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Over the past century technological and institutional innovations have dramatically raised global food production capacity, causing the specter of Malthusian famine to recede, although the challenge of equitable food distribution remains. However, a neo-Malthusian pessimism suggests that while food production potential may keep pace with population, our capacity to maintain environmental integrity may not.

This article examines the connections between population, agriculture, and natural resource management. A broad overview of land quality issues is presented. The example of land management under population pressure in tropical hillsides is then used to analyze the sustainability of agricultural production and the maintenance of environmental services. Somewhat surprisingly, the evidence indicates that the effect of population on land quality is indeterminate, with other economic and institutional factors being more significant in determining outcomes.

The Nature and Scale of the Problem

Since the early 1960s, cultivated area has increased by 18 million hectares (ha.) in Asia, 28 million ha. in South America, and 31 million ha. in Africa. Area in permanent pasture expanded even more, while forest and woodland area declined. While deforestation is likely to continue, area in crop production is likely to expand only another 12% over 1997 levels by 2010. Rising total population means that arable land per capita has actually declined from just under 0.5 ha./cap in 1950 to under 0.3 ha./cap in 1990, and it is expected to continue to decline to between 0.1-0.2 ha./cap by 2050.

Average crop yields have grown rapidly since the 1970s, and yield gains are projected to continue, though at lower rates. Per capita yields rose much more slowly due to the effect of rapid population growth. In addition to food requirements, rural land and resources were increasingly needed to provide other livelihood needs. Although rural growth rates have declined from 2.2% per annum in 1960-65 to 1% per annum in 1990-95, the absolute number of rural dwellers will continue to increase at least through 2015. In 2015, the developing world will have 3 billion rural dwellers, 94% of the world's rural population.

The Global Land Assessment of Degradation (GLASOD) estimates that nearly 2 billion hectares of agricultural land, pasture, forest and woodland (22.5% of the total) have been degraded since the mid-1900s. About 3.5% is severely (perhaps irreversibly) degraded, and just over 10% is moderately degraded, requiring significant on-farm investment to restore. Nine percent is lightly degraded, and could be restored through good land husbandry.

Damage to forests and agricultural lands is most widespread in Asia, and damage to pasture in Africa. Poor agricultural practices, over-exploitation of vegetation, overgrazing, and deforestation all contribute to land degradation. However, GLASOD figures may overstate the scale and impact of the problem, since damages may be compensated by non-land inputs or by land-improving measures such as terracing, nutrient enrichment, contour hedges, or agroforestry. While there is considerable local evidence documenting land degradation, there is less data on productivity or income effects.

Dynamics of Change

Four different patterns of land use change can be identified for different types of rural land:

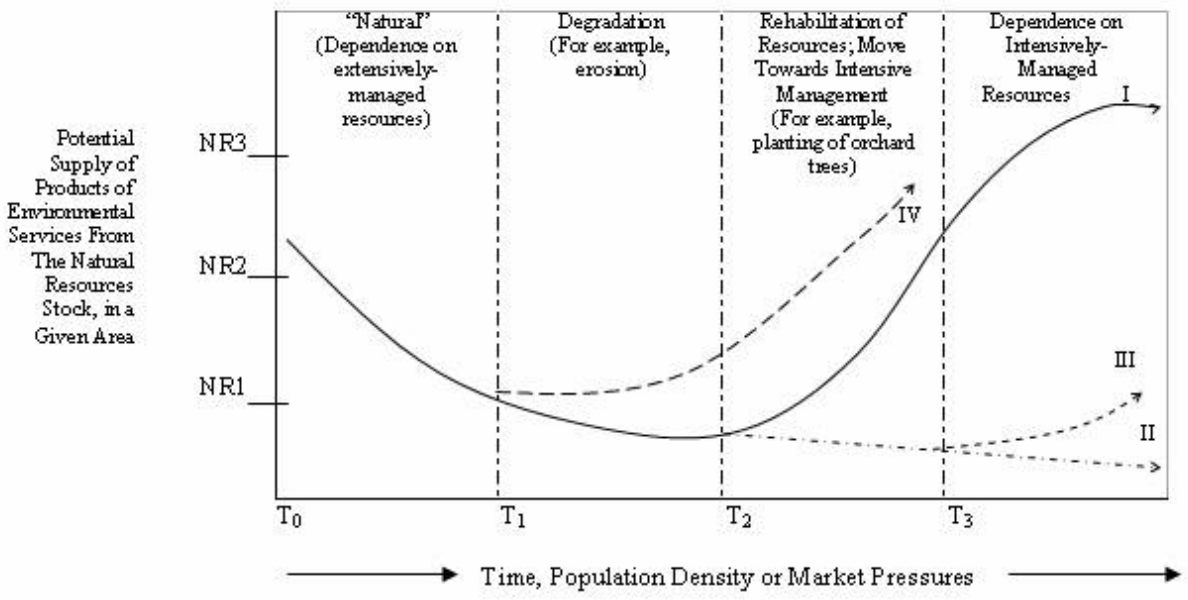
• **Irrigated lands:** Irrigated area grew by 100 million ha. between 1961 and 1990, mainly in developing countries. Irrigated areas are now 17% of cropland, but produce a third of world food output. Green Revolution gains are concentrated on irrigated lands, but so also are problems of salinization, ground-water decline, water-borne diseases, and water pollution from fertilizer, pesticide, and animal waste runoff.

• **High-potential rainfed lands:** Intensification in areas with fertile soils and reliable rainfall has made permanent cropping (sometimes export cropping) possible, with increased fertilizer application and improved seeds. This pattern is characteristic of parts of India, Zimbabwe, the uplands of Java and the Kenyan highlands. Environmental concerns include mechanization damage to soils, acidification, pesticide pollution, and deforestation. The resources in these areas are generally resilient, and with proper incentives technologies for sustainable management can be adopted.

• **Long-settled marginal lands:** In areas with less favorable environments such as drylands, rainforests, shallow or acid soils, or steep slopes, population and demand growth have forced a transition from long-fallow to short-fallow or permanent cropping systems. As a result, these lands are threatened by soil erosion, fertility depletion, and devegetation. Further ecological impacts include loss of biodiversity and degraded watersheds. Frequent
crop failures can lead to depletion of forests and other resources to meet consumption needs. Poor infrastructure and an inability to undertake land-improving investments compound problems in regions where poverty and subsistence production is widespread. Some promising technical approaches for such areas have been developed, but they have received only limited research attention.

• **Frontier marginal lands:** Migration of landless and displaced people has led to new settlements and land-clearing in marginal environments. Long-fallow cropping and livestock production have replaced traditional shifting cultivation systems, with resulting deforestation, biodiversity loss, and watershed degradation. Problems of lack of infrastructure and inputs are even more acute in these regions. Examples include the Amazon and the Atlantic zone of Central America, West African drylands, and the Indochinese hill country.

While total population is highest in the two higher-potential areas, as of the mid-1980s, half of the poorest people in developing countries were living in marginal lands. Pathways of development vary widely under all four land patterns, with intensification sometimes leading to land degradation and sometimes to land improvement. Improvement of productivity, human welfare, and protection of the natural resource base are dependent on interactive relationships between population and economic growth, technology, institutions, investment, and infrastructure. In some circumstances, the end result can be a neo-Malthusian collapse of the resource base, while in others resource-conserving intensification can lead to a sustainable outcome (Figure IV.3).



Path 1: resource degradation leading to induced innovation and sustained output increase
Path 2: over-exploitation and continued resource decline
Path 3: delayed resource conservation with limited potential
Path 4: accelerated innovation leading to successful intensive management

Figure IV.3. Induced innovation in natural resource management

Land Quality and Population Growth in Tropical Hillsides

Around 500 million people now live in tropical hillsides and mountains. Extensive empirical studies of such areas find that increases in population density are associated with higher rates of deforestation, but also with increases in planted tree density. Similarly, denser population leads to shorter fallow and more frequent cropping, but also to more land-conserving investments. Overgrazing tends to occur at moderate population densities, but at higher human and livestock densities there is a shift from land-intensive to labor-intensive feeding methods.

"Most of the environmental impacts of production increases in the hills and mountains thus depend on whether sufficient microeconomic incentives exist for people to choose production systems. . . that enhance land characteristics or, at least, retard their degradation." (42) Successful intensification has been documented in the Machakos district of Kenya, and in the mixed crop-livestock systems of western Kenya. Increased market opportunities and better product prices are conducive to farmer investment in tree-planting and soil conservation. Secure land tenure and co-operative land improvement associations also help to sustain production at higher population levels without excessive resource degradation.

"Higher rural population is not directly associated with degradation. However, a slower rate of demographic growth or decline allows people more time to innovate or adapt products, technologies, property rules, and collective management. Evidence suggests that endogenous processes of induced innovation are widespread, but they are too slow, relative to high current rates of population growth, to achieve sustainable outcomes (and avoid irreversible degradation) in the short to medium term." (44) Policy initiatives are therefore essential both to slow population growth and to promote innovation and investment.

Research and extension programs must integrate agricultural and ecological analysis. Land improvement strategies need to be designed with farmer input. Improved or subsidized credit may sometimes spur improvements, but price incentives which make innovation intrinsically profitable, together with appropriate extension and farmer organization, are more effective and reach more producers. Secure property rights, women's land rights, and involvement of local organizations and NGO's in land management are essential. Improvement of transport infrastructure and market access, removal of price distortions which lower land values, and proper pricing of irrigation water, logging concessions, and farm inputs can create markets for higher-value products which are environmentally suitable.

"A neo-Malthusian scenario may indeed threaten large parts of the rural South, but only if public policies fail to provide a supportive environment and long-term commitment for land-improving investment. National and international attention to this challenge is long overdue." (47)