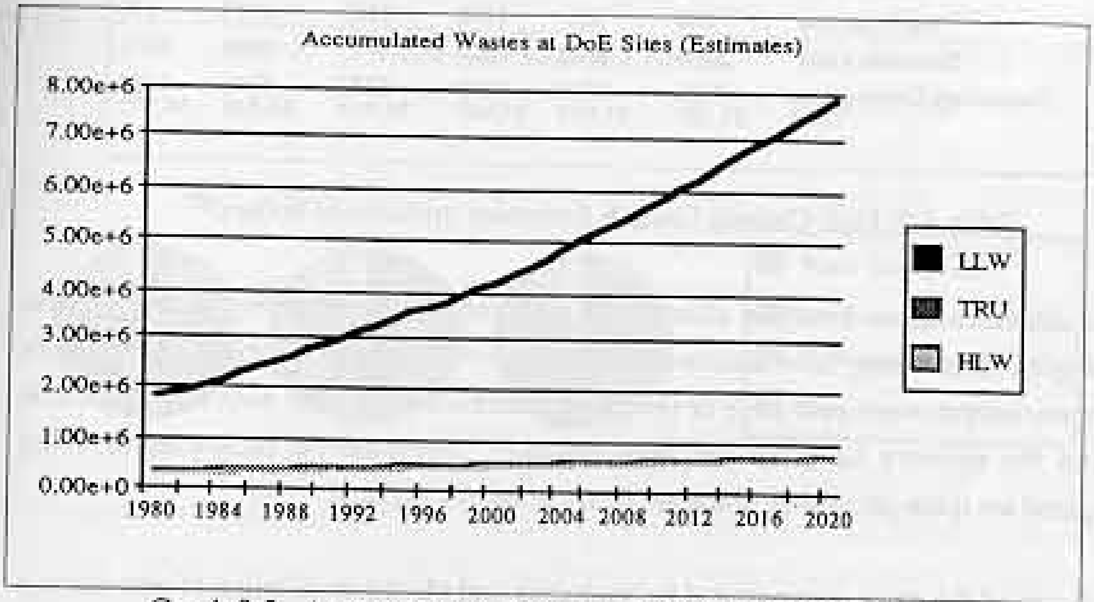
Note the effects of arms reduction and test ban. Retiring Naval reactors will increase flow through Idaho Falls in the near term. Fewer reactors operating in the future will reduce the amount of spent fuel to be recycled. Total wastes are represented by a single circle even though, as detailed earlier, the wastes are actually located at numerous sites. Table 8-1 summarizes the total wastes at all DoE sites for 1988.

1982	HLW (cubic meters)	Thousands of Curies	1988	HLW (cubic meters)
Savannah River	115000	828	Savannah River	128000
Idaho Falls	11500	72	Idaho Falls	11000
Hanford	183000	487	Hanford	244000
	TRU (cubic meters)	Thousands of Curies		
DoE Total Buried	298000	1.06		
DoE Total Stored	72000	2.04		
	LLW (cubic meters)	Thousands of Curies		

Table 8-1: DOE Wastes 1982 & 1988

Darnay Arnsen, Statistical Record of the Environment, (Gale Press: Detroit, MI,1992) p. 97 and National Advisory Committee on Oceans and Atmosphere Nuclear Waste Management and the Use of the Sea, ,(U.S. Government Printing Office:Wash D.C.) April 1984, p. 17

Graph 8-8 shows the projected wastes levels based on a linear fit of the data points from Table 8-1, and curves estimated in 1982 for all nuclear wastes (commercial and military), apportioned to the DoE figures.



Graph 8-8: Accumulating Wastes at DoE Sites (Cubic Meters)

Darnay, Arnsen, Statistical Record of the Environment, (Gale Press: Detroit, MI,1992) p. 97 and National Advisory Committee on Oceans and Atmosphere Nuclear Waste Management and the Use of the Sea, ,(U.S. Government Printing Office:Wash D.C.) April 1984, p. 17

VII. Summary and Conclusions

The production of nuclear weapons and propulsion systems has resulted in substantial environmental damage, not just in the U.S. but in other nations as well The cost of cleanup and the cost to public health are only now being calculated.

Cleanup Costs

The DoE has begun to assess the costs of environmental cleanup. A five year plan was published in 19989 for FY 1992-1996. Cleanup costs have been projected through 1995. Most of these costs estimates are for exploratory research. A large part of the problem is simply establishing how large the problem is. The estimates complied by region are tabulated in table 8-2.

DOE Regional Field Offices	1990	1991	1992	1993	1994	1995
Albuquerque	$256	$360	$807	$802	$751	$661
Chicago	$28	$62	$73	$61	$73	$68
Headquarters	$76	$143	$379	$529	$526	$398
Idaho	$300	$369	$718	$657	$601	$520
Nevada	$11	$24	$67	$88	$127	$122
Oak Ridge	$417	$567	$1,214	$1,408	$1,637	$1,634
Richland	$430	$627	$1,302	$1,385	$1,514	$1,460
Rocky Flats	$136	$89	$167	$193	$196	$189
San Francisco	$48	$51	$138	$161	$137	$90
Savannah River	$475	$585	$822	$777	$888	$872
Technology Development	$186	$206	$280	$353	$359	$359
Total	$2,363	$3,083	$5,967	$6,414	$6,809	$6,373

Table 8-2: DoE Cleanup Costs & Estimates (millions of dollars)[52]

A sizable amount has been allocated to research and development of remediation technologies. It had long been assumed that by the time it became necessary to deal with nuclear wastes that we would have developed the technology to deal with it. The time is near and the answers have not yet been found.[53] Some of the technologies being investigated are quite promising, some are likely to inspire derision.

Some of the more conventional technologies include the installation of new storage tanks at Savannah River and Hanford to take up wastes from tanks that are leaking. Vitrification plants are under construction at Hanford and Savannah River. The Savannah River Defense Waste Processing Facility (DWPF) is planned to start operations in 1992-1993. It will convert HLW into glass logs. The glass wastes will be stored at the Waste Isolation Pilot Plant, now under construction near Carlsbad, MN. The Hanford Waste Vitrification plant has not yet begun construction and is not expected to be operational until 1999[54]

DoE is exploring more exotic technologies. One of these is a transmutation study which is exploring the possibility of "transmuting" radioactive wastes into more benign materials. The project call for converting matter by means of a particle accelerator. Although the idea sounds like alchemy. While it may be possible given today's technology, it hardly seems feasible. The process is sure to require large amounts of energy (probably far too much to be practical).[55]

The dilemma facing DoE is the tradeoff to be made between remediation now, at a high, but known cost versus remediation later using yet unknown technologies at a potentially lower cost. The third factor is the cost of delaying cleanup. The longer wastes sit in holding tanks or settling ponds the greater the potential spread through the water table. Delay has a cost. Funding strategies will be determined by these priorities. The pie charts in chart 8-1 indicate DoEs current and planned funding priorities.

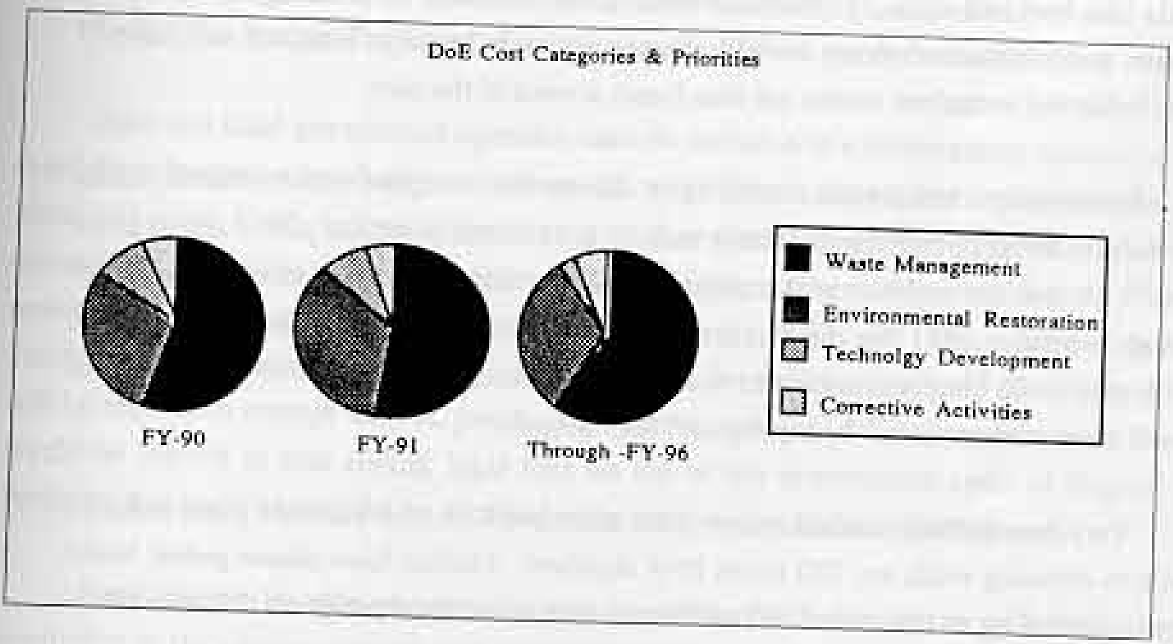


Chart 8-1: DoE Cleanup Cost Allocation[56]

The charts show DoE's near term priorities as waste management and environmental restoration but with a considerable portion also devoted to Technology development. Later, proportionally less money will be devoted to technology development and even more into waste management.

The nuclear weapons complex is being opened up to greater public scrutiny and regulatory oversight. The EPA has finally gained access and regulatory jurisdiction over the plants. None of the plants are in compliance with EPA regulations. All have significant soil, ground water and surface water contamination. Plans are just now being made to bring the plants into compliance. Long range plans call for complete cleanup in 30 years.[57] Given the level of contamination, that may be an optimistic goal.

Public Health Impacts

Thousands of children have received significant doses of radiation as a result of Hanford operations. Many of the contaminants released into the environment are well known as threats to public health. Among the materials are cesium-134 and 137, strontium-90, americium-241, plutonium-238 and 239, uranium 234 and 238. All of these radionuclides are human carcinogens. In addition there are substantial amounts of heavy metals like lead and mercury (a neurotoxins), and chromium, (a carcinogen). Benzene, toluene, and trichloroethylene, are all common solvents found at many of the plants.[58] Other industrial hazardous wastes are also found at most of the sites.

Fortunately, the extensive security at the nuclear weapons plants limited human exposure. The best protective measures may be to continue to restrict public access to the sites.[59] A serious problem is the migration of contamination beyond site boundaries through ground water. For the foreseeable future the best policy for protecting public health may be to simply continue to restrict public access and try to curb the spread of ground water contamination by a pump and filter program.

Very few definitive studies have been completed. At the Hanford plant radiation levels in drinking wells are 250 times EPA standard. Studies have shown public health impacts including an estimated 187 additional cancers to local residents due to airborne Uranium.[60]

Policy Implications

A key to any remediation program will be new policies to facilitate greater public awareness and better oversight of the cleanup process. The Office of Technology Assessment has recommended four policy initiatives toward that end:[61]

1. Greater Congressional oversight over the federal agencies involved in the

environmental restoration and waste management activities (DoE, EPA, DoD,HHS, Interior, etc.). Safe waste storage standards are needed, site monitoring plans and programs must be established.

2. Enhance the structure and process for assessing the public health impacts of the contamination and waste left by the nuclear weapons complex. An office under the Surgeon General could be established, or a separate health assessment office. Independent non-governmental organizations should be included.

3. Develop a structure and process for public participation in key cleanup policy and technical decisions, (advisory boards at each site headed by a national board).

4. Establish a radioactive waste management mechanism independent of the DoE, (The Nuclear Regulatory Commission, the EPA or a new national body).

State and local government agencies must be included in a participatory manner to avoid them becoming involved in an adversarial way. This is already becoming an issue. Idaho Governor, Cecil Andrus is threatening to close the states borders to naval nuclear wastes because of what he considers to be the lack of cooperation on the part of the Navy in providing information about spent fuel shipments to the INEL. In 1988 he closed the state's borders to waste shipments from Rocky Flats for similar reasons.[62] The cleanup will be expensive enough as it is, just because of the technical difficulty of the task. It would be foolish to risk adding legal fees on top of the remediation costs to litigate problems that could be avoided by allowing early participation by local governments.

Participation by non-government organizations could also add a great deal of credibility to the cleanup process and potentially reduce legal costs. Allowing local and national environmental groups a voice and a participatory role in decision making, might not only lead to less litigation, but better decisions as well. Opening the process up to the larger scientific, environmental and medical communities may help speed the solution.

Conclusion

The end of the cold war has brought with it the revelation of major ecological and public health consequences of 40 years worth of unsupervised environmental contamination at nuclear weapons production facilities. The immediate effect of arms reduction treaties and force reductions will actually exacerbate the problem in the short run. Remediation efforts are just beginning and will most likely continue well into the year 2020.

Appendix A: The Problem in the Former Soviet Union

The problems outlined so far are, of course, not limited to the United States. Britain, and France will also face cleanup problems. By far the most serious task may face the states of the former Soviet Union. They must find ways of storing the radioactive wastes from their nuclear weapons stockpile and naval reactors. In many ways their problems will be worse.

The Soviet bomb developers labored under an even greater level of secrecy than did those in the United States and with even less regard for environmental impact or public safety. The first Soviet bomb was developed in a rush to meet the arbitrary deadline of conducting a test prior to Stalin's birthday.[63] Chelyabinsk, the Russian counterpart to Savannah River, is thought to have released 1.2 Billion curies of radiation into the environment.[64] Hanford by comparison is thought to have released something on the order of 3.6 to 4 million curries.[65]

The breakup of the Soviet Union has disrupted continuity of many of the controls and administrative structures of the nuclear weapons complex in the CIS. This disruption and the extreme secrecy with which the work was carried out may make it difficult to trace all the facilities and waste site. The weak economies of the states of the former Soviet Union leave them ill prepared to deal with the cleanup costs.

The nuclear weapons complex of the Soviet Union similar to that of the United States, but somewhat more centralized. Table 8-A-1 lists the site in both countries.

Location	State	Plant Name	Ctry	Latitude	Longitude	Primary Function
Sarova	RUS	Arzamas-16	CIS	55.20N	43.52 E	Bomb Design
Ozhorsk	RUS	Chelyabinsk-40	CIS	55.10N	61.25 E	Tritium Production
Synezhinsk	RUS	Chelyabinsk-65	CIS	55.10N	61.25 E	Bomb Design
Zhelenogorsk	RUS	Krasnoyarsk-26	CIS	56.13N	92.25 E	Plutonium Production
Zhelenogorsk	RUS	Krasnoyarsk-45	CIS	56.13N	92.25 E	Uranium Enrichment
Zarechniy	RUS	Penza-12	CIS	53.10N	45.00 E	Bomb Production
Novo-uralsk	RUS	Sverdlosk-44	CIS	56.51N	60.36 E	Bomb Production
Rusnoy	RUS	Sverdlosk-45	CIS	56.51N	60.36 E	Uranium Enrichment
Seversk	RUS	Tomsk-7	CIS	56.29N	84.57 E	Uranium Enrichment
Torifurny	RUS	Zlatoust-36	CIS	55.13N	59.39 E	Processing
Chkalovsk	TJK	Vostakremet PO	CIS	56.48N	43.00 E	Processing
Kurckatov	RUS	Sempalatinsk	CIS	50.28N	80.29 E	Testing
Arctic Ocean	RUS	Novaya Zemlya	CIS	72.00N	54.46 E	Testing
Albuquerque	NM	SANDIA SNLL	USA	35.05N	106.40 W	R & D Weapons Design
Los Alamos	NM	LANL	USA	35.53N	106.20 W	R & D Weapons Design
Idaho Falls	ID	INEL	USA	43.30N	112.01 W	Feed Materials Production
Oak Ridge	TN	Y-12	USA	36.01N	84.15 W	Feed Materials Production
Richland	WA	Hanford	USA	46.17N	119.19 W	Plutonium Production
Rocky Flats	CO	Golden	USA	39.44N	105.15 W	Plutonium Trigger Production
Livermore	CA	LLNL	USA	37.41N	121.46 W	R & D Weapons Design
Savannah River	SC	Aiken	USA	33.32N	81.43 W	Plutonium & Tritium Production
Fernald	OH	Fernald	USA	39.28N	84.69 W	Feed Materials Production
Astabula	OH	Ashtabula	USA	41.55N	81.43 W	Feed Materials Production
Paducha	KY	Paducha GDP	USA	37.05N	88.36 W	Feed Materials Production
Piketown	OH	Portsmouth GDP	USA	39.03N	83.01 W	Feed Materials Production
Miamisburg	OH	Mound Facility	USA	39.40N	84.20 W	Warhead Components Production
St. Petersburg	FL	Pinellas Plant	USA	27.47N	82.38 W	Warhead Components Production
Kanasas City	KS	Allied	USA	39.05N	94.35 W	Warhead Components Production
Amarillo	TX	Pantex	USA	35.14N	101.49 W	Warhead Assembly & Disassembly
Nevada Test Site	NA	NTS	USA	37.40N	1116.50 W	Underground Tests
Tonopa Test Rang	NA	TTR	USA	38.05N	117.15 W	Underground Tests

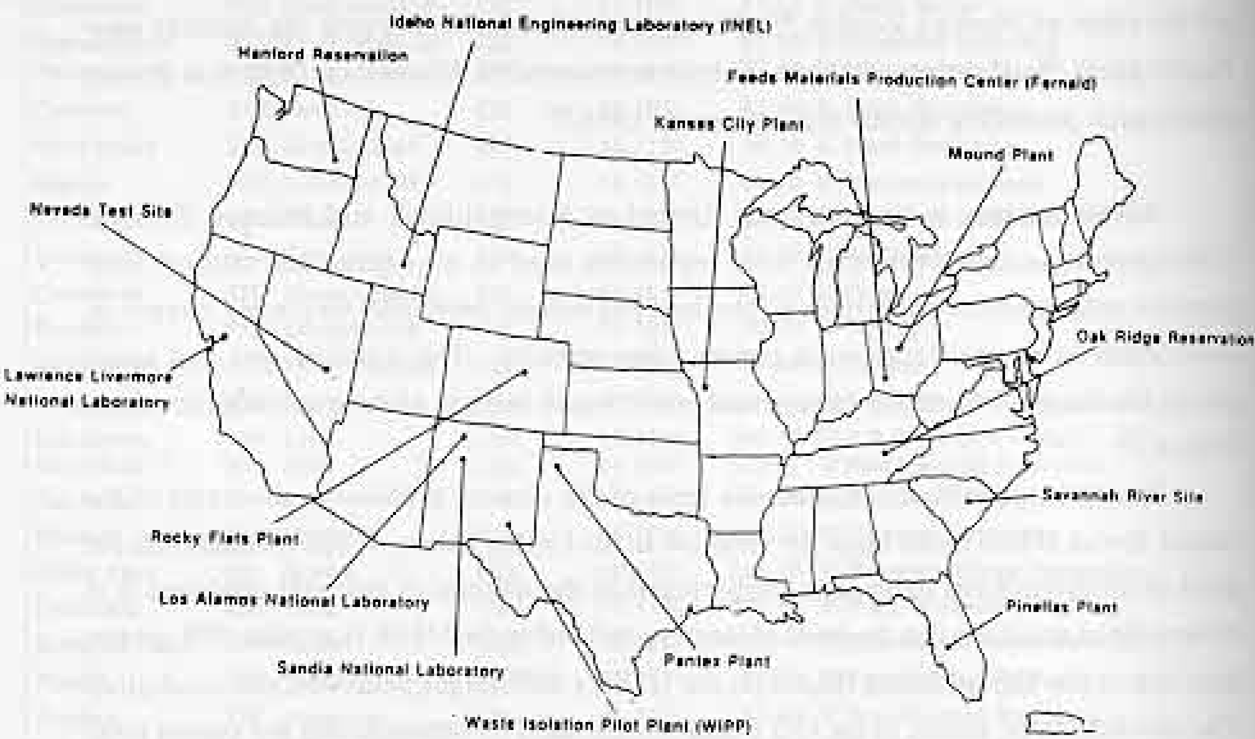
Table 8-A-1: Locations of U.S. and Russian Nuclear Weapons Sites
Caution Geographic locations are not exact. U.S. Site are based on nearest town. Locations in the USSR are based on city locations in Goode's World Atlas, but because code names were used the actual locations are not listed in standard atlases. The CIS sites are from Steven Zaloga. "The CIS Nuclear Weapons Industry", Jane's Intelligence Monthly, Sept. 1992 p. 32-33

The Soviet nuclear warhead stockpile and excess plutonium are shown in graphs 8-4 and 8-5. The Soviet stockpile was approximately 40% larger than the U.S. stockpile and was still increasing until 1988 (see graph 8-4). The Soviet navy also contained a large number of nuclear powered submarines and a few surface ships. Russia has approached the U.S. Navy requesting assistance in decommissioning between 80 and 150 nuclear submarines over the next seven to years.[66] There have been reports that the soviets disposed of a number of nuclear submarine reactors by dumping them in the arctic ocean off the coast of Novaya Zemlya.[67] Plans currently call for burying the reactors near Krasnoyarsk.[68] Russian president Yeltsin announced in November 1992 that Russia would cease producing nuclear submarines by 1995.[69]

Soviet nuclear testing was not limited to Semipalitinsk and Novaya Zemlya. Underground nuclear explosions were reportedly used in oil exploration and oil field pressure enhancement experiments. Nuclear explosions were also employed simply to move earth in several large scale construction projects. The resulting soil and water contamination, environmental damage and public health impacts of these activities is not yet known.[70]

It may be possible to estimate the scale of the cleanup problem in the states of the former Soviet Union based upon the situation in the United States. If one assumes that the level of environmental damage is proportional to the amount of material produced it is reasonable to conclude that the level of wastes produced in the USSR is at least 40% greater than that in the United States (based on the USSR's 40% larger peak weapons stockpile). The distribution of wastes in the CIS could be estimated by extrapolating the known level of wastes at sites in the U.S. to sites in the CIS that performed the same function.

Appendix B: Map of Nuclear Weapons Production Sites.



SOURCE: Office of Technology Assessment, 1991.

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[1] Nuclear Notebook, Bulletin of the Atomic Scientists, Nov. 1989, p. 53

[2] Congress of the United States, Office of Technology Assessment, Complex Cleanup, The Environmental Legacy of Nuclear Weapons Production, U.S. Government Printing Office, Wash. D.C., Feb. 1991 p. 3

[3] Ibid, p. 42

[4] PU239 is the isotope of Plutonium with an atomic mass of 239, likewise U235 and U238 are Uranium isotopes with atomic masses of 235 and 238 respectively.

[5] Ehrlich & Birks, p. 153.

[6] Ibid. p. 154.

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[14] Data derived from: Arnsen Darnay, Statistical Record of the Environment, (Gale Press: Detroit, MI)1992 p. 100

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[20] Ibid.

[21] Ibid, p. 30

[22] Complex Cleanup, p.17

[23] Ehrlich & Birks, p. 29

[24] John May, p. 307

[25] Complex Cleanup, p. 17

[26] John May, p. 307

[27] John May, p.302

[28] Ehrlich & Birks, p. 25

[29] Nuclear Waste Management, p. 91

[30] Erhlich & Birks, p. 24

[31] John May, p. 303

[32] Ehrlich & Birks, p. 32

[33] Ibid

[34] Ibid, p. 19

[35] Ehrlick & Rirks, p. 26

[36] Ibid, p. 31

[37] Ibid, p. 28

[38] Complex Cleanup, p. 19, 163

[39] Ibid, p.163

[40] Ibid, p. 19, 163

[41] Ibid, p.162

[42] Ehrlick & Birks, p. 30

[44] "USA and Soviets Agree to START Cuts", Jane's Defense Weekly , 27 July 1991, p. 131
[45] Ibid.
[46] By using implosion designs fission bombs can be made with as little as 11 kg of plutonium, 13.2 kg are required for "gun type weapons and represent an upper bound. Engel & Wolf, Defense World Almanac, p.14
[47] Jane's' Fighting Ships 1971-72.
[48] All U.S. submarines have only one react, except for one (USS Triton, which had two). Surface ships typically have two reactors, except for USS Enterprise which initially had eight; later modernized with only two.
[49] "Billions Lurking in Nuke Decommissioning"Navy News and Undersea Technology, 12 Oct. 1992, p. 3
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[56] Derived from : Complex Cleanup, p. 58.
[57] Complex Cleanup, p.5
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[61] Complex Cleanup, p. 10
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Chapter 9: Stephen Uche

Title: POPULATION AND FORESTRY DYNAMICS: AT THE CROSSROADS IN NIGERIA.

INTRODUCTION

A recent census conducted in Nigeria in 1991 revealed a population of 88.5 million. This figure has been a significant reason for concern to many Nigerian policymakers, demographers and environmentalists who had long been apprehensive that the population growth was exceeding the carrying capacity of the land and represented a "detrimental force" to the environment. With a population growth of 2.9% (Population Reference Bureau, 1990) and a predominantly rural population (more than 70%), which thrives on a subsistence agrarian and pastoral economy, the environmental implications are obvious. A web of complex causative factors have been implicated in environmental degradation. Most of these are attributed to human activities on the environment, but these pressures may be seen to be directly linked to the underlying cause: rapid population growth.

Correspondingly, Nigeria's natural forests have progressively disappeared as a consequence of rapid population and pressure to expand agricultural land culminating in over-cultivation, overgrazing and deforestation. In 1897 when the first forestry department was established, Nigeria's tropical forests covered 60 million of its 98 million hectares of land. Today, they cover less than 9.8 million hectares. (American Embassy, Lagos, 1986; Oguntala, 1986) Nigeria loses 2.7% of its available forests annually and it is speculated that serious deforestation may affect 10% of the available land in the north where the sparse remaining shrub cover is significant a shelter barrier to desertification (American Embassy, 1991).

Rangelands become less productive as vegetation is overgrazed and water and soil systems become more vulnerable to forces of desertification. Farmlands grow smaller and scarcer due to the large number of landholdings, increasingly subdivided with each successive generation. Driven by poverty and a struggle for survival, more rural families clear marginal lands for agricultural purposes and in desperation, facing drought, continue to graze animals on severely degraded lands, exacerbating vegetation loss. These did not go without cost to Nigeria. Such costs include environmental problems like desertification, soil erosion, changes in climate and rainfall, siltation of water systems, declines in agricultural productivity and threatened loss of biodiversity. (Brown and Wolf, 1985; Anderson, 1987 and NEST, 1991)

Pastoralism is the dominant occupation of the northern regions of Nigeria which are characterized by a grassy, Savannah of an arid and semi-arid feature. It takes the form of traditional nomadic or transhumant systems based on common rangelands. Adejuwon (1976) established that before human beings came with their growing numbers, economics and cultures to dominate the environments, Nigeria was covered by three major types of vegetation among which grass was not an important feature. Today, grass, shrubs and cacti dominate the northern vegetation. These are among other signs of desertification processes in the northern fringes of Nigeria bordering the Sahelian regions.

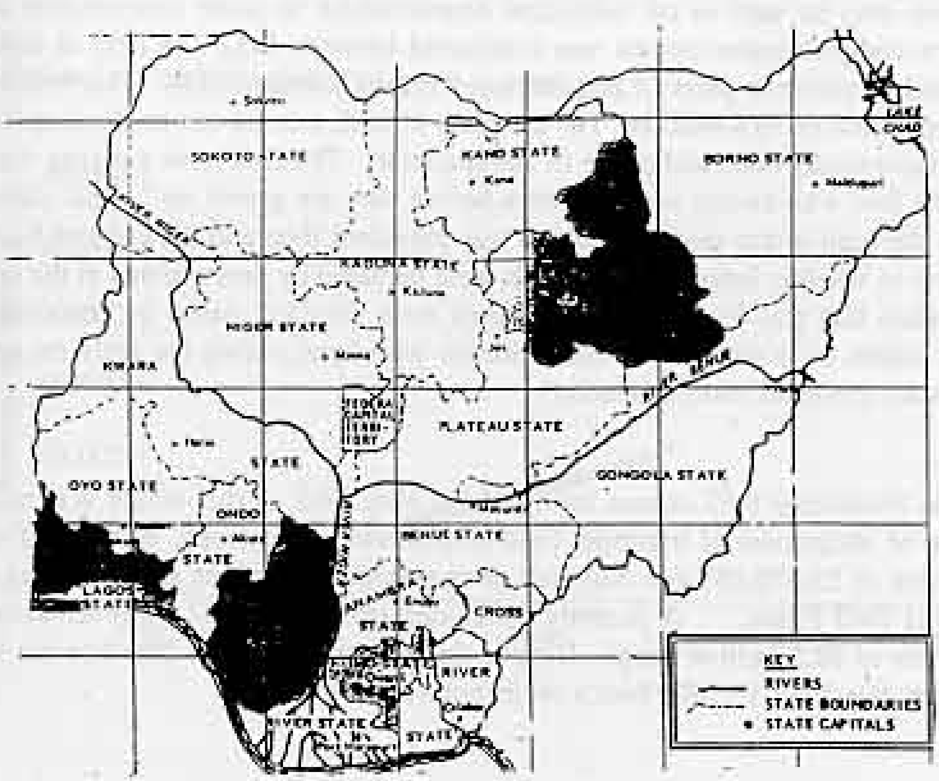
The memories of the tragedies of the ecological disasters of 1968-1973 and 1981-1986 which ravaged the Sudano-Sahelian regions including their contiguous proximities, are still fresh in the memories of most Nigerians. "Certainly, no attention was given by the international media to the millions of drought-affected Nigerians who, in the 1970s, out-numbered those of Senegal, Mauritania, Mali and Niger combined." (Mortimore, 1989) The reason was that Nigeria had oil wealth then, and was expected to cope with its problems. This did not help the country because it did not raise the public or government awareness of the causes or long range consequences of desertification threats in Nigeria.(see Fig.1) It is estimated that Nigeria lost about one million cattle, goats and sheep in the catastrophe (Van Apeldoorn, 1978a, 1981; Mortimore, 1989 and NEST, 1991), confirming that the "drought occurred in Nigeria on a scale and at an intensity comparable with other areas in Africa." In addition, displaced ecological refugees from Niger and Chad Republics migrated southwards into Nigerian northern territories with their surviving herds, thereby exacerbating the Nigerian situation.

Population and forestry concerns and policies have been rhetorically stressed by different governments in Nigeria. While a population policy has since been designed for the country, several forestry programs have been engaged, particularly reforestation, social forestry, afforestation and agroforestry projects. How many of these rhetorics have been translated into practical demonstrations? What is the current trend in the dynamics of these two variables and how do they compare with those of the past?

Mortimore (1989) has noted that, "in the outburst of concern over the African crisis, and in particular, the linked phenomena of drought, famine, desertification and impoverishment, too little attention has been given to empirical investigation. Worse, relationships have been postulated without the intervening variables even being identified or the nature of the linkages supposed." He concludes that practical solutions are elusive as governments tend to intervene late, inadequately or ineffectively. How could these be avoided? What are those intervening variables? How could knowledge of these help policymakers in designing practical and effective policies and projects?

While this study will try to articulate how many of these questions have been answered, it will establish a sequence of relations and trends in these events.

Figure 1. Map of Nigeria showing its national boundaries.



POPULATION TRENDS IN NIGERIA

There is a lack of any acceptable, accurate nationwide census and there is no nationwide vital registration system in Nigeria. (U.N, 1980) This constitutes the most basic problem for research, projection of trends, precise assessment of Nigeria's actual situation, and for design of policy to alleviate present stresses or prevent future crises. No one "knows with certainty how many people live in Nigeria, how many children are born and how many people die." With the rejection of the 1973 census for political and methodological reasons, the 1963 census still remains the base from which all national and regional population estimates are made. Occasional sample surveys, however, provide vital statistics for the country. "No African government and development agency knows, within any acceptable margin of error, either the birth rate, the mortality rate or the food production of any African state. These statistics are normally accepted with an error of 30% or more." (Walker, 1986) This statement is quite true of Nigeria. It is this paucity of information and data that has weakened the ability of the nation to design accurate plans that best reflects the population and environmental needs of the country.

a. Censal History: Nigeria has been conducting censuses regularly at ten year intervals since 1911, with the exception of 1941 when World War II interrupted the process. Those pre-World War II counts were, however, only estimates based on tax collection data as well as on individual enumerations in some metropolitan areas. The first comprehensive census was conducted between 1952 and 1953 at different times and in different parts of the country (Gyepi-Garbrah, 1985). This recorded a total population of 30.4 million. The accuracy of such a count can be dismissed since it was haphazardly done and prone to manipulation. The Ibos have a saying that it is "only the fool who counts one's children before they are grown up." This statement reflects the high infant mortality which was prevalent then and the cultural basis for doubts as to whether infants and children were included by their parents in the counts. It is certain that pre-World War II censuses were similarly based on headcounts of taxable males, as is recalled by older citizens who lived during the early decades of the century.(personal communication)

The November 1963 census followed the May 1962 census which was nullified because of allegations of improper field enumeration procedures. It recorded a total population of 55,670,055 and Nigeria's demographic projections are still being made from this 1963 figure. A recently concluded census in 1992 however showed a population of 88.5 million people. Despite this, this paper will be based on the World resources data 1992-93 from which projections are available.

b. Demographic Changes: It could be said that Nigeria is at its early phase of the demographic transition. According to a United Nation's estimate, the crude birth rate (CBR) has remained virtually unchanged around 50 births per 1000 population since the early 1950s (Gyepi-Garbrah, 1985), while the levels of mortality in Nigeria have fallen considerably. The crude death rate (CDR) was 27, for instance, in the 1950-1955 period, but went down to 17 in the early 1980's, a decline of 37%. A UN estimate in 1991 puts it at 14.0. (see Figures 2a,b,&,c, showing total population, CBR and CDR) These estimates indicate that Nigeria does not deviate from the general pattern that typifies Africa's demographic dynamics, namely, a high rate of population growth as a result of high but declining mortality and high, and almost constant fertility. (Nigerian Population Commission, 1983) This improvement in mortality figures resulted from advances made in public health care, especially in sanitation and nutrition, increased maternal education and increased health services coverage. The consequence of this change was a surge in population which has had a serious cost to the Nigerian environment and economy. There has been an exponential growth in the population and with a rate of 3.3%, the current size of 108.5 million will double in about 21 years. If this reality is not adequately addressed, it could present a serious future for a nation whose economy is currently in shambles. Of equal importance is the high percentage of the economically, non-contributing age specific population. Nigeria compares poorly with most countries of the world and this has its economic implications. (see Table 1) There is a high percentage of the 15-65 age group in all the developed countries, indicating a higher productive force rather than the consuming and dependent age groups of under 15 years.

Figure 2a. Total population trend from 1950-2025.

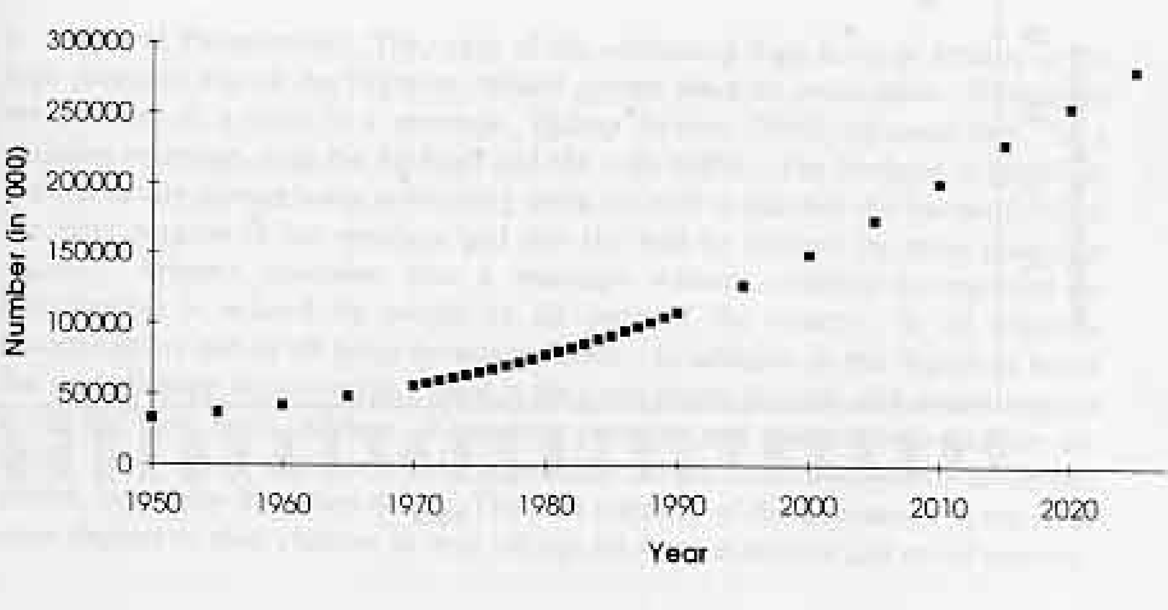


Figure 2b. Crude Birth Rate in Nigeria from 1950-2025.

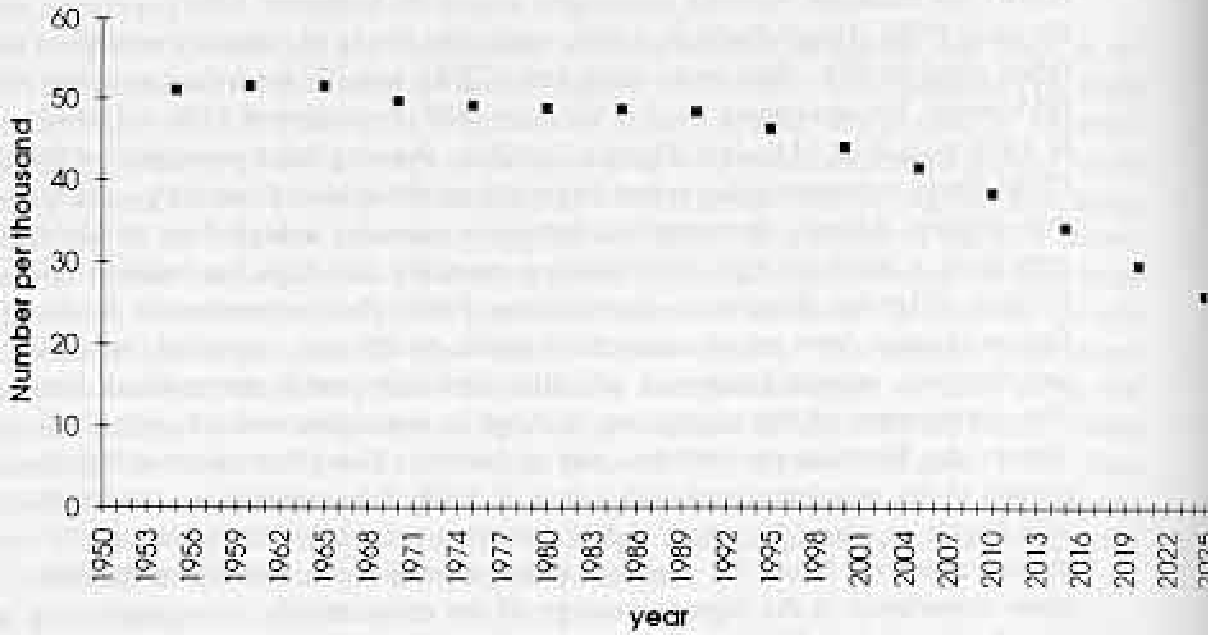


Figure 2c. Crude Death Rate in Nigeria from 1950-2025.

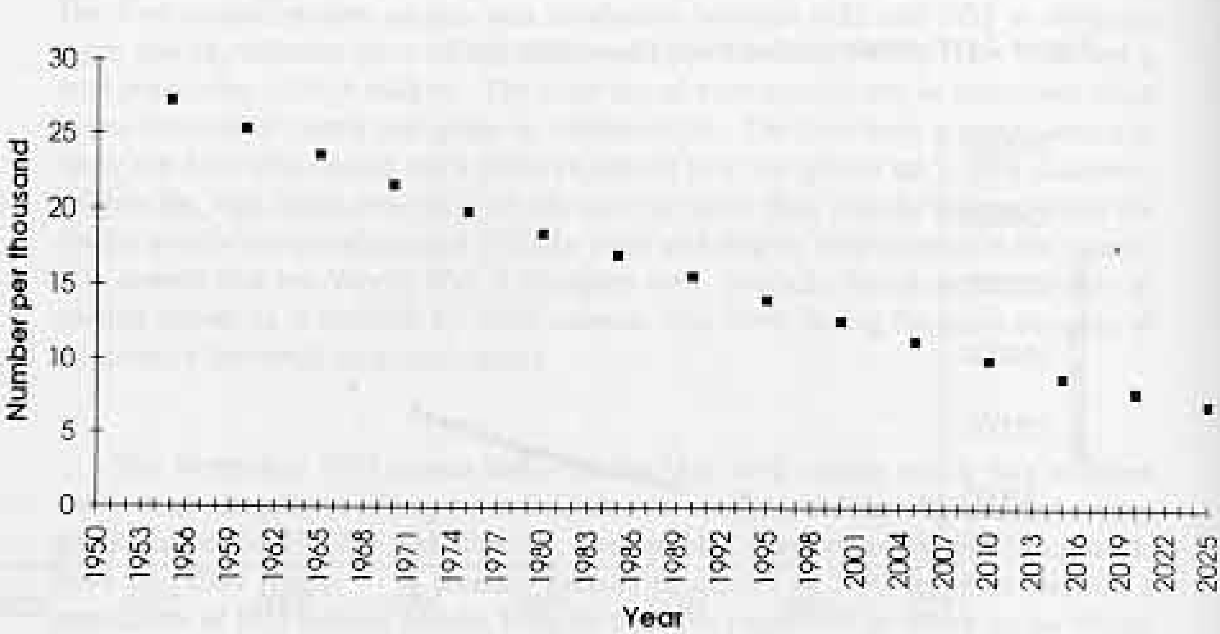


Table 1. Percentage of population in age-specific groups in selected countries. Data from World Resources Institute, 1992-1993.

Location	1975			1995		
	<15	15-65	>65	<15	15-65	>65
World	36.8	57.5	5.7	32	61.5	6.5
Africa	44.8	52.1	3.1	44.9	52.1	3
Nigeria	46.5	51.1	2.4	47.3	50.1	2.6
U.S.A	25.2	64.3	10.5	21.2	65.9	12.9
Japan	24.3	67.8	7.9	17	69.2	13.8
Europe	23.9	63.8	12.3	18.9	66.9	14.2
S/America	39.6	56.2	4.2	33.7	61	5.3
USSR	26.1	64.4	9.5	24.8	64.3	10.9

c. Cultural Perspective: The cause of the continuing high level of fertility is the high premium that all the Nigerian cultural groups place on procreation. Writing on the position of a child in a marriage, Bishop Arinze, (1986) espoused that, "in a childless marriage, both the husband and the wife suffer. The husband is mortified that his family lineage is not continuing while the wife is sad that she has not fulfilled the main purpose of her marriage and that she will be insulted by some people in society." Arinze's statement that a marriage without children is regarded as unsuccessful is echoed by people in all parts of the country, in all religious denominations and at all socio-economic levels. In addition to the ingrained belief that one's lineage must continue, there is the expectation that one will derive support in old age from one's children. Retirement pensions and medical insurance are the luxury for a small segment of the population which has employment in certain sectors, especially the urban-based. The vast majority of the population in the rural areas depend on their children in their old age for some economic and social security.

In the rural areas especially, large families are the norm because subsistence agriculture is labor-intensive. A high fertility is regarded as a blessing. In addition, families could anticipate that some children would not survive. High infant mortality rates are an encouragement to have more children to replace the deceased ones. Currently, the IMR is 96 per 1000 live births. (WRI, 1992)

The complex belief systems supporting large families have been so deeply etched into the emotions and culture of Nigerians that any mention of reducing family size for any reason is met with resistance and the power of tradition. The average citizen continues to aim for a large family because it is still the norm. The total fertility rate (TFR) is as high as 6.6 despite the worsening economic situation and government efforts to stabilize the population growth. The leap in conscious understanding has not been made to link one's family size and the desired number of children, with the shrinking of a family's landholdings, poverty, inability to feed one's children or visible signs of environmental crisis.

If the linkage has not been made at the individual level when planning one's own family, there is this same consciousness in national planners who generally have only begun to articulate the relationships between population increase and the nation's inability to solve social and environmental problems. Culture and tradition have a dominant influence to play in the reality of family planning, both within the family and at the national level. It has only been in recent years that the educated elite and policy makers have accepted innovative shifts in consciousness concerning the value of smaller families to reduce strain on resources at family and national levels.

d. Political Perspective: Population issues have political dimensions in any nation which has ethnic and religious diversities. In Nigeria, there is always the fear and consciousness among different ethnic groups of being dominated by others. The politicians have always played this issue to their advantage whenever they wanted the votes and support of a given ethnic group. They have had to be cautious in verbalizing the topic because in the past, the population issue had been an untouchable controversy which no politician dared approach. Ness (1990) observed that wherever a state's population is ethnically divided, population policies will be faced with deep, primordial fears of population decline, and with changing relative numbers of different ethnic groups. He surmised that while many other environmental policies may be subject to at least some economically rational argument, population policies continue to raise deep primordial reactions.

This is not to say that governments, people and the environment had not all along felt the pressure of the rapidly growing population. It was not until 1988 that the present military government called for the design of a comprehensive population policy which states that "national development policies, plans, and programmes shall be based on an integrated approach that takes into account the inter-relationships among population factors, resources and environment." How much has been done and achieved in this regard remains to be seen.

e. Population distribution: The population lives predominantly in rural areas where subsistence agriculture is still the primary occupation. The high rate of urbanization is similar to the rapid urbanization trend which is not only common in Subsaharan Africa, but also across the developing countries. Projections show that by the year 2000, 65.4 % of the Subsaharan African population will be rural and by 2025, it will be 54%. (The World Bank, 1986) The Nigerian urban population, according to U.N. estimates, has been growing at an annual rate of 5% since the early 1960's and this trend has accelerated in the last few years.(see **Figures 3 a** & b) The implications of such a surge are obvious as transportation, housing, food scarcity, high energy and water use, and other infrastructures would present with their problems, leading to public health inadequacies.

Figure 3 a. Total urban population growth in Nigeria, 1950-2025. Data from WRI, 1992-93.

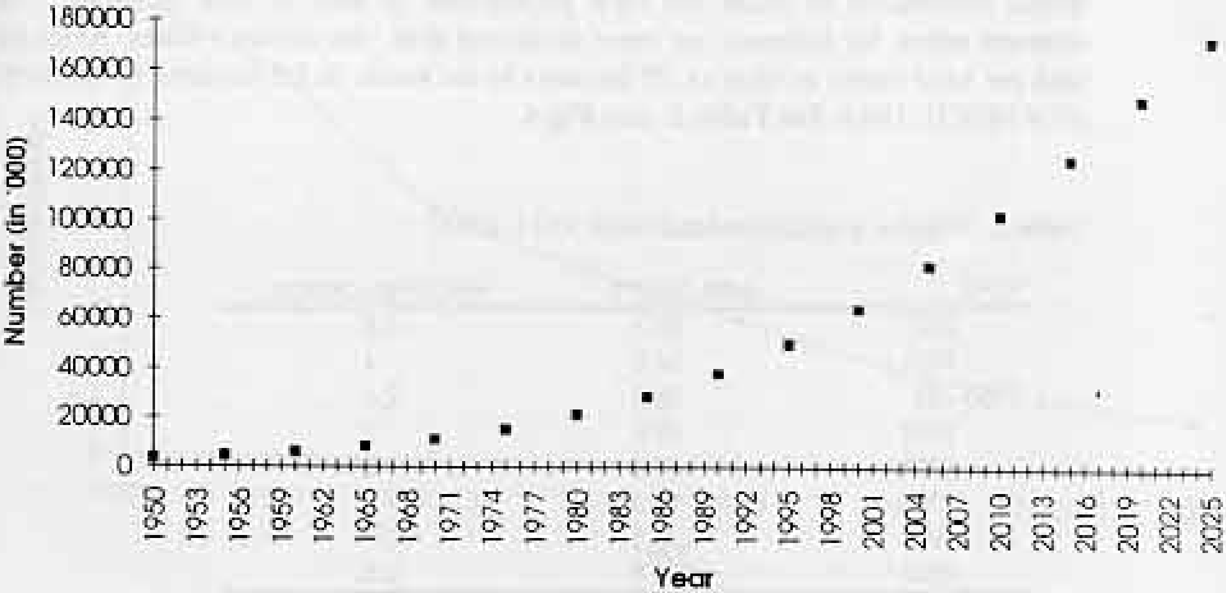
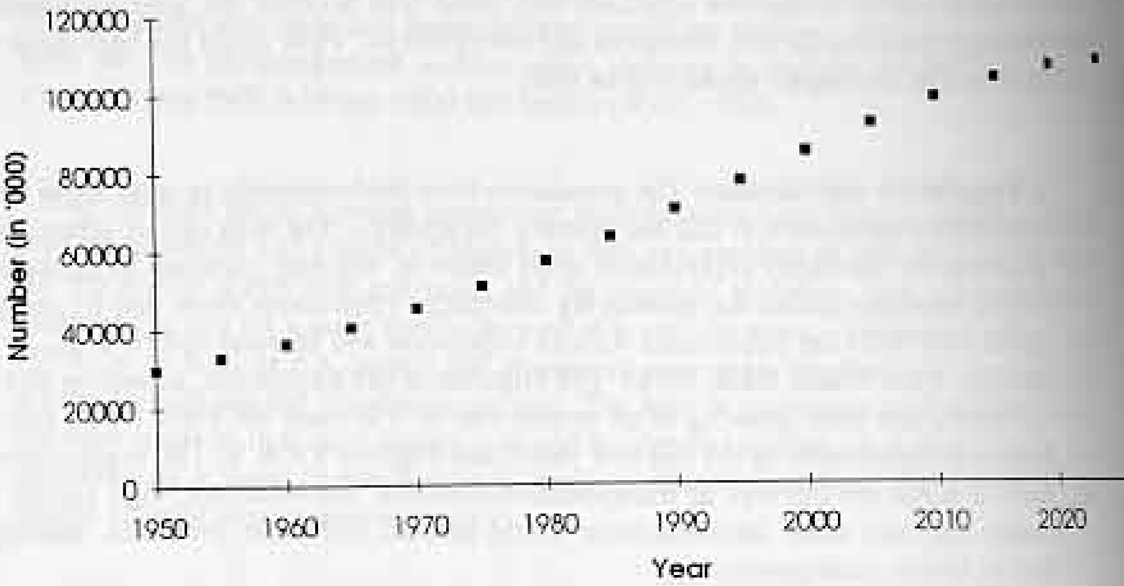


Figure 3b. Total rural population growth in Nigeria, 1950-2025. Data from WRI 1992-93.



There have been significant changes in the features of Nigeria's urban structure in terms of large localities with populations of half a million and more. This has been stimulated by rapid economic, social and political changes. From only two such cities, Lagos and Ibadan, the numbers of such urban areas increased to 19 between 1965 and 1980. (Gyepi-Garbrah, 1985) There are also marked differences in the spatial distribution of urban and rural populations, as well as their densities. The southern states, for instance, are more urbanized than the northern states. Available land per head varies as little as .07 hectares in the south, to 3.2 hectares in the north. (FORMECU, 1989) **See Table 2 and Fig.4.**

Table 2. Nigeria: population-land ratio, 1921-2003.

YEAR	pers./sq.Km	Hectares/person
1921	20.7	4.8
1931	24.8	4
1950 - 53	38.5	2.6
1963	49.8	2
1973	68.3	1.5
1983	98.3	1
1993	146.3	0.7
2003	220.8	0.5

Source: Based on population data as reconstructed and projected by P.O. Olusanya and J. A. Ebigbola (1991). Nigeria's Population Dynamics: Problems and perspectives. Ile-Ife, Rewaju House Press.

Figure 4a. Nigerian population density, 1921-2003.

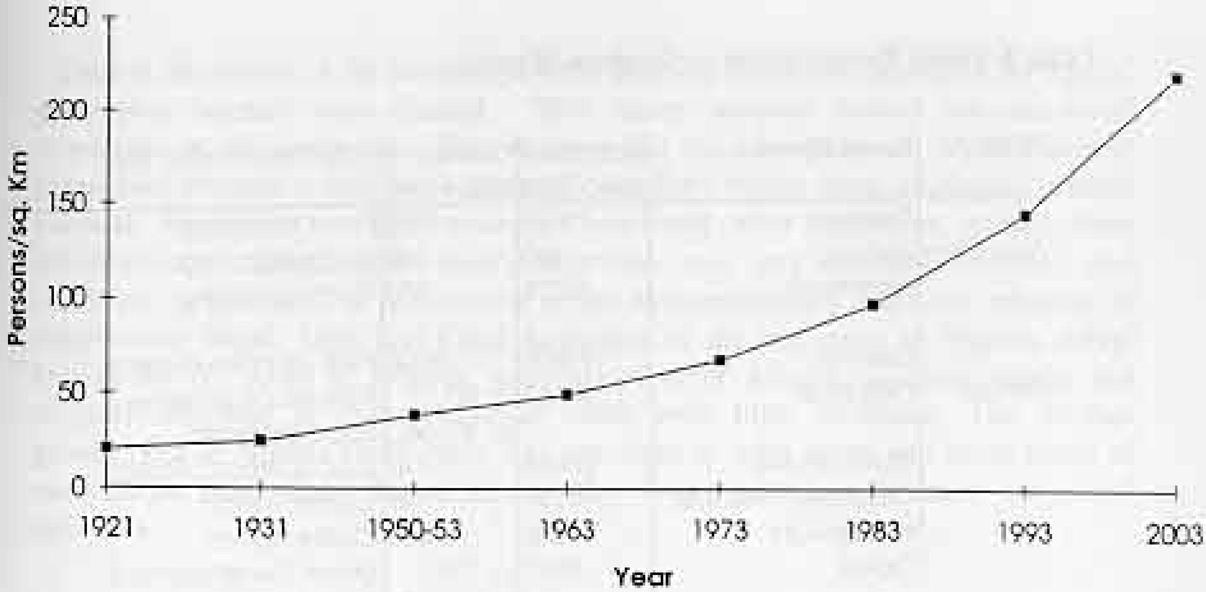


Figure 4b. Land-person ratio, 1921-2003.

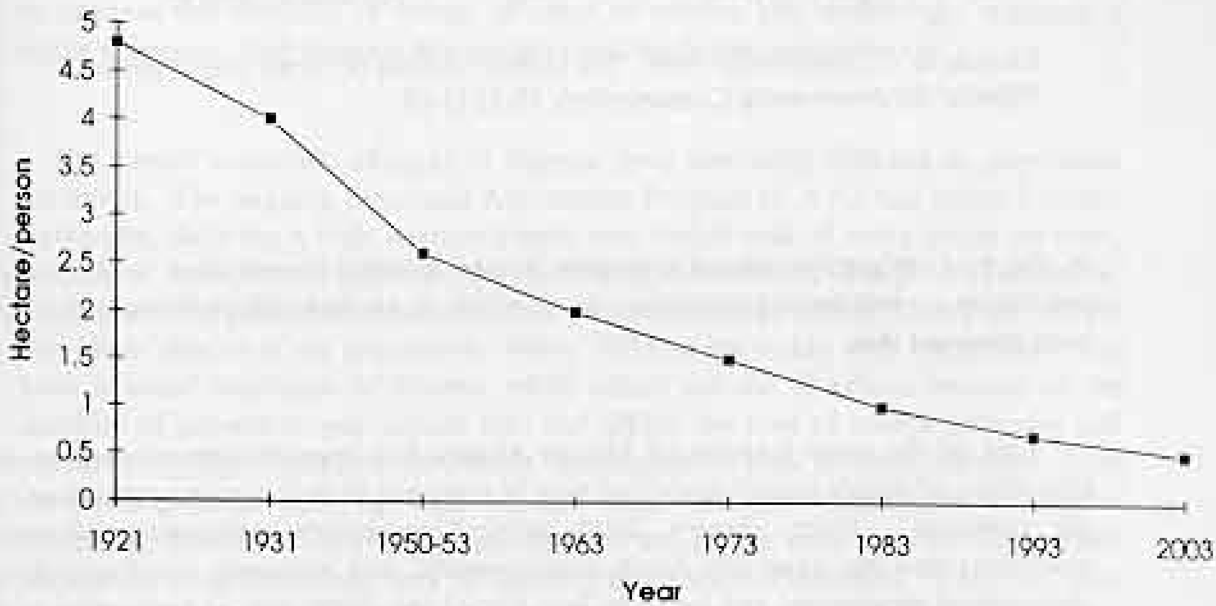


Table 3. Forest Dereservation in Southern Nigeria.

State	Forest Reserve	Gazetted area (ha)	Dereserve area (ha)	Alternative Land Use
Anambra	Osomari	12098	1500	Food cropping
	Akpaka	450	100	Food cropping
	Anambra	14575	500	Food cropping
Bendel	Okomu	123809	15000	Fed. oil palm project
	Orle River	40663	a. 60	Petroleum pipelines
			b. 19166	Food cropping
	Iguobazuwa	26936	1810	Cocoa Board Project
	Ologholo-Emu Urlo	14996	145	Cattle Ranch
	Ivi-Ada-Obi	18002	580	Cattle Ranch
	Ogba	5517	a. 720	Urban Development
			b. 1010	Food cropping
Akwa Ibom	Stubbs Creek	31080	11	Food cropping
	Ekinta	10878	10878	Food cropping
Imo	Ubibia	755	106	Food cropping
	Achara-Ihe	794	300	Oil Palm Project
Rivers	Upper Imo River	9696	10	Food cropping

Source: G. J. Osemeobo, 1988: 'The human causes of Forest Depletion in Nigeria', Environmental Conservation, 15(1):18-28.

In the past, migration among countries helped correct for resource scarcity and population growth among countries. In an effort to explain this phenomenon it has been observed that:

" One of the main features of African history has been the almost continuous migrations of people across space and time in response to the changing conditions on the continent. Wars, slavery, local political upheavals, unfavorable climatic conditions and the generally harsh environmental and economic conditions have precipitated movements and more or less forced the dispersion of population over wide geographical areas in the continent for a long period before the era of colonialism." (Nelson, 1982).

During the advent of the colonial powers, with the subsequent scramble for Africa, geographic borders were created. This factor severely limited intra-territorial migrations in the continent. This dictated that the absorption of Africa's natural population increase would be increasingly confined within these artificially created national boundaries. This situation continued after countries gained their independence. Illegal inter-country migration was very common however, and continues to this day. It is common to see environmentally displaced refugees of neighboring Niger, Mali and Chad Republics in the big cities of Nigeria today. During the oil boom of Nigeria, nationals of other African countries legally and illegally migrated to many Nigerian cities with little inhibition. The civilian government of Nigeria (1979-1983) was provoked to track down and expel many of such illegal aliens from the country as they began to engage in many anti-social activities.

f. Summary: A U.N. medium variant projection has postulated that Nigeria will continue to experience annual population growth rates for some time with a peak of 3.6% during the 1995 to 2000 period. A gradual decline will follow this peak through the 2020 to 2025 period which will record an annual growth rate of 2.3%. (Gyepi-Garbrah, 1985) Other U.N. estimates have also shown the Nigerian annual growth rate to be continually exceeding the average for Africa and its neighboring West African countries. These demographic features have implications for Nigeria's efforts to improve her standard of living, advance in science and technology, maintain a stable economy, and preserve her environment for future generations.

The current economic changes in Nigeria have inevitably affected its population dynamics. The ongoing Structural Adjustment Program (S.A.P.) had called for belt-tightening, dictating a high unemployment rate, withdrawal of many social services, scarcity of basic needs, inflation, devaluation of the currency and general economic hardships. The effects of these economic policies are very visible among the middle and lower classes of the population. Many children are sickly with malnutrition and have lowered resistance to disease, while others are out of school because of the inability of parents to pay school fees and afford the cost of school uniforms and materials. Many children are dying unnecessarily due to poor harvests from diminishing lands held by each family which are now inadequate to support increasing numbers. The Nigerian government and people must embrace the national population program as one way of averting more serious tragedies. Given the slow growth of the economic sector, a slow population growth becomes a prerequisite for a sustainable development in the country.

THE ENVIRONMENTAL TRENDS - FORESTS, WATER AND SOIL

Nigeria is divided into three principal ecological zones: the coastal humid forest zone with 1,600 mm of annual rainfall, a central humid forest zone with 1,150-1,500 mm of annual rainfall and the northern savannah area which receives annual rainfall of 250-1,000 mm. (Iyegha, 1988) These ecological variations dictate the type of agricultural activity practiced in each region. Nigeria has an estimated 98.3 million hectares of land area of which 40 million hectares are available for grazing animals. (Nuru, 1986) Patterns in environmental changes are discernibly visible in the following areas:

a. Subsaharan African Environmental Changes: There have been recent trends of climatic changes in Subsaharan Africa. Since the late sixties much of Africa has suffered from below average rainfall but this problem became acute in the Sahelian region, which includes the northern border states of Nigeria, during the late sixties and early seventies. There has been a progressive desertification process traceable to the overall breakdown of delicate environmental balance. The decline in rainfall may have been caused by vast land use changes such as deforestation which increases water run-off, reduces evapotranspiration and increases reflectivity. (Mortimore, 1989)

The climatically critical rainforests of West Africa are disappearing at the rate of 5% annually. (Shunkla and Mintz, 1982) It is now being surmised that the rainforest zones are not only important in themselves, but also act as moisture-filled buffer zones which significantly influence the environmental balance in the savannah areas and help ward off desertification in the northern arid zones. With the near disappearance of the forests throughout West Africa, there are residual side-effects as overall patterns of flow of moisture are destabilized. With the diminution of trees, the critical watershed areas supporting the continent's systems of springs, streams and rivers are threatened.

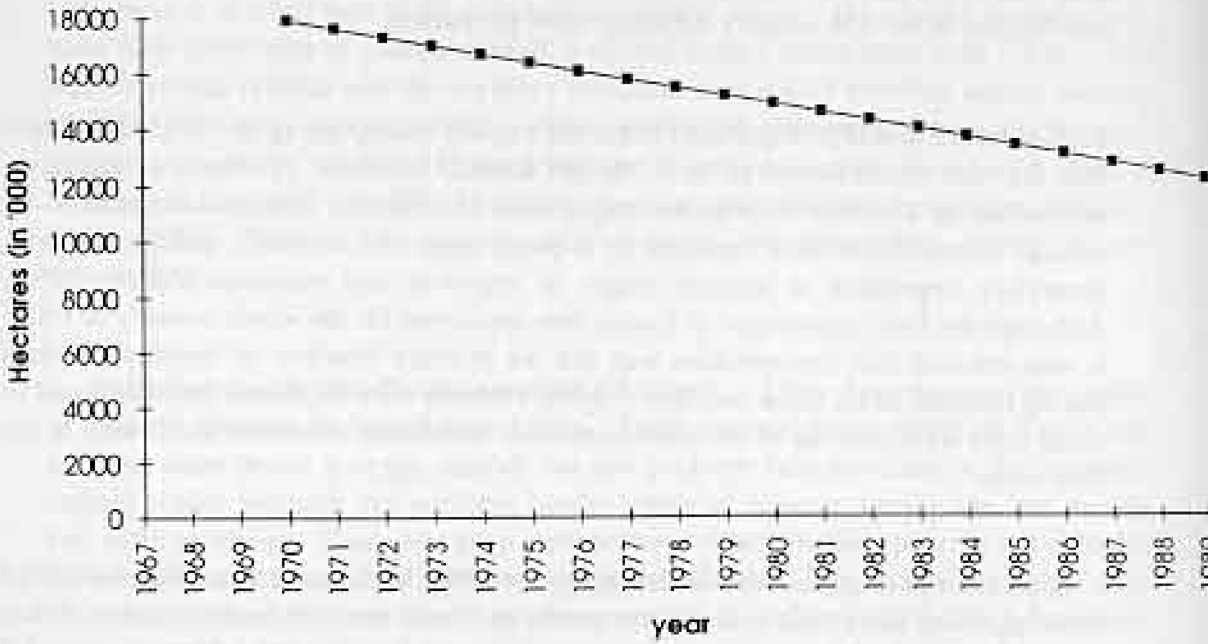
Fragile tropical topsoils are lost in the flood of heavy rainfalls which break soil particles loose, carrying them as silt into water systems which dam up, and even disappear. Thus one can see that changes in rainfall are only one aspect of climatic changes in moisture patterns. Drying of flowing water systems meant that the entire cycle of rainfall, evapotranspiration and intra-soil absorption is altered. Soil erosion causes the land to loose its permeability, particularly when layers of vegetation which had previously decayed and replenished the soil in forested areas no longer protect the surface. In turn, increasing lack of permeability means that rainfalls become more destructive. Water that is not absorbed and utilized by vegetation becomes a hazard as flooding over the surface further erodes the land, carving out gullies which increase in size with every rainfall and with each passing year, further degrading the land and ecosystem. Deforestation across Africa had these chains of consequences and Nigeria is but one country suffering from the pattern.

b. Nigerian Forestry: Nigeria's forests are rapidly disappearing and it is speculated that the rate of deforestation is 2.7%. (FORMECU, 1989) Perhaps a vegetation untouched by a human activity no longer exists in Nigeria. Today, what used to be natural forests have been reduced to a patchwork of farmlands, plantations, and secondary vegetation at various stages of regrowth and maturity. (NEST, 1991) Although the first conservator of forests was appointed for the whole country in 1902, it was obvious that conservation was not the primary function of forestry officials during colonial times since much of Nigeria's forests were exploited for export and in those days were just one of the many resources which had interested the British in the first place.

In an attempt to protect the dwindling forests from total destruction, legislation had been launched since then to create the numerous forest reserves in the country. It has been substantiated that the colonial forest policy had succeeded in demarcating 8.6 million hectares of forests as forest reserves, scattered all over the country and that only an additional one million hectares of new reserves have been added since Nigerian independence. The total area of forest reserves in Nigeria today is about 10% of the total land area of the country. The question then arises, what impacts are increasing population, changing agricultural patterns, urbanization, modern development and industrialization having on the remaining forests?

c. Deforestation: Large scale exploitation of timber from Nigerian forests started during the colonial period and timber exportation was intensified after the second World War. The Nigerian government prohibited the exportation of timber, and strictly regulated the exploitation of forest products in the 1970's. Unfortunately most of the trees had already been felled and exported. There have been other forms of large-scale deforestation that have occurred for reasons other than exploitation and exportation. The need for expansion of farm lands to meet the agricultural demands of the increasing population in rural areas, and the need for food for urban dwellers have been a major cause of deforestation. The fallow system of allowing fields to regenerate in wild vegetation for many years has been shortened and almost abandoned as farm land becomes scarce. (see fig. 5) There has been rapid deterioration of forest cover in Nigeria since the mid 1960s to the present.

Figure 5. Forest area trend in Nigeria. Data from WRI, 1992-93.



Overgrazing of the arid lands in the North has exacerbated the trend of desertification, which expands southwards into the savannah regions with each passing year. In a zone where rain, streams and vegetation are already scarce, it is all the more important to protect whatever plant life already exists to act as a stabilizing influence on soil and moisture patterns. The root systems and leaf cover of any vegetation, protect the particles of sandy soil from erosion caused by wind or rain. Overgrazing has tragic consequences when herds of domestic animals are allowed to multiply, beyond the carrying capacity of the land. Figure 6 shows the trend of cattle raised in Nigeria. It is interesting to note the high volatility in number reflecting the climatic changes in the sahelian region. Here again, increases in population lead to another form of land pressure, encroachment on the equally delicate ecosystem of an arid land that cannot be denuded of vegetation without becoming virtually uninhabitable.

Some observers have stressed caution in overblaming nomads for overgrazing, a view that was predominant in the 1970's. More recent analysis has shown that overgrazing is only part of the problem, and that attempts to settle nomads permanently, with ranching or agriculture, or to otherwise interfere with their traditional living patterns, worsens environmental degradation and destabilizes their lives. (Timberlake, 1986)

Figure 6. Total cattle population in Nigeria, 1967-1990. Data from WRI, 1992-93.

Industrialization has contributed to deforestation. Wood is the most important commercial product obtained from the forest. In 1985, the world's total wood removals were 3.2 billion cubic meters of which 1.5 billion were harvested for industrial purposes. A slightly larger volume (1.7 billion cubic meters) was burned for fuel. (The World Resources Institute and the International Institute for Environment and Development, in collaboration with the United Nations Environment Programme, 1988) The Nigerian total industrial consumption of forest wood is estimated by the Federal Department of Forestry to be approximately 5 million metric tons per year. This wood supplies the nation's needs for paper and building materials required for the rapid growth in economic development, and urbanization in general. Two large paper mills, commissioned by the federal government, 25 large private saw mills and an additional 1,000 smaller mills process the wood materials.

In Africa, about 90% of the population relies on fuelwood for their cooking needs (American Embassy Report, 1986). It has been estimated that this figure is slightly lower in Nigeria today because the domestic oil industry and the development of domestic refining capacity have allowed consumers to substitute cooking fuel for wood, especially in urban areas. In spite of its availability, it is still not economically feasible for the rural majority to afford this luxury. It is far more economical for a farming family to cut a tree or search for fallen branches than to purchase fuel at any price. As the rural population increases, more demands are placed on remaining wooded areas near villages when fallen dead wood becomes insufficient for everyone's needs. (see fig.7)

Figure 7. A firewood market near a village. Photographs from NEST, 1991.

Bush fires also are very damaging to the remaining forests and these are periodic, recurring, "natural" phenomena, especially in the dry season. It is said that over 70% of Nigerian land covered by savannah is burned annually (American Embassy Report, 1986). These fires are natural when they are set by lightening or storms but in most cases are deliberately set by farmers or hunters for their own selfish ends, with disastrous consequences to the environment. There have been laws prohibiting bush burning but lack of enforcement and the education to enlighten the rural population has militated against such sanctions.

d. Reforestation: This is a major means of countering deforestation and reduction in vegetative cover. Nwoboshi (1986) shows that a total of 30,000 hectares or about 10% of the annual deforestation rate has been reforested. The large gap between deforestation and reforestation stems from "lack of funding, lack of cooperation from the land users, and lack of appreciation by the public .... as well as the narrow perception of forestry practice by foresters." Currently federal and state governments are embarking on various forestry projects in their efforts to tackle the problems of deforestation.

THE IMPACTS OF DEFORESTATION IN NIGERIA

A sustainable development is a path of human progress that meets the needs and aspirations of the present generation without compromising the ability or chances of future generations to meet their needs.(Brown, 1990; World Commission on Environment and Development, 1987) The forest has been unsustainably used in Nigeria for many years. This has resulted in the enormous environmental crisis situation which Nigeria faces today. The land degradation problems arose from a combination of physical factors, and intensive and cattle pressures on land. (Forestry Management, Evaluation and Coordinating Unit, 1989) Although "natural disaster" has been applied to the many forms which the crisis takes, a closer look will show that these disasters have human activities as their main cause. Deforestation and unsustainable land use patterns have had the following consequences:

a. Soil: The fragile nature of tropical soils, easily prone to erosion and depletion of nutrients if not carefully protected, makes them particularly vulnerable when population pressures cause deforestation and a shortening of the fallow period. Soil erosion is a quiet crisis. Its impact is gradual but over time results in the same tragic consequences that are reminiscent of those of drought and famine. Two major types of soil erosions in Nigeria are wind and fluvial erosions. Wind erosion is more pronounced in the northern savannah while fluvial erosion, consisting of sheet, rill and gully erosions, is more common in the rainforest zones in the south.

Nigeria has, in recent times, expended huge sums of its limited resources to combat the effects of erosion. Contracts for millions of Naira are awarded to build retaining walls of concrete once a gully has reached many miles in length and breadth, having engulfed entire villages and countless farmlands which plunged into its cavernous depths - an exercise in futility. The government has not designed a system of enforceable laws and guidelines strictly governing construction activities for roads and buildings, protecting vegetation from bushfire, overgrazing and deforestation, and protecting critical areas, particularly in the watersheds, which are known erosion points. Education of the public to help the average citizen understand the causes, consequences and prevention of erosion would be the most effective channel for government intervention. Waiting to pour money into a soil erosion disaster site, with soils that are collapsing in a momentum that cannot be reversed once it has gained such strength, is poor resource management and planning. Unfortunately, such gullies are highly visible, whereas the gradual erosion by wind and rain in the northern regions and sheet erosion which removes topsoil from farmlands in southern regions, attract little attention.

It has been estimated that soil erosion causes a loss of 30 million tons of soil annually within the eastern states of Nigeria, accounting for half of the total annual loss in the country. (Kio and Okorie, 1986) The arid zones in northern Nigeria are also vulnerable, although little exact information is available on the loss.

"Soil erosion, which is perhaps the most dramatic symptom of environmental malaise, threatens to force millions more African farmers into landless destitution. By the year 2000, current rates of erosion, if unchecked, are projected to reduce the population carrying capacity of much of semi-arid Africa by a stunning 30 to 50 percent." (Lemma, 1988; Harrison, 1987)

Northern Nigeria is included in this region and it can be expected that desertification, further loss of vegetation cover and arable land will result as soil erosion continues. Sheet erosion in southern regions will equally account for significant loss of arable land, precisely at a time when population pressures require more land of sufficiently protected fertility and arability to sustain increasing numbers of people.

b. Rivers and Other Water Sources: Forests protect rivers and other water systems from siltation by eroding soils. This load of soil is deposited in the streams, rivers and, eventually to the sea. In effect, the most precious topsoil, containing the nutrients which have accumulated over centuries of decay, and which sustain the health of crops and the people who eat them, is lost to the floors of valleys, river and the ocean. Not only is the soil lost from the land, but the entire ecosystems around water systems are altered, with devastating consequences.

A frightening evidence of deforestation, erosion and siltation is the disappearance of the main water sources which people depend on in thousands of villages across Nigeria. (personal communication) This has occurred primarily because of changes in land use patterns, reduction in the fallow period and encroachment of farming into areas of watershed critical to the protection of streams. Farming now occurs even on steep hillsides leading down to streams and in most areas, no provision has been made for terracing and ridging to prevent topsoils from flowing directly into water systems.

The best forms of protection of water systems, through prevention of further soil erosion and siltation, would be community-wide education campaigns and campaigns to stop deforestation and farming in watershed zones, particularly on slopes above valleys with water systems. Apeldoorn (1981), after a thorough analysis of agricultural crises and famines in Nigeria, recommended that planning to prevent future disasters should be done with the people. "The community has to be involved and proposed changes must act on the ecological system as a whole, not on isolated parts of it. Strategies must be based on the total local environment."

This should include community-wide participation of citizens in replanting those same areas with trees and vegetation. An informed and committed local leadership and the inclusion of women's associations, all local farmers and schoolchildren would ensure that the lessons in soil and water conservation are internalized in the population which directly influences the land, and applied directly in a change of daily land use practices at the village level.

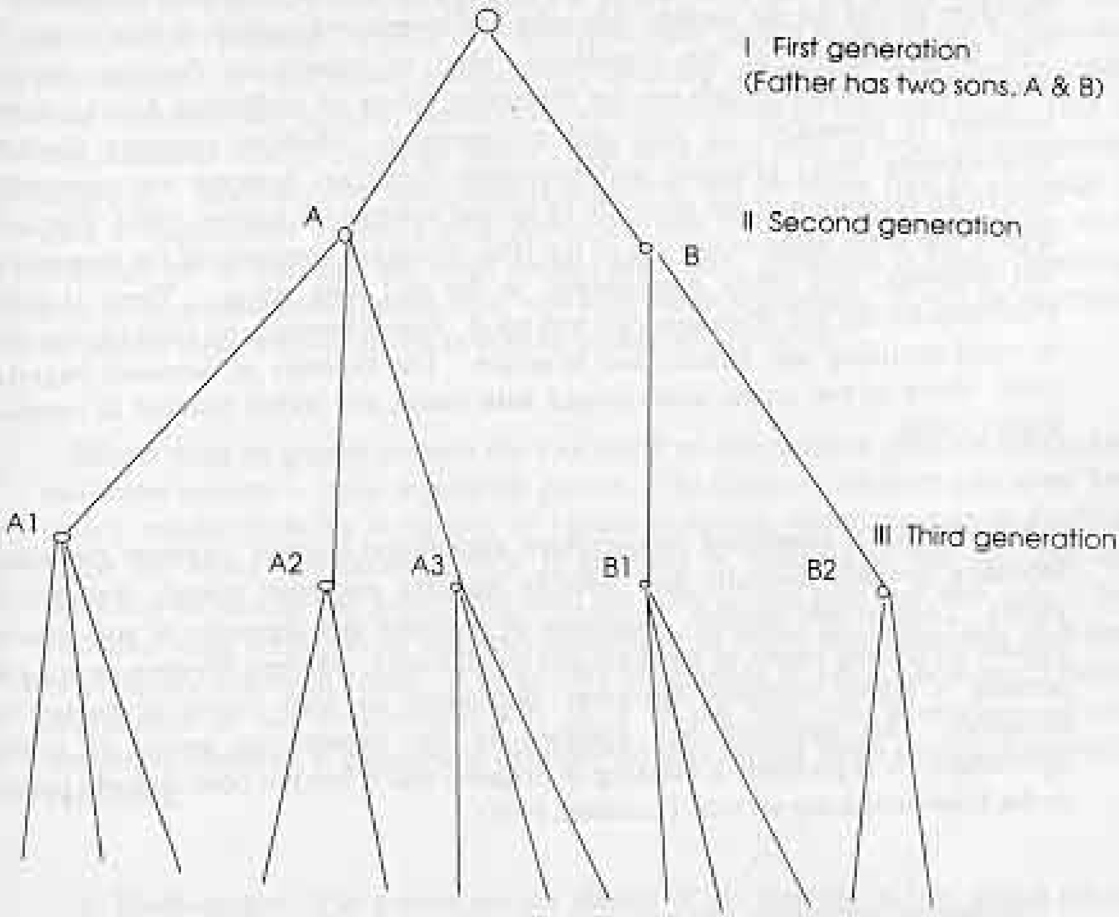
Reaching the people with such education and demonstration projects will necessitate a serious commitment by government to establish linkages from research and educational institutions in forestry and agriculture directly to the rural citizenry who are to learn, embrace and practice conservation. Policies must adequately address the various forces which militate against active peoples' participation and involvement in conservation efforts. Not only must the educational institutions and research stations be better supported with sufficient funding, but the extensions workers, must be trained in vast numbers and supported. This will necessitate a significant redirecting of funds towards prevention of erosion, siltation and loss of water systems by an enlightened leadership which has the vision to recognize the present and impending crisis.

Timberlake (1986) has cautioned that extension service in African nations in general has "two contradictory failings: It is often wrong and it is often unavailable. African governments spend too little on it." He points out that they often lack the practical knowledge that will really help farmers, a prerequisite if working relationships of mutual respect are to be established. Often the advice brought by extension workers is from foreign experts or research oriented personnel from institutes and research facilities. It can be incorrect, maladapted to idiosyncrasies of local regions and even damaging to the environment. Many extension service projects, funded lavishly by government, and international agencies, were based on ill-conceived notions for improving crop yields, and did not succeed because they were inappropriate and maladapted to local conditions. International and Nigerian research institutions are certainly making valuable contributions, but care needs to be taken in selecting the areas of knowledge of sustainable agriculture and forestry to be stressed in the future by extension workers who actually teach the people.

c. Agriculture: In the agricultural sector, the population had, in the face of economic strangulation, exhausted the land frontier in most parts of the country. People had continued to engage in traditional agriculture, but abandoned the traditional practices of conservation that had protected the environment in past generations. The rapid population growth had necessitated the diminution of the available arable lands and their overuse. With the land frontier gone, families now share inherited land of ever smaller portions.

In Nigeria land is inherited by offspring who must equitably distribute portions of land, leading to fragmentation of farms into many small landholdings which are being divided and redivided with each succeeding generation.(see Fig. 8) People used many devices to cope with this reduction in per capita land availability, including expansion in the area under cultivation, reduction of fallow periods, cultivation of virgin land or intensive cultivation of permanent fields, characterized by land investments for terracing, drainage, irrigation and intensive manuring systems, as well as mechanization. Agricultural technologies and methods, imported from adaptations from abroad, or from international and national research stations have not generally reached the average small farmer who still continues with the traditional subsistence farming methods.

Figure 8. Land inheritance and progressive reduction in land available per heir. Based on U. M. Igbozuruike, "Land inheritance and land alienation in parts of Imo State, Nigeria," School of Environmental Studies, Imo State University, Okigwe, 1987.



It may be expected that permanent cultivation, characterized by intensive agriculture and mechanization, will continue to elude the country, knowing the traditions and culture of the people unless a committed government adopts and supports appropriate adaptations of innovative ideas and technologies. Experts are now recommending that mechanized agriculture be promoted with extreme caution, however, and only if such introduction of harsh, destabilizing forces to delicate lands be accompanied by prevention of soil erosion which occurs when large tracts of land are cleared for agribusiness and mechanization.

For some years after Nigeria had gained independence, there had been a mad rush for imported agricultural technology and methods, stressing plantation farming and monoculture for crops for export, with the hope that this could increase yields and therefore profits for the wealthy few who had investment capitals in this sector. The vast rural majority of the population, used to subsistence farming, remained untouched. Lambert points out the protective values of traditional African farming methods in protection of soils and environment. "Multiple cropping (including intercropping, relay cropping and sequential cropping) systems are essentially a simplified recreation of the diversity of natural systems."(Lambert, 1988) The author argues that these make better use of the land, minimize competition for nutrients and soil moisture, and return nourishment to the soil with decay. There is greater protection for the soil from sun, rain and wind. Monocropping, by contrast, can result in rapid declining soil fertility and structure. The example of Northern Nigeria is cited, where cotton crops, intercropped with maize and millet resulted in combined higher yields.

Maintaining a simplified monoculture agricultural system, against the natural tendency towards diversity and stability requires excessive energy and resource inputs. Loss of soil fertility, depletion of nutrients and alteration of soil structure require increasing inputs of fertilizer and conditioners. Modern Western farming has become a highly complex operation, depending on high inputs of energy and resources. This approach has operated in the export-crop sector of tropical agriculture. It is probably a blessing in disguise that it has not been actively pursued in the food-producing sectors. (Lambert, 1988)

Subsistence agriculture can only support a slow, steadily growing population, but not an exploding population that reaches beyond the carrying capacity of land in rural areas, and creates a rising demand for food among urban dwellers. Drake (1992) surmises that for each of the sectors in the family of transitions, there is "a critical period when society is especially vulnerable and during that period, rates of change are high, societal adaptive capacity is limited, in part, due to this rapid change." In such a period, it is possible that the "key relationships in the dynamic become severely imbalanced." In Nigeria both rural and urban populations combined have more needs for food today, necessitating the importation of much of her food.

To worsen this situation, many arable lands are being converted for other purposes, with the advent of urbanization, industrialization and modern development.

Buildings, markets, schools, roads and factories are but a few examples of encroachment on previously arable land which further reduces the total available area for cultivation. It is population pressure, combined with changing standards of living accompanying development, which has caused these forms of land diminution and culminated in the intensive and non-sustainable use of farmlands. Deforestation, soil erosion, lack of rain and decreasing permeability of soils, along with other climatic changes, have grossly affected agricultural productivity and the entire economic base in this sector. Humans, by their own activities, have caused losses in soil fertility and depreciations in agricultural productivity, resulting in poverty, migration to cities, food insecurity and scarcity, malnutrition and dependence on imported food. This, in turn, exhausts foreign exchange which could have been used in other developmental programs. Ironically, the more land is degraded, and the more foreign exchange is used to supplement Nigeria's own yields, the less resources are likely to be made available for investments and other social causes like, programs in family planning, education, environmental protection, and sustainable agriculture. It will be necessary to support these areas if the cycle is to be broken and reversed.

Efforts must be geared towards the root cause of this massive pressure on the land and water systems -- rapid population growth. The chain of consequences noted here clearly results from the expansion of human activities, under pressure to feed and house the rising population. What is alarming is recognition that the land was sufficient to sustain the population until the very recent past and that only a few variables were needed to so seriously destabilize an entire ecosystem that took eons of planetary history to create. It takes little imagination to project how much further degradation of the environment will occur in the next few generations of ever increasing numbers, if agricultural demands on land further strain its ever diminishing capacities.

d. Biodiversity: The forests are the abodes of all varieties of life, which coexist prudently to maintain a natural equilibrium. Any form of deforestation dislodges this balance and jeopardizes the survival of species of animals and plants. Humans, by their activities in Nigeria perhaps have caused a rapid rate of extinction. As such vast portions of the original rainforests have disappeared, so have the flora and fauna which they harbored been equally threatened.

Although Nigeria has created some protected forest reserves (10% of the original total forested area), efforts must be made to educate her public on the need for preservation and conservation of what is remaining. There has been little research to document how much of Nigeria's biodiversity has gone into extinction or is in danger of disappearing. There is no doubt that much damage has already been done.

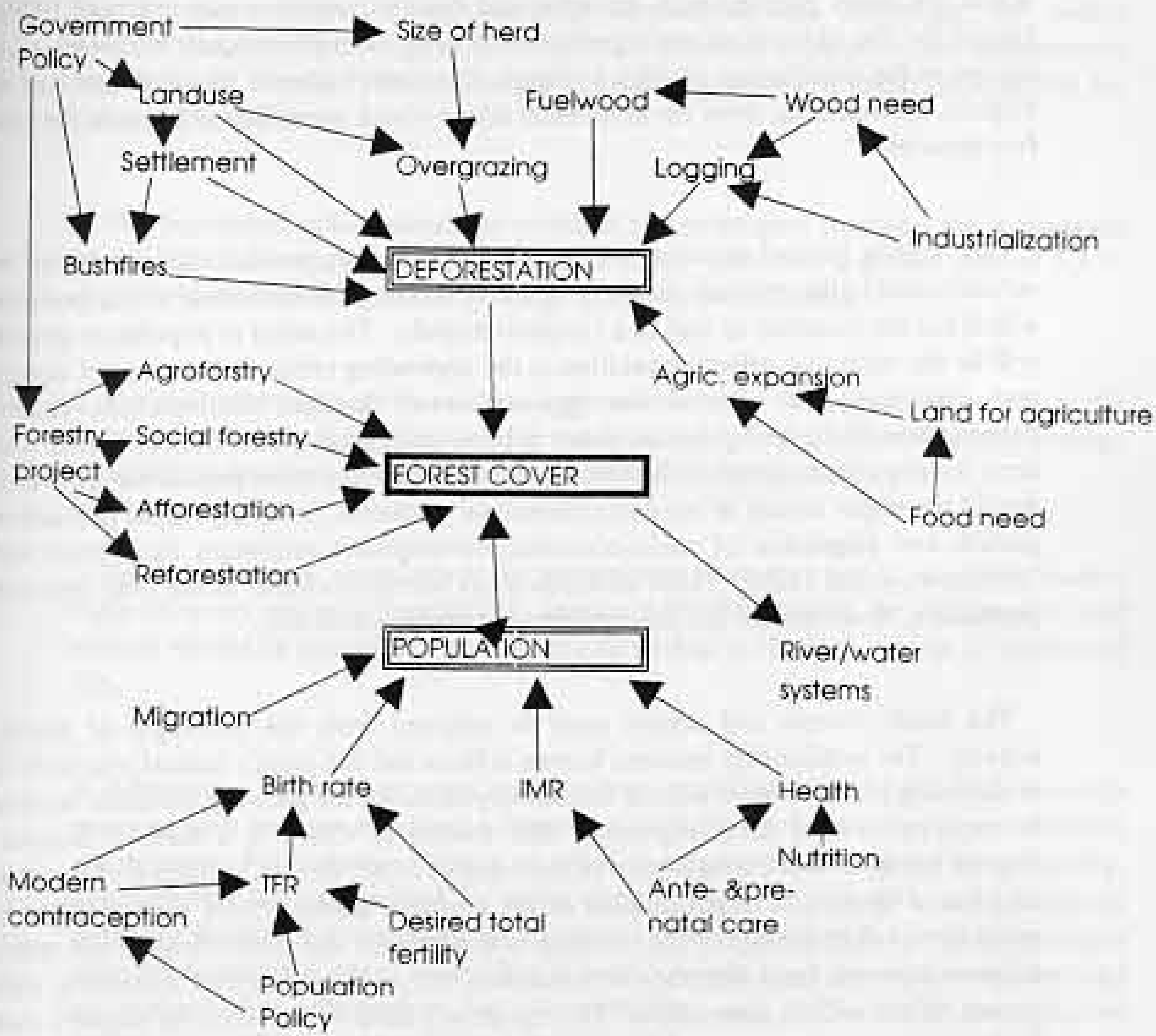
INTERRELATIONSHIPS : schematic representations.

The identification of the causes and mechanics of environmental bankruptcy is a prerequisite to the formulation of preventive measures and remedies. Ecological events unfold quietly, and almost imperceptibly, presenting an enigma to the untrained eye. Understanding the interaction between human activities and the natural environment requires an analytic approach and multidisciplinary inquiry. What happened and continues happening to Nigeria's environment is the result of a complex web of interactions which this paper could only explore in a superficial way. The more research and analysis can utilize holistic approaches, considering the grand harmony in nature's original design of ecosystems, the greater the chance of discovering explanations and answers for environmental problems. Discerning the relationships and interconnections is a fundamental step towards striking a balance between human plans and environmental capacities.

The Club of Rome's Report, *Beyond Famine*, stresses such a holistic approach for the gathering and sharing of research among scientists and policy-makers in different areas of discipline who share the common goal of protecting the environment and population of Africa from further crises (Lemma, 1988). The long term goal of preserving Nigeria's environment so that the needs of future generations are not compromised, will necessitate the adaptation by its leaders and research scientists, of methods of communication and information sharing which the international community of scientists and policy-makers are now developing. Effective policy must be based on a larger comprehension of interconnectedness of all life forms, reduced to understandable terms where the most important variables responsible for environmental destruction can be addressed as priorities.

Expanding population, deforestation and pressures of development without accompanying measures to protect the environment from the impact of modern technology, are such key variables which have been identified as primary agents of environmental degradation. Correcting the situation will necessitate a focus of attention and resources in these areas which so dramatically influence the web of interconnected life in Nigeria's ecosystem.(see Fig. 9)

Figure 9. Schematic representations



CONCLUSION AND POLICY IMPLICATIONS

The fate of Nigeria's environment hangs in the balance. Ethiopia and Somalia, which are today plagued with droughts and famines, were as recent as the 1930s, known for the richness of their genetic diversity. Drought-stricken Mali was once known as the breadbasket of Africa. Niger, Chad and Sudan to the north and east of Nigeria, are suffering from environmental crises which were non- existent in the past few decades.

Has Nigeria learned any lessons from these victims? A positive affirmation can be substantiated in the way and manner Nigeria is tackling the root cause of this problem which has the potential to lead to a common tragedy. The arrest of population growth will be the most cost-effective solution to the impending crisis. No amount of energy and resources will reverse the environmental damages and prevent further deterioration of the land if the increases in population pressure are not controlled. The need for population control arises from two reasons. First, rapid population growth is one of the major causes of most environmental problems. Secondly, rapid population growth and stagnation of socio-economic development reinforces each other and "creates a vicious cycle." These understandings are made clearer as the links between population, development and environment are better articulated.

The lands, forests and waters must be relieved from the onslaught of human activity. The relationship between human actions and the earth's natural resources is at a turning point. Nature cannot indefinitely sustain ever growing demands beyond its capacity to heal itself, regenerate and constantly return to a state of balance. Nigeria has been witnessing a pace of destruction of her forests, denuding of the soil, siltation of rivers and desertification of the northern border. These have resulted in much irreversible damages. The warning is that erosion and desertification can reach points where the earth becomes so hardened, dry and parched that replanting with human efforts will be impossible. The region will have to wait eons for nature's own healing process to regenerate what took Earth's history to design. That region would be virtually uninhabitable if it looses the capacity to nurture and sustain vegetation.

There seem to be great odds against a vision of a re-balanced ecology, economy and agriculture in Nigeria. Fortunately there are many optimistic signs that recognition of the crisis proportions of the problem is helping leaders and citizens, educated and uneducated, to embrace solutions. The search for ecologically sound answers has yielded numerous local success stories. Community and agro-forestry projects, reforestation campaigns, media attention to the problems of overpopulation, deforestation and soil erosion, and recent policies by the Nigerian government to stress family planning and reforestation are but a few examples of optimistic signs.

Despite these efforts, I speculatively recommend the following for policy considerations in an attempt to harmonize the dynamic population and environment transitions in Nigeria. These ideas are not the only truth and could be modified for easier applicability.

1. The population policy should be revisited and redesigned to reflect the seriousness of the population burden. A doubling time of 21 years and a growth rate of 3.3 % depict a bleak future for a country whose economy is in shambles.

2. National efforts should be made to aggressively lower the population growth to 2.5 in the next decade through a massive media campaign, aggressive family plannings and public education. Funding must be provided for this purpose.

3. Formal education, especially at the primary and secondary levels, should be made a right of every citizen. Specifically, female education should be encouraged, and women should be provided with opportunities equal to those of men in all spheres of life.

4. Admittedly, Nigeria has many conservation organizations and laws. Unfortunately many of such laws are not given a deserving publicity neither are they given effective enforcement. For instance, there is no effort to enforce the law against bush burning, although this law has existed for some decades now. An intensive and continuous publicity should be given to all the existing conservation laws while more stringent ones are formulated. Mass media, TV, schools, churches and mosques should be used as avenues for propagating and disseminating such information. An effective enforcement effort must be planned and executed.

5. State and national governments should not only be concerned with the improvement of qualities of life in the urban cities but also those of the local and rural populations. Rural infrastructures like feeder roads, water, clinics, schools, and electricity should be created to improve the rural standard of living. This will not only enhance their quality of life but also discourage the urban migration of the youths.

6. No amount of forest dereservation will solve the problem of land hunger and meet the needs of a massive subsistence farming method. Low credits and fertilizers could be provided to enable the farmers use their available land intensively.

7. More forestry programs like agroforestry, social forestry, afforestation and reforestation, should be engaged at all the levels of government - local, state and federal. As in family planning, such forestry needs, practices and benefits should be included in the educational curricula and taught in all formal and informal educational systems in the country.

8. Forestry programs should be specifically designed to include women in all facets. The colonial forestry legacy of "only men for forestry" should be discarded.

9. Attempts should be made to educate the nomads on the need for a sustainable use of the land. The herd population and the migratory movements of the nomads should be monitored and regulated.

10. Environmental education and consciousness should be instituted among all classes, ages and peoples of Nigeria.

11. The operations of environmental non-governmental organizations should be encouraged and motivated.

Individuals, organizations and nations, as well as international efforts in cooperation among nations are demonstrating the concern, will and dedication to take similar steps to right the environmental wrongs and ensure a sustainable development. The recently concluded UNCED in Rio, Brazil, is a pointer to the seriousness of global and national environmental deterioration and the urgency for its remediation.

Keeping a unified vision of the contribution of each effort in the scheme of rebalancing the Nigerian environment is essential. Discerning and working on the primary causes of environmental deterioration will yield the greatest returns and help avoid cosmetic or superficial action-plans, or wasting of valuable resources that should be directed at the underlying causes of the problem. Causes rather than symptoms should be cured. There is now hope that the full dimensions of the crisis, and the potential, irreversible nature of the damages are being fully articulated. More than ever, there is the need to focus research, policy, and all action plans on the long-range solutions, keeping national commitment and priorities on the responsibility to protect Nigeria's environment for future generations.

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CHAPTER 10: HURNG-JYUHN WANG

THE CULTIVATED LAND-RURAL INDUSTRIALIZATION-URBANIZATION-POPULATION DYNAMICS IN TAIWAN

10-1. Introduction

For decades, Taiwan has been successful in economical development. The success has been attributed to its hardworking and educated population. A series of policies beginning with Land Reform and encouraging the wealthy to invest in industries also deserve attention. Growth of high-tech industries and production of quality goods are considered essential for continuing an economic growth in Taiwan (Galenson, 1992). However, the country faces some challenges after decades of rapid industrialization. Because of the country's scarcity in natural resources and the degradation of its environments, there is concern about long term sustanability.

For Taiwan those challenges are even more immediate and acute because of high population density. Over 20 million people who must live, work, and go about life on a small island of 36,000 square kilometers; an area smaller than the Netherlands. Does the government have population policy to deal with population growth? What is her demographic transition pattern? How many people are able to live on this island with sufficient life-supporting food, goods, and health environments?

If population growth is not managed, the limited cultivated land has to supply at least part of the life-supporting food, while active industrial sectors expand everywhere. The more intense and broad rural industrialization is, the more there is degradation of living environments. Moreover, the industrialization produces its by-product, pollution, affecting urban as well as rural areas.

In summary, the dynamic of cultivated land transition involves many sectors. In Taiwan, rural industrialization and urbanization are driving forces. Agricultural transition approaches its maximum production per hectare. Rural labor force induces the bases of rural industrialization and rural to urban migration.

10-2 The Demographic Transition

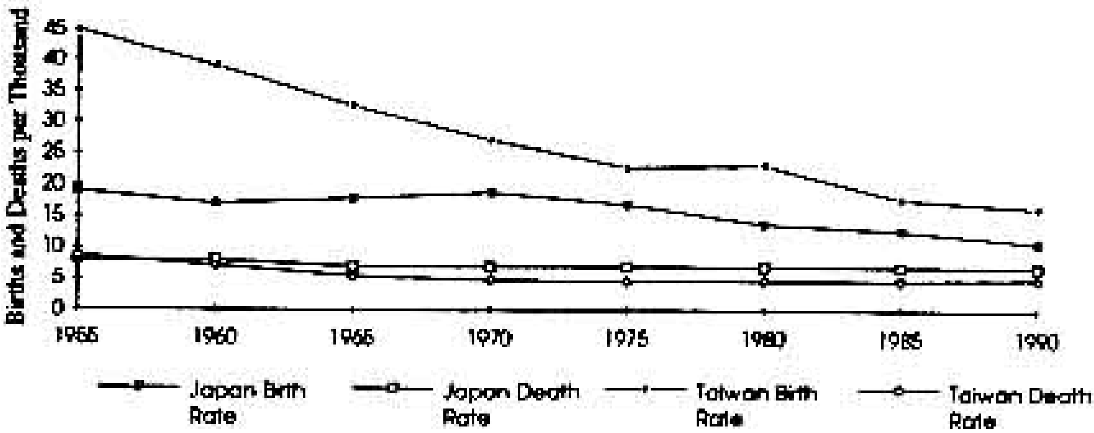
10-2-1 Introduction:

Demographers have postulated from population transitin patterns a theory called the demographic transition. According to this theory, at low levels of industrialization countries both fertility and mortality are high, and population growth is slow. As nutrition and health services improve, the death rate falls. Birth rates lag behind by a generation or two, opening a gap between fertility and mortality that produces rapid population growth. At the last stage, as people's lives and lifestyles evolve into a fully industrial mode (or well educated), birth rates fall too, and the population growth rate slows again (Meadows et al., 1992). In viewing Taiwan statistical data, her demographic transition has showed a very small gap between death and birth rate in the 1990s. Births per thousand are 16.6, deaths per thousand are 5.2. Population grows at a rate of 1.13%. Is Taiwan's population going to a steady state? What is her demographic transition pattern? Those are interesting questions to begin with.

10-2-2 Demographic Transition in Taiwan

Demographic transition is the pattern of birth rate and death rate. In order to better understand Taiwan's Demographic transition, I take Japan's demographic transition for comparison. The choice of Japan is based on several reasons. Taiwan and Japan have similar cultural background, the same experience on the economic growth beginning at different years, and the same topography consisting of mountains over half of their total areas. Fig 10-1 shows that two countries have similar patterns of birth and death rates. However, the demographic transition pattern in Taiwan is unique. Fig 10-2 shows that her birth rate and death rate converge within a very short time period as compared to some developed countries.

Fig 10-1 Demographic Transition Taiwan vs. Japan 1955-1990



Sources: Taiwan Statistical Data Book 1991, Table 2-3 and Okazaki 1990, Fig 2

I pick 35 years data and divide the transition into three stages. Fig 3 presents this three-stages transition. Phase I (1955-1965) has a high birth rate and high death rate. During this period, the postwar baby boom[1] increases the birth rate to about 40 per thousand per year. While the high death rate of about 9 per thousand per year average has partly offset the birth rate, the population keeps the growth rate in a range around 3%-4% per year.

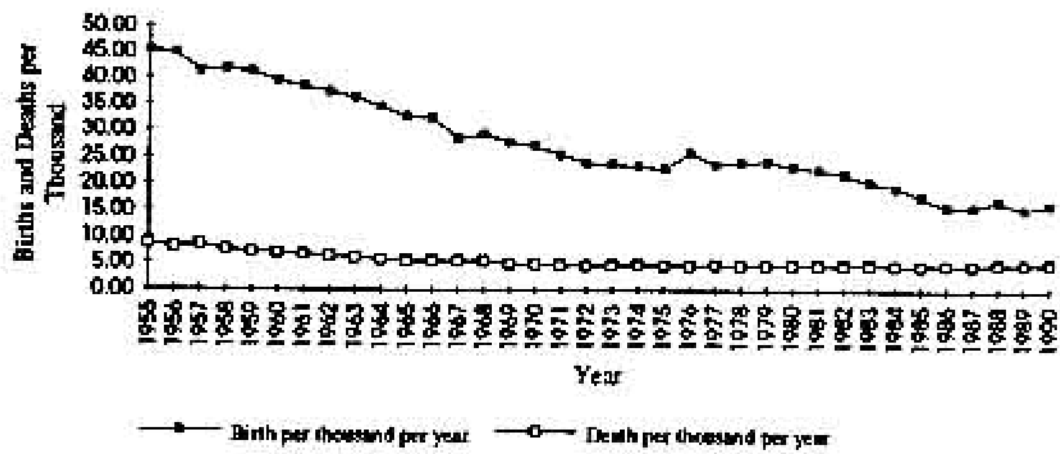
Phase II (1966-1980) presents a transition of moderate birth rate and a low death rate. In the later 1960s and 1970s, the birth rate declines to 25-30 per thousand per year. The death rate reaches a plateau of around 5 per thousand per year. The population growth rate declines into a range of around 2%-3% per year.

Phase III (1981-1990) reaches a stable low birth rate and low death rate. Entering 1980s, the birth rate continuous to decline in the early 1980s, reaching to the historical lowest point of 15 per thousand per year at 1986. The long-steady death rate since 1970 starts a slow increase from 4.9 to 5.2 per thousand per year in the 1987[2]. The population growth rate in this period ranges from 1%-2% per year.

[1]Young age group (age under 15) counts 43.4% of total population in year 1955 and has slight growth during this period.

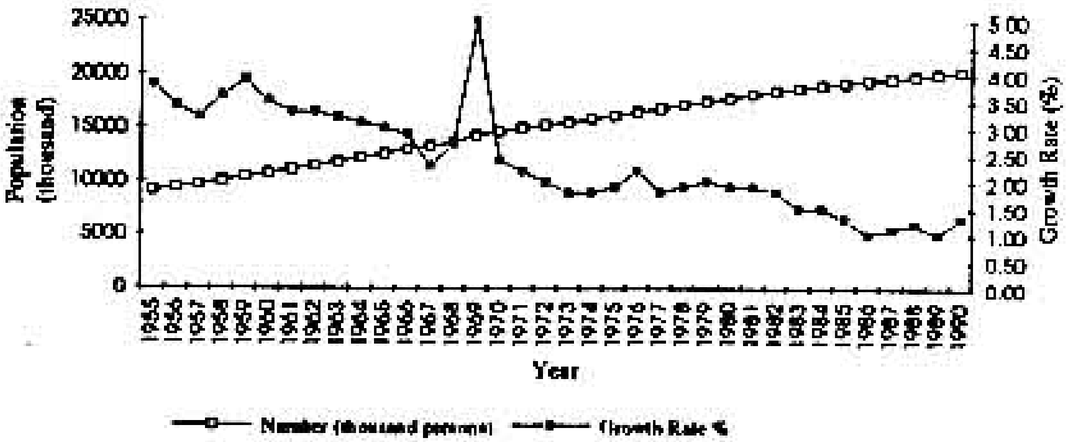
[2]This is considered the aging population (age over 65). During this period, aged population percentage rises to 6.2% comparing 0.1% aged population percentage in the period 1955-1965.

Fig 10-2 Demographic Transition in Taiwan



Source: Taiwan Statistical Data Book 1991, Table 2-3

Fig 10-3 Population Transition and Growth Rate in Taiwan 1955-1990

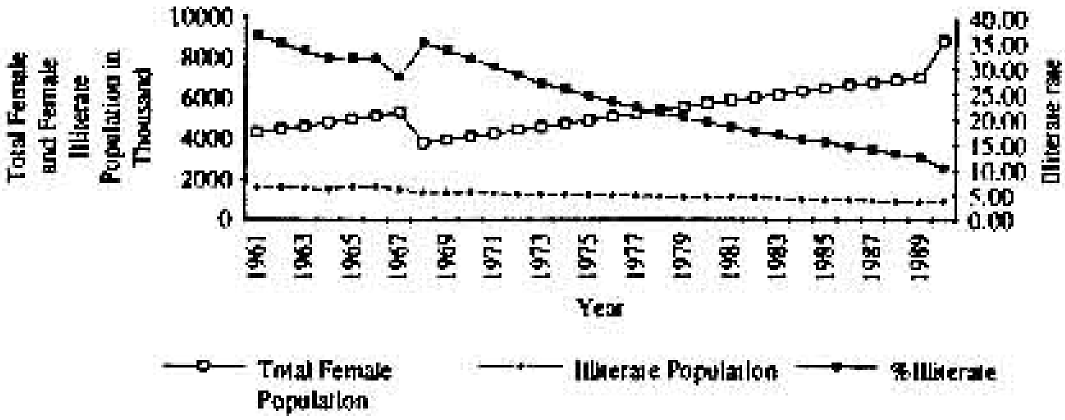


Source: Taiwan Statistical Data Book 1991 (1955-1990[3]), Table 2-2

[3]Beginning in 1969 the figures include armed forces living on military bases and inmates of institutions which were omitted previously. This accounts for the exceptionally high growth rate for that year.

William Drake states in his paper "In North America, where death rate reductions were more gradual, birth rates decreased without much influence by public policy" (Drake, 1992). However, the family program effectively starting in the 1960s is the key to reducing the birth rate in Taiwan (Freedman et al, 1974, Davis, 1967). Education of childbearing age women is considered as another factor contributing to the continuous decline in the birth rate. Fig 10-4 portarys the illiteracy rate of female and female population above free school age from 1961-1990.

Fig 10-4 Female Illiterate Population Above Free School Age in Taiwan



Sources: Statistical Yearbook R.O.C. 1991[4], Table 7

Because the family program is the key to the demographic transition in Taiwan, it is important to review Taiwan's population policy in the past few decades. As I mentioned earlier, the family planning program and percentage of women above the level of illiterate, are two important factors that cause the birth rate to decline substantially. However, when the family planning program expanded in the early 1960s, it encountered tremendous obstacles. I summarize Li's (1988) findings. These are (1) An effort to control population growth has been hindered by Chinese ethics, culture. (2) Many people believed, in the 1960s, that if the food supply is adequate, population control and family planning are not necessary. (3) A population decline is the same as to weaken the country's military strength. In other words, to allege birth control is not adaptable (Li, 1988). Because of those obstacles the government's attitude was neutral in the mid 1950s. The government would not openly advocate a family program or adopt a population control policy, but it would not interfere with those people who practiced birth control.

[4]Beginning in 1967 the total years of the compulsory education were raised from 6 years to 9 years. Therefore, the total female population above free school age decreases. As a sequency, the rate of illiterate female increases.

The first official step for a family planning program came in 1954 with the establishment of the China Family Planning Association whose aim was to introduce wives of military dependents to the idea that family planning had benefits to avoid illegal abortion as well as family burden. In 1959, the governor of Taiwan province agreed to set up Pregnancy Health Services (PHS) at local public health stations, which then took over the main task of promoting family planning programs. It was not officially endorsed by the central government, although the PHS program was operated under local public health station.

Also, in the same year (1959) the Joint Commission on Rural Reconstruction (founded by American Aids) and the provincial health department founded a family planning program in Nantou, an agricultural area in central Taiwan, under Pregnancy Health Service. By 1963 this health service had expanded as part of the maternal and child health program. PPH workers would educate women on contraceptive methods during visits to their homes. Throughout the 1950s and 1960s, the Pregnancy Health Service played a key role in promoting family planning.

The major successful step was in 1964, the provincial government reached an agreement with Council for International Economic Cooperation and Development to support and fund a five-year program to carry out an island-wide family planning program emphasizing the use of the Lippes Loop (an IUD). During the 1964-1972 period, over 45 percent of married women were provided with IUD, while another 3 percent unable to use them were given oral contraceptive (Li, 1988). They set a goal that each five IUDs insertions would reduce the number of birth by one per year. In 1964 this goal was not met, according to analysis of the data later. However, the population growth rate below 2 percent per year was achieved in 1973, which was two years earlier than expected.

Finally, in 1968, the executive yuan promulgated the regulations governing the implementation of family planning in Taiwan, officially adopting what had been an unofficial program. There were five major proposals in the anouncement.

(1) The objectives of family planning were to improve health, raise the level of family life, and achieve a reasonable population growth.

(2) Public health agencies would provide married women with free or low cost pregnant examinations, maternal and child health guidance, and information on contraceptives.

(3) A married woman with three or more children could ask a public health agency for contraceptive services.

(4) To implement family planning, health organizations could employ additional personnel, including a full time doctor or midwife and home visitor at each health station.

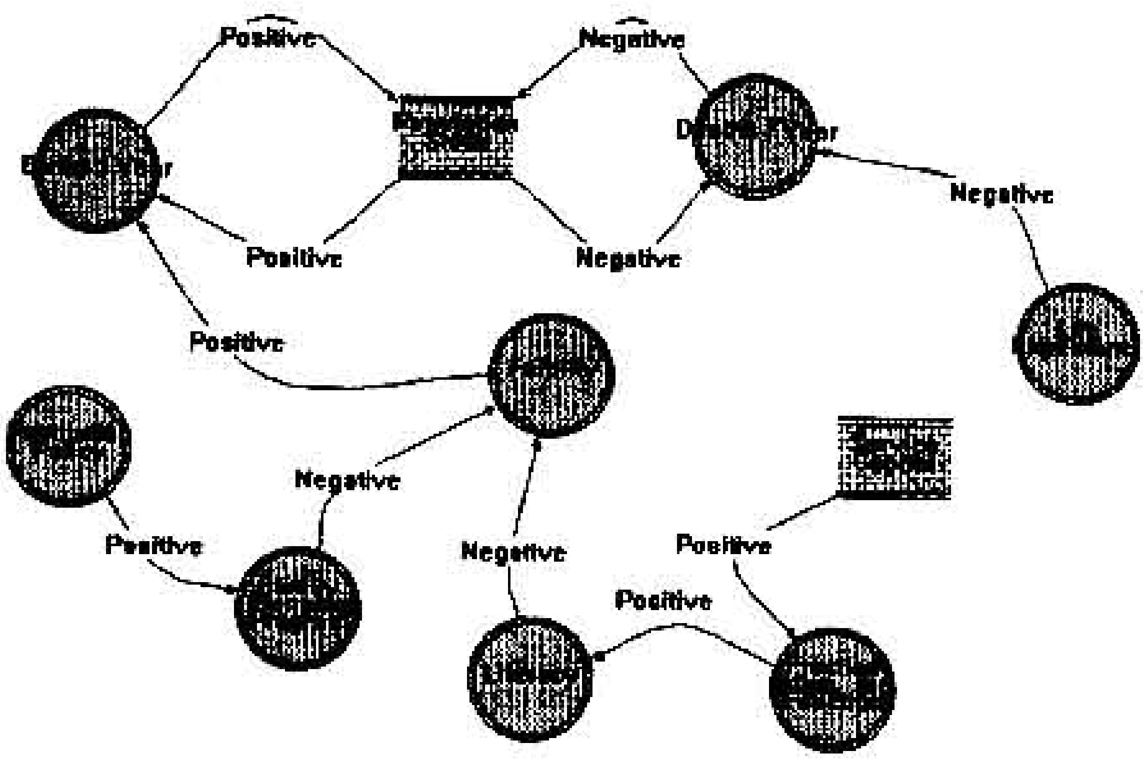
(5) Motivational and educational activities and short-term training courses and seminars were planned.

In 1984, the Eugenic Protection Law was enacted. Coordinated measures were taken by agencies concerned to discourage more than two births per family. The direct effect was the people who worked for government would only receive up to two child subsides thereafter.

Education is another important factor affecting birth rate decline in Taiwan. However, the Chinese traditional family value, with strong emphasis on having three or four children and at least one or two sons, still needs massive educational reform. I would say, as results of those efforts both on comprehensive family program and the continuation of broad education in famiy health, living standard, and child spacing, that the demographic transition in Taiwan will reach its final stage in the near future.

As the demographic transition is approaching the final stage, the aging population and the family program of the control on fertility rate are the main tasks to cope with in the 1990s. Fig 10-5 portrays the casual relationships of population sector in Taiwan.

Fig 10-5 Casual Relationships of Population Sector in Taiwan



10-2-3 Curve Fitting - Logistic Function

The logistic function will be employed as a curve fitting technique for Taiwan population growth. The logistic population equation of P.F. Verhulst is often written as'

$$\frac{dp}{dt} = ap - bp^2$$

The term ap in this equation represents the tendency of population to grow at a rate proportional to the size of the population, the standard assumption of exponential growth. Verhulst intended the term involving the square of population to represent conflict and stress arising contacts between people, which he assumed would be roughly proportional to p square. The result is the familiar nonlinear logistic equation (Richardson, 1991). Implementation of this equation needs two explicit parameters, a and b. The a would be a population natural growth rate per thousand, i.e., Birth rate per thousand minus death rate per thousand. The b would be a parameter representing a mixed effect of environmental stress and government intervention.

An equivalent form of the logistic equation is:

$$Yt = \frac{q}{1+ae^{bt}}$$

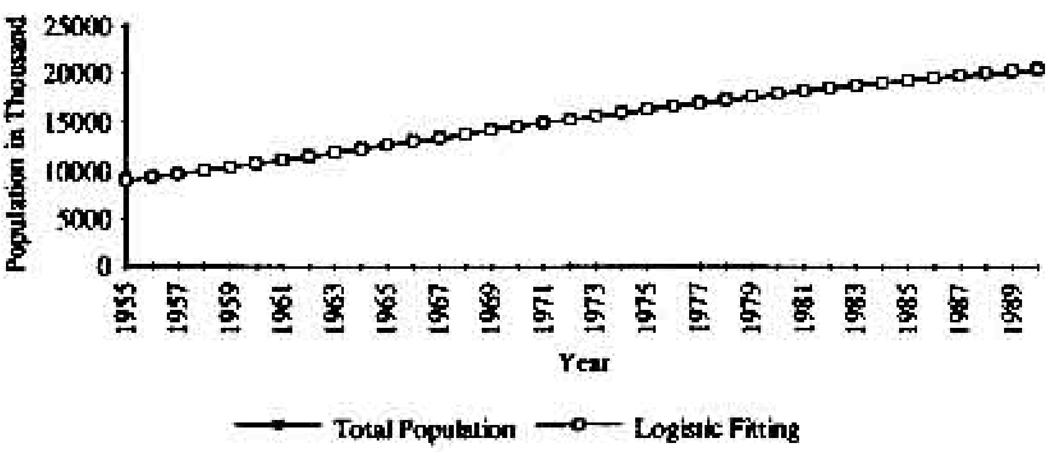
In it, I make an assumption of q = 25,000 thousand people that serves as logistic function upbound. I also choose population in 1955 (Yt = 9078, t = 0) and 1990 (Yt = 20,359, t = 35) to solve the other two parameters a and b. The logistic function hence equals to

$$Yt = \frac{25000}{1+1.754e^{-0.06t}}$$

where t = 0, 1, 2...

According to elementary mathematical manipulations (Arlinghaus, 1991), the coordinates of the inflection point of this particulate logistic function are 9.4 years and 12,500 thousand people. This is where the population growth rate reaches its maximum population 12,500 thousand at year 1965 and starts a decreasing growth rate from there forward (in time). Fig 10-6 shows a logistic curve fitting for Taiwan population. At the end of 1980s, the logistic function portarys a slightly higher population than that observed.

Fig 10-6 Logistic Curve Fitting for Taiwan Population



10-3 The Urbanization Transition

10-3-1 Introduction:

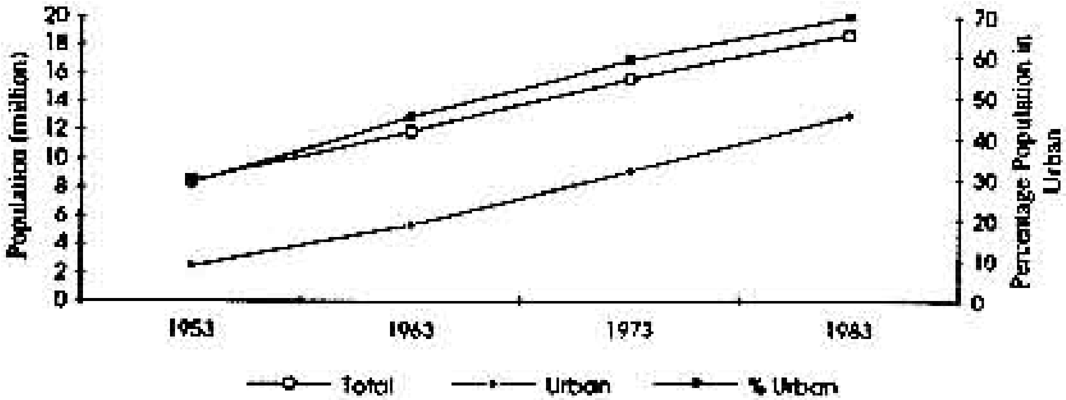
The desire to move from rural to urban areas is the result of many forces. The first set of forces are "pull" conditions such as availability of jobs in the urban area and the perception of better educational and health opportunities, especially for children. The second set of forces are "push" conditions such as living difficulty in rural area, lack of rural infrastructures needed for implementing improvements and insufficient land holdings to support an expanding family (Drake, 1992). According to Speare's research the factors resulting in the immigration to urban areas in Taiwan are (1) Unemployment, which is very low in urban area. This implies that only few migrants in urban area are having difficulties in finding adequate employment. While in the rural area the labor forces are in surplus. (2) Many potential migrants expect that moving to urban areas will result in an increase in income (Speare, 1988).

10-3-2 Urbanization Transition in Taiwan

Taiwan, an area of 36,000 square kilometers, is divided administratively into two central municipalities, five provincial cities, and sixteen prefectures. Each central municipality and provincial city is subdivided into districts, and each prefecture is subdivided into a prefecture city, Chen, and Hsiang. In 1983 there were twenty prefectures cities and 289 Chen and Hsiang. The central municipalities, provincial cities, and prefecture cities are essentially urbanized areas. Whereas Chen and Hsiang consist of semi-urbanized townships and rural area.

During the three decades of 1953-1983, Taiwan's urban population, loosely defined as the population living in cities, Chen, and Hsiang with more than 50,000 residents grows form 2.4 million to 13 million. During this time period, the total population grew from 8.4 million to 18.7 million. As a result, 70% of people live in urban area at the end of 1983. Fig 10-7 presents total and urban population in Taiwan during 1953-1983 period.

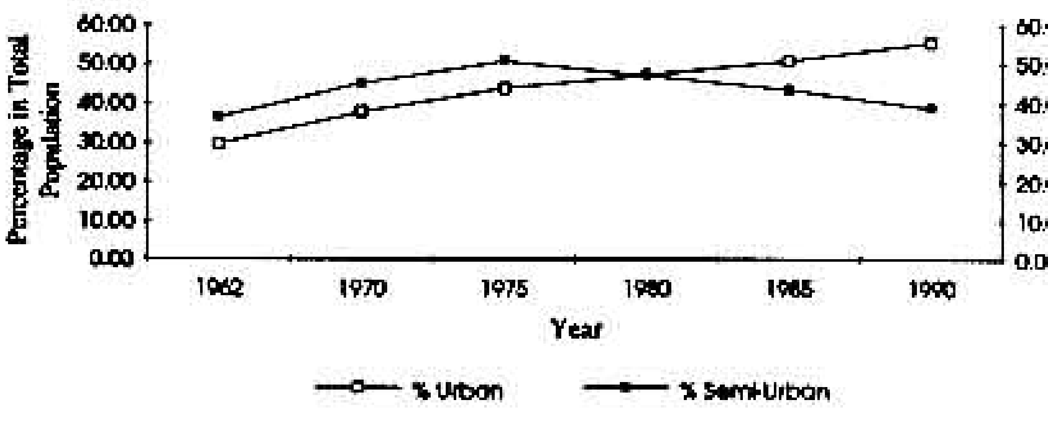
Fig 10-7 Total Population and Urban Population in Taiwan 1953-1983



Source: Tsai 1987, Table 11-1

Suppose we define urban area as more than 100,000 residents and semi-urban area as 20,000-100,000 residents. The urban area aggregates 55.4% population and the semi-urban area accumulates 38.7% population at year 1990. Fig 10-8 presents the urbanization transition during 1962-1990 period.

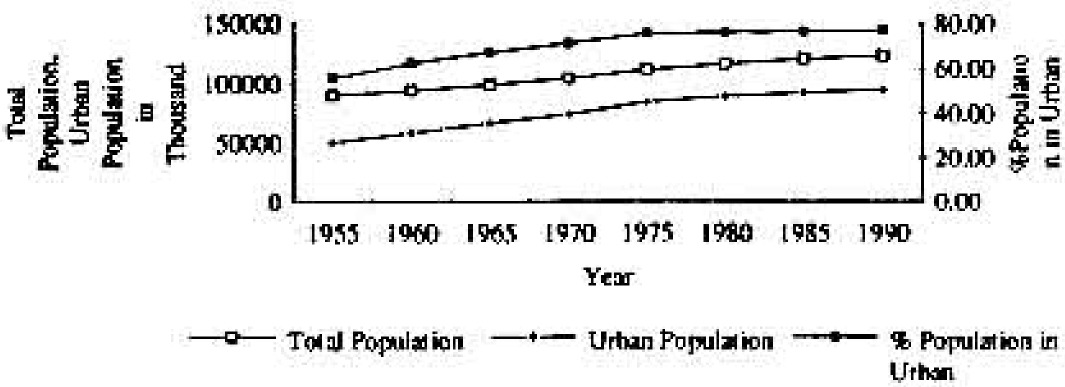
Fig 10-8 Total Urban and Semi-Urban Population Percentage in Taiwan 1962-1990



Source: Statistical Yearbook 1991 R.O.C., Table 6

Japan is in the end of her urbanization transition. Fig 10-9 shows that the population living in urban areas is increasing slowly.

Fig 10-9 Urban Population and Percentage Population in Urban in Japan 1955-1990



Source: World Resource Data Base 1992

10-4 The Rural Industrialization Transition in Taiwan

Taiwan's urbanization would have been much more rapid had it not been for the spread of industrialization into rural areas. Rural industrialization is also a key factor to affect the stock of cultivated land.

The origins of rural industry can be traced to the development of agroindustries during the 1930s under the Japanese. One of the first major rural industries was sugar refining which was followed by the industries of canning of fruits and vegetables. The development of these rural industries were promoted by investment in infrastructure in the rural area. During the 1930s, the Japanese built schools in rural areas and attempted to make primary school education universal. They also began the process of rural electrification, which by 1960, included 70% of rural households. In addition, the Japanese began the development of an extensive system of rural roads. By 1970, Taiwan had about 215 kilometers of paved roads per 100 square kilometers (Ho, 1979).

Land Reform in the 1950s undoubtedly played an important role in facilitating rural industrialization in Taiwan. By granting ownership to the tenants of small plots where they were tilling, land reform greatly increased the number of households which had a stake in remaining in rural areas. Because their plots were typically too small to provide full employment for all children, rural households had extra labor as their children reached to normal age for labor force entry. This implies that there was a labor surplus in rural areas which had an attachment to these areas and thus was more willing to work in or near the town than to the city.

Rural industrialization was also encouraged by government's policies. when entering the 1970s and 1980s. Between 1968 and 1981, the government established 62 new industrial zones in Taiwan. Only 10 of these were in the 5 large cites, 22 were in the four metropolitan counties, and 30 were in the remaining more rural counties (Tsai, 1982).

Another factor promoting rural industrialization was agricultural development which increased farm output through the use of improved seeds, fertilizer, irrigation, and so forth. This increased productivity resulted in growing farm incomes and a growing demand for nonfood consumption (Ho, 1979). For example, there was an increased demand for building materials such as bricks and roof tiles which could easily be produced by small factories in rural area. In addition, there was a growing demand for clothing which was met, in part, by an expansion of textiles and apparel manufacturing in rural areas.

Selya (1974) describes the outward expansion of industrial sites as a "leap frog" pattern. "Plants are strung out with major interruptions in the pattern by paddy (rice field) or marginal land. This interrupted spaces may be filled in later if and when the farmer owning the land decides to sell. The landscape then assumes a mixed appearance, even within the industrial sectors: old and new often stand side by side" (Selya, 1974).

The growth of manufacturing in rural areas is reflected in the official figures for the number of factories by county. In 1979, 20,996 out of 58,465 factories or 36% were located in one of the 12 more rural counties (Tsai, 1982). The rural areas tended to attract the more labor-intensive industries. Ranis points out that the industries specializing in producing goods were much more likely to be allocated in one of the five large cities than industries specializing in consumer goods (Ranis, 1979). In addition to food processing and lumber where the attraction of rural areas is obvious. The textiles, chemicals, and metal manufacturing were also located in the rural areas (Tsai, 1982). This relationship between capital intensity and level of urbanization of manufacturing locations was further strengthened by the national development plan in 1979 which stated that labor-intensive industries should go to small towns and rural areas (Tsai, 1982).

Taiwan government might make such a plan that industries should keep growth as high as possible. As a result, the rate of rural industrialization will increase as well. The cultivated land will decrease not only by the effect of industrial extension but the uncontrolled pollutants in the rural area.

10-5 The Agricultural Transition

10-5-1 Introduction

Agricultural transition describes that the agricultural production increase shifts from extension of cultivated land to improvement of cultivated land productivity. The final stage of agricultural transition would be an experience of diminishing returns in yield per hectare (Drake, 1992). Some critiques about agricultural transitions are summarized belows:

(1) Yield per hectare is a measurement of the stage of agriculture transition, given the increasing application of fertilizers and pesticides. In general, North America may be approcaching the point of disminishing returns. Asian countries are between the increasing-to-returns[5] to constant-to-returns, while African countries are in the stage of increasing-to-returns.

(2) Rural to urban migration must occur because the landholders are unable to increase land productivity. As a result, the surplus of labor forces in rural area when the yield reaches disminishing returns move to urban areas.

(3) Heavy pesticide, fertilizer usage in agricultural would bode well for toxicity transition.

10-5-2 Agricultural Transition in Taiwan

In order to Analyze the agricultural transition in Taiwan, an overview of area of cultivated land, yield per hectare fertilizer used, and farm population with time dimention seems appropriate.

Fig 10-10 presents area of cultivated land transition in Taiwan. Cultivated land refers to land now being utilized for actual cultivation; it excludes: (1) Land which has been devastated and turned into waste disposal. (2) Land buried with sand and not cultivable. (3) Land duly registered but converted to a building site, a highway, or used for some purposes other than agricultural cultivation. (4) Land burned down for farming but then allowed to lie idle.

Taiwan, an area of 36,000 square kilometers, has a total population of 20.36 million and population density 565 persons per square kilometer. Two thirds of its area are hills and mountains ranges greater than 100 meters above sea level. These are very difficult to utilize. Forest area covers 52% area of this island. The remaining 48% includes rural area, urban area, and semi-urban area.

The land available to human activities is extremely limited. Fig 10-10 shows that total cultivated land in Taiwan reaches its highest in 1975 with 917.1 thousand hectares. After 1975, the total in paddy fields continues to decrease to 476.9 thousand hectare in 1990 (total paddy field reaches its highest in 1965).

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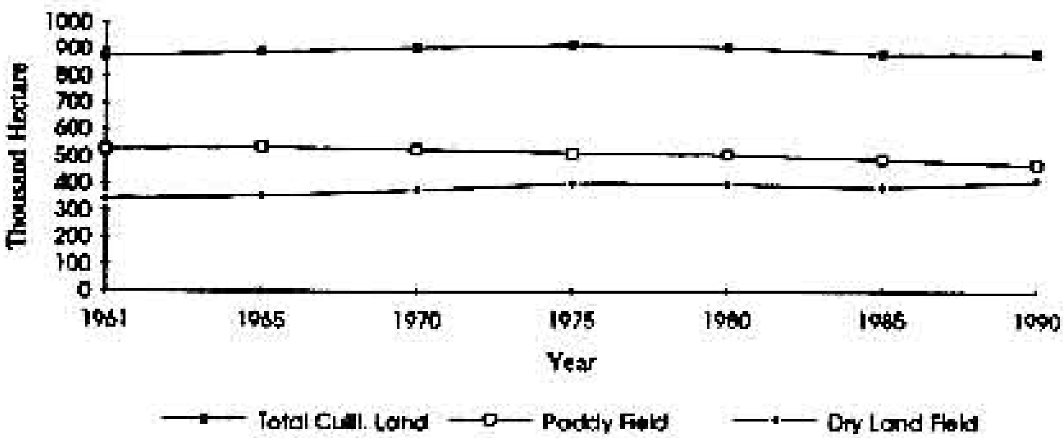
[5] Increase-to-returns means that if you double any one input amount, the others are no change, you will have twice as many as the yields per hectare that you had before.

Fig 10-10 Total Cultivated Land in Taiwan 1961-1990



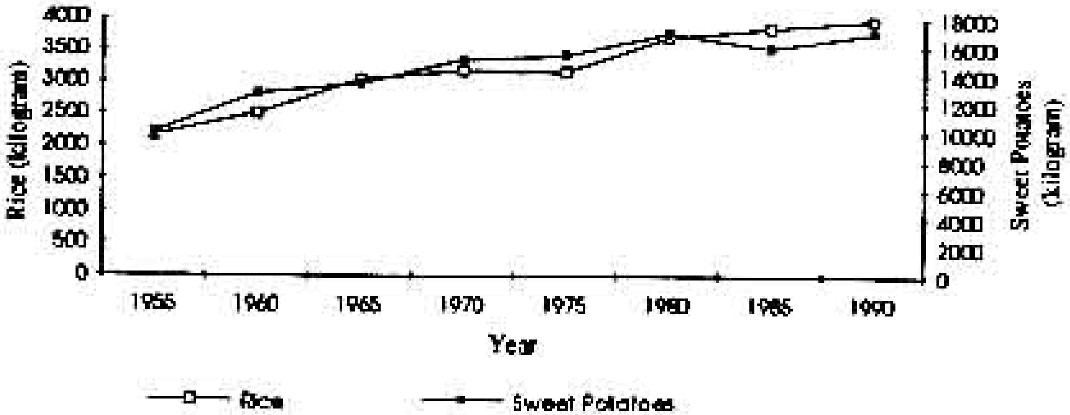
Source: Statistical Yearbook R.O.C. 1991, Table 140

As mentioned in the rural industrialization section, the decrease in area of paddy field is due to the rural industries expansion. Selya (1974) in his paper described this mixed paddy field and industrial plants in Taiwan rural area as "leap frog", referring the pattern of land use of rural industrialization.

However, the dry land has been relatively stable in the past decades. This is because the dry land is less competitive for human use. Most of the dry lands are remote and devastated. Considering the future cultivated land stock, it is appropriate to make an assumption that 900 thousand hectares is a steady state if the extension of rural industrialization and land pollution are under control.

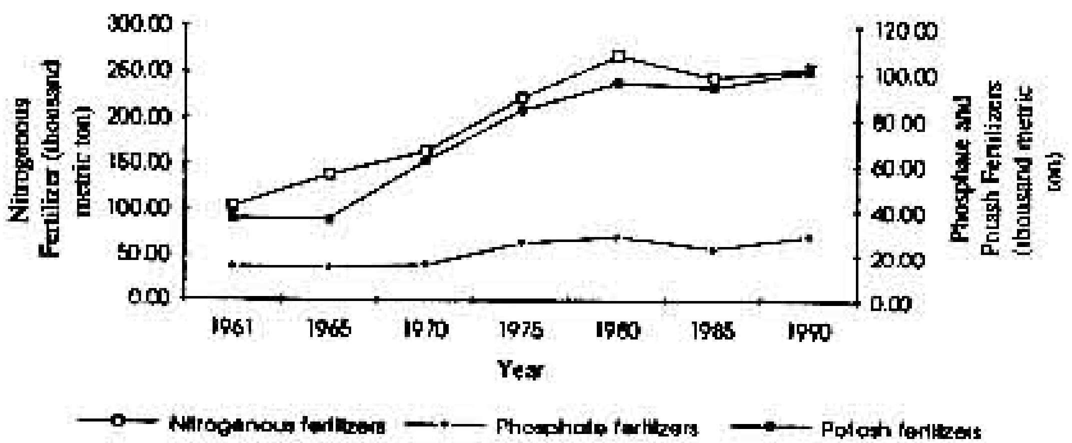
Agricultural transition in Taiwan is approaching diminishing returns. Given the increasing usage of fertilizers on fig 10-12, the yields per hectare for major crops, rice and sweet potatoes, are approaching their maximum production, 4000 kg/ha for rice, 17,000 kg/ha for sweet potatoes. fig 10-11.

Fig 10-11 Yield per Hectare for Two Crops in Taiwan 1955-1990



Souce: Taiwan Statistical Data Book 1991, Table 4-6 a

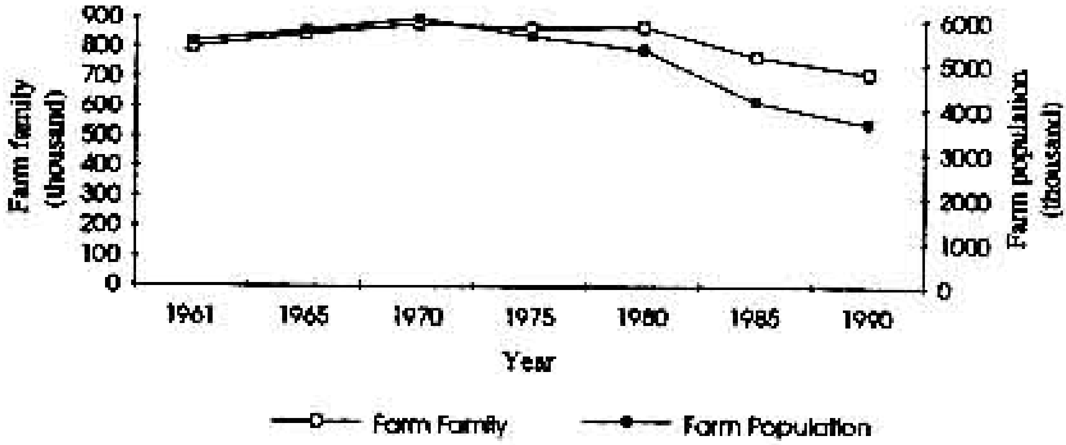
Fig 10-12 Fertilizers Use in Taiwan 1961-1990



Source: Statistical Yearbook R.O.C. 1991, Table 137

The interesting finding is that both the number of farm families and the farm population are in steady decline in the past decades, although population keeps a 2% average growth rate per year during the past decades (fig 10-13). The reason for the continuous decline of farm population is the rural to urban migration. Farmers face a fixed cultivated land holding, a maximum land production, and high income with low unemployment rate in the urban area.

Fig 10-13 Farm Families and Farm Population in Taiwan 1961-1990

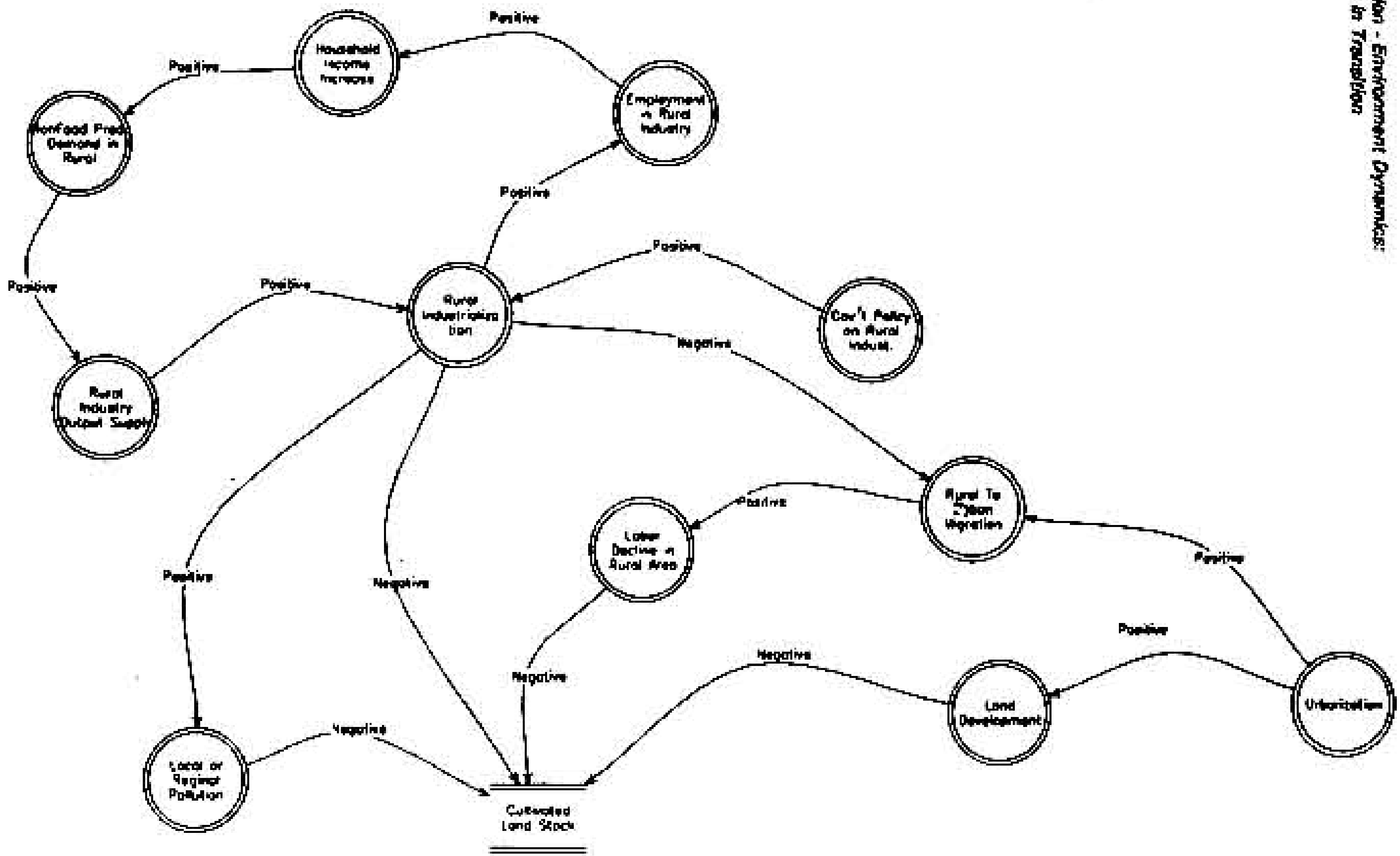


Source: Statistical Yearbook R.O.C. 1991, Table 139

10-6 System Dynamics of Cultivated Land - Rural Industrialization - Urbanization in Taiwan

The cultivated land of Taiwan is approaching the steady total area and might be a slight decline due to the development of rural industrialization. Fig 14 presents the casual relationships of cultivated land sector, where the rural industrialization and urbanization are two driving forces causing the transition of cultivated land. A positive feedback loop exists in rural industrialization.

Fig 14 Casual Relationships of Cultivated Land Sector in Taiwan



10-7 Possible Policy Implications

The developed countries historic records are often viewed as a prototype for developing countries. The characters of transitions in developed countries therefore may be transferred to other countries with similar culture and development background. For example, Taiwan demographic transition begins a secular decline in birth rates since 1950s, the process appears to follow a regular monotonic form until a low level birth rate has been reached, which are experienced by the most developed countries. As mentioned in the section of demographic transition, Taiwan and Japan have similar culture background. The demographic trend of Taiwan is more or less retracing the Japan's pattern but at an accelerated pace. Entering 1990s, aging population issues and comprehensive family planning programs are expected to be the main tasks to cope with. As a result, Taiwan government may adapt some transition characters from Japan or other developed countries when makes a comprehensive population policy.

Because Taiwan is poor in nature resources and the population density is high, the development of agriculture and industry is very important to keep check in its balance. The dilemma between sustainability of domestic agricultural productions and industrial developments of continuous economic growth needs to solve. How many hectares of cultivated land needs to protect in order to produce sufficient food. How much subside needs to distribute to agriculture sector under the scenario of a subsistence agriculture. How can the government develop the industries and keep the health environments at the same time? Those are the issues of interfering with each others when the Taiwan government and policy maker make any individual policy. As a result, the application of transition theory by viewing the complex dynamics of population and the environment as a family of transition is explicit.

Finally, the transition analyses can facilitate for modeling and simulation analyses by means of determination of system causal relationships within sectors, although the real world is far more complex than the assumed modeling world.

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