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Chapter 18

APPROACHES TO MITIGATE TROPICAL DEFORESTATION BY SUSTAINABLE SOIL MANAGEMENT PRACTICES

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ABSTRACT

Deforestation and subsequent changes in land use in the tropics are responsible for 18% of global warming during the 1980s, with expected rates during the 1990s to increase. Third world population growth forces landless rural populations to migrate and over exploit tropical rainforests. The resulting agriculture is unsustainable and leads to further deforestation and migration to urban centers. Research has shown that deforestation rates can be decreased, by eliminating the proximate cause. An integrated approach consisting of development and application of sustainable management technologies for tropical soils and appropriate government policies will eliminate the pressure for further deforestation. The principal management technologies are based on low input systems for acid soils of the humid tropics which lead to agroforestry, legume based pastures or continuous crop cultivation. Some management technologies are available while others are still evolving. For every hectare put under sustainable agriculture five to ten hectares of rain forests are saved each year.

THE PROBLEM

Recent estimates indicate that about 18% of the global warming is due to the clearing of tropical rainforests (EPA 1990), which is occurring now at a rate of 7 to 10 million hectares of primary forest per year (Melillo et al. 1985). Deforestation is also decimating the world's largest depository of plant and animal diversity (Wilson 1988). Tropical deforestation is driven by a complex set of demographic, biological, social and economic forces described in Fig. 18.1. Population growth in developing countries continues at a high rate, while most of the fertile and accessible lands are already intensively utilized. Government policies often exacerbate land scarcity by allowing gross inequities in land tenure. These factors result in an increasing landless rural population which essentially has three choices: stagnate where they are, migrate to the cities, or migrate to the rainforests that constitute the frontier of many developing countries. Although urban migrations are spontaneous, national policies in key countries include the occupation of their tropical rainforests, notably Brazil, Peru and Indonesia via colonization programmes.

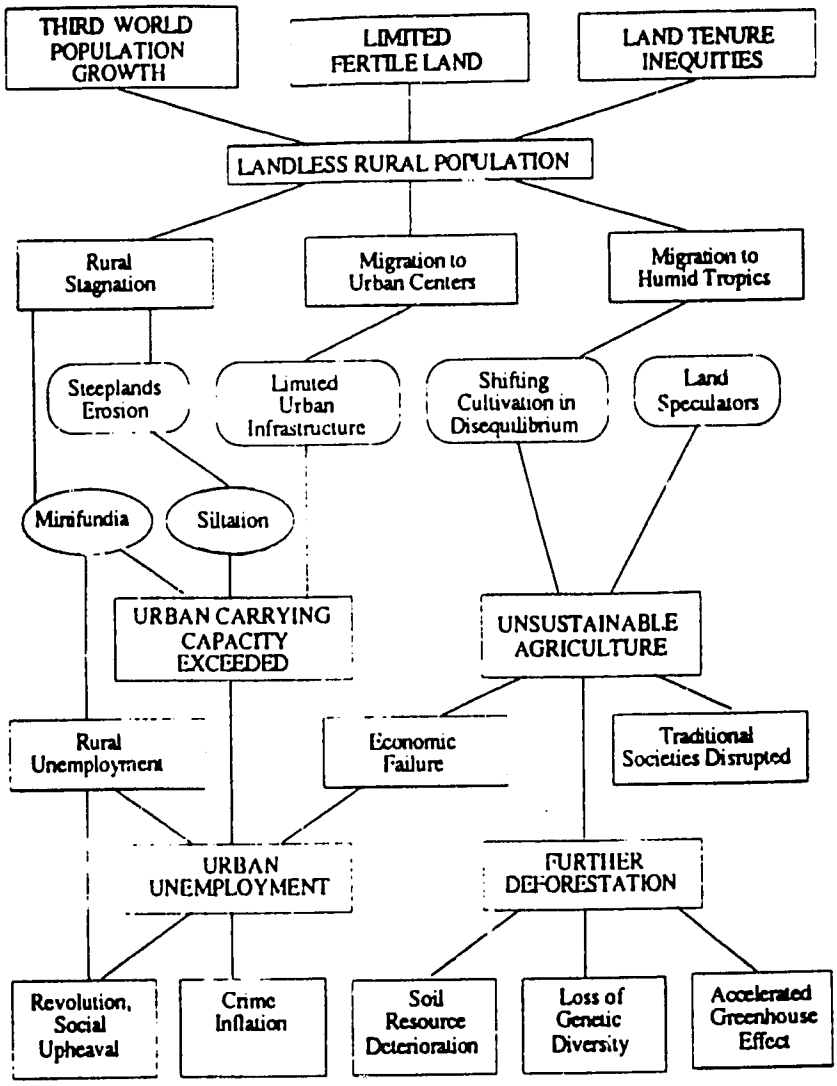

Fig 18.1 Complex set of forces driving to tropical deforestation

Densely populated rural environments such as the Andean valleys, Northeast Brazil, and Java suffer from an ever decreasing farm size and the overuse of steepland areas. This results in widespread soil erosion, siltation of reservoirs and other adverse off site effects to urban centers. Migration to the cities in search of a better life results in bitter disappointments, and coupled with limited urban infrastructure, produces unmanageable cities with populations far exceeding their carrying capacity and infrastructure.

Migration to the humid tropics seldom results in a bountiful cornucopia (with few notable exceptions). An equilibrium between the rainforest and shifting cultivation by traditional humid tropical societies is broken by the colonists, and

in some countries by land speculators as well. The result is shifting cultivation in disequilibrium which quickly turns into various forms of unsustainable agriculture. Traditional societies are disrupted, economic failures abound and migration to urban centers follows.

The two end points are **urban unemployment and further deforestation.** The consequence of the former is abject urban poverty which leads to widespread crime, poor health and in many cases social upheaval. Deforestation depletes the ecosystems' limited nutrient capital, decimates plant and animal genetic diversity and accelerates global warming due to carbon dioxide, methane and nitrous oxide emissions.

STRATEGIES TOWARDS A SOLUTION

Several strategies have been proposed to mitigate tropical deforestation. These include: 1) economic development and more equitable land tenure in densely populated areas; 2) encouraging migration to less fragile areas such as the Cerrado of Brazil; 3) preserving the remaining forests by a vast network of well-protected national parks; and 4) sustainable use of the forests as extractive reserves. While policies that promote these four strategies should be pursued, all are necessary but insufficient to stop deforestation. The first strategy requires long periods of real economic growth which are too slow to offset current deforestation rates. The second strategy is clearly insufficient in deflecting migration; the third one is unrealistic in preventing hungry people from clearing land; and the fourth one, extractive reserves, is likely to support a very small segment of the humid tropical population.

A fifth strategy is to stop deforestation in situ by eliminating the need to abandon cleared land. Land use management options are urgently needed that improve the economic status of subsistence farmers, maintain agricultural productivity on deforested lands and recuperate productivity of degraded lands. Such options will provide sustainable development of the Amazon and other humid tropical regions in a way that satisfies human needs and preserves the ecosystem. These options must be compatible with the various socioeconomic needs in the region so that they are readily and widely adopted.

Is such an approach possible in the predominant acid, low fertility soils of the humid tropics? Our answer, based on long-term research, is an emphatic yes, with the use of alternatives to slash and burn. The key is an integrated approach consisting of: 1) development and application of sustainable management technologies for tropical soils; 2) appropriate government policies that provide incentives against further deforestation; and 3) effective, economically sound rainforest conservation methods.

Farmers do not cut tropical rainforests because they like to; they clear them

out of sheer necessity to grow more food. Deforestation, therefore, can be reduced by the widespread adoption of sustainable management practices that permit the use of cleared land on a continued basis. Sustainable management options for acid soils of the humid tropics have been developed at Yurimaguas, Peru, and elsewhere to fit different landscape positions, soils and levels of socioeconomic infrastructure development (Sanchez et al. 1987).

The principal sustainable management options and alternatives to slash and burn are: paddy rice production on alluvial soils, low input cropping, continuous cultivation, legume-based pastures, and agroforestry. Their place in the landscape is shown in Fig. 18.2.

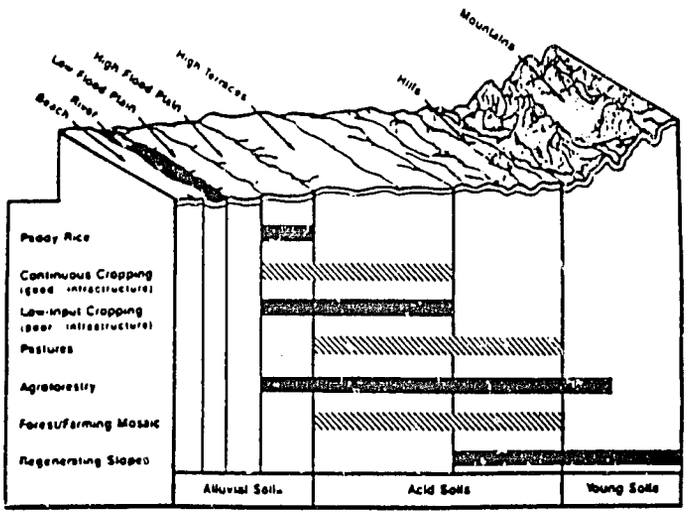

Fig 18.2 Some soil management options for humid tropical landscapes dominated by Oxisols and Ultisols (Sanchez 1988)

Additional options developed by other research institutes include perennial crop production (rubber, oil palm), plantation forestry and alley cropping for the higher fertility soils (Kang et al. 1981; Alvim 1982). They are also part of the solution.

Most of the options are based on low input systems which serve as transition technology to agroforestry systems, legume-based pastures and continuous crop rotations. In spite of the continuing need for both strategic and applied research, there is no question that the technological basis for sustainable management options for acid soils of the humid tropics is available now. The following describe some of the main management options.

Land clearing that does not damage the soil

All the options are based on slash and burn clearing, using axes, machetes and chain saws as opposed to mechanized bulldozer clearing. We found that the

slash and burn system is better because the burn provides a liming and fertilizing effect of the ash and does not disturb the topsoil while conventional bulldozer clearing often compacts the soil and removes valuable topsoil (Seubert et al. 1977). When these results were transmitted to colleagues in Brazil and Indonesia, policies to discourage bulldozer clearing were instituted. We also found little difference in fertilizer content of the ash after burning primary or secondary forests (Smyth and Bastos 1984) giving a further impetus to clear secondary forests, instead of primary ones.

Paddy rice in alluvial soils

Alluvial soils encompass approximately 11% of the Amazon region. In addition to accessible water and river transportation to markets, large proportions of these soils are characterized by high fertility status. Adaptation of Asian flooded rice technology to Yurimaguas alluvial soils led to the establishment of the following components: 1) land is cleared by slash and burn and land leveling is performed only to ensure gravity flow of water along natural contours; 2) supplemental irrigation, by either gravity flow or pumping from rivers, increases yields by about 50% as compared to crops dependent on rainfall; 3) transplanting provides higher yields during initial crops but may be replaced by broadcasting pregerminated seeds in subsequent crops after paddies are adequately leveled; 4) fertilizer responses are thus far limited to nitrogen deficiencies with continuous use; and 5) with yields averaging 5.5 tons ha^{-1} $crop^{-1}$, at the farmer level, one hectare of paddy rice provides the equivalent to 14 hectares of upland rice under shifting cultivation, since two crops are grown per year (Arévalo et al. 1983).

This technology has been adapted rapidly by settlers migrating into the Amazon Basin from rice producing areas at the coast of Peru. Approximately 75,000 hectares of new irrigated rice land was put into production within five years in the Peruvian Amazon (INIPA 1984), making it one of the major rice producing regions of Peru. In Brazil, the State of Amazonas alone contains about 25 million hectares of such soils, underscoring the vast rice production potential of the Western Amazon.

Low input cropping

This management option has evolved as a transition technology between shifting cultivation and several sustainable options. It enables the farmers to drastically increase short-term crop production while preparing themselves and their land for sustained land use alternatives. This option is targeted for farmers on acid, infertile soils in rural areas with limited capital and marketing infrastructure and is therefore applicable to large areas of the humid tropics. Its principal features are: 1) clearing secondary forest fallows by slash and burn; 2)

using of acid-tolerant upland rice and cowpea cultivars in rotation, with only grain removal to minimize nutrient export; 3) no use of fertilizers, lime, or external organic inputs; 4) establishment of legume fallows when weed competition and nutrient deficiencies make cropping unfeasible; and 5) elimination of the fallows by slash and burn after one year, shifting to other management options such as grass-legume pastures, agroforestry, or mechanized continuous cropping (Sanchez and Benites 1987). Current results indicate that the initial cropping cycle lasts two or three years and that there is a progressive reduction in cycle length after each legume fallow. The system is presently only considered as transitional because of two major constraints: nutrient depletion and weed encroachment. Ongoing investigations seek to prolong the duration of low input cropping by: 1) broadening the base of acid tolerant cultivars and species; 2) increasing knowledge on components of the nutrient depletion process; and 3) improving weed management through crop rotations, plant density, and frequency and time of legume cover crop fallows.

Agroforestry

Research on agroforestry began in Yurimaguas in 1983. It was the first and remains the most comprehensive agroforestry research program for acid soils of the humid tropics. Agroforestry is an attractive management option for much of the humid tropics because it can be adapted to a wide range of socioeconomic and soil-landscape conditions. Research has focused on: 1) selection and management of acid tolerant leguminous trees; 2) food-tree production systems; 3) managed fallows; and 4) alley-cropping (Szott et al. 1990). Legume selection trials have identified *Inga edulis*, *Cassia reticulata*, *Erythrina* sp. and certain varieties of *Gliricidia sepium* as promising species (Salazar and Palm 1987). These species are fast growing and respond well to pruning, making them good candidates as multipurpose trees for acid soils.

Work with native fruit trees has concentrated on peach palm (*Bactris gasipaes)* for fruit and heart of palm production but work has also begun on arazá (*Eugenia stipitata)*, achiote (*Bixa orellana*), and carambola (*Averrhoa carambola*). Managed leguminous fallows performed well compared to natural secondary fallows. Some of the managed fallows restored stocks of nitrogen, phosphorus, and potassium and suppressed weeds faster than the natural fallow (Szott et al. 1990). Current work in managed fallows is looking for the optimum crop-to-fallow period ratios.

Alley cropping trials, however, have had limited success on acid soils. Soil phosphorus levels soon became limiting to crop production because competition between trees and crops is severe and reduces crop yields considerably. Current research is aimed at overcoming these problems and testing alley cropping on slopes, where it is obvious soil conservation advantages could be maximized.

Grass/legume pastures

In contrast to the bad reputation associated with extensive pastures for beef production in the Amazon, our soil-plant-animal research has focused on the development of pastures for dual purpose (beef-dairy) production in small land holdings where farmers will also grow crops and trees. Initial investigations sought to adapt technology from CIAT's Tropical Pastures Programme, developed primarily in savanna ecosystems, to humid tropical conditions. Legume and grass ecotypes were screened for their performance under acid soil conditions and, subsequently evaluated for their persistence and compatibility when subjected to various grazing intensities. An ongoing 11 year old grazing trial in Yurimaguas is the longest running replicated trial testing acid tolerant grass-legume mixture in the humid tropics (Ayarza et al. 1987). If current persistence of legume-dominated pastures prove to be sustainable, then a new concept for cattle production may emerge in the humid tropics. New studies are also underway to gain further insight on nutrient cycling and to refine management practices used for the transition to and from pastures to crop and/or tree production.

Mechanized continuous cropping

Initial investigations seeking to quantify the production potential and primary soil constraints of humid tropical ecosystems, focused on this management option. It is targeted for farmers near urban areas where favorable marketing infrastructure ensures that fertilizer-based continuous food crop production can be used. Large Amazonian cities currently import most of their food from other areas. There is a potential comparative advantage in growing such food crops near the cities where the infrastructure is available. Sustained crop yields have been obtained with continuous cropping trials for 41 crops (17 years) in Yurimaguas Ultisols (USDA)/Acrisols (FAO) and 17 crops (8 years) in Manaus Oxisols (USDA)/Ferralsols (FAO) (Sanchez et al. 1983; Alegre and Sanchez 1989; Smyth and Cravo 1989). The key to continuous production is effective crop rotations and the judicious application of lime and fertilizers. If vigorous crop growth is insured by adequate liming, fertilization, and mechanization, soil chemical properties improve with continuous cultivation. Primary research thrusts in this soil management option are currently directed towards improving nutrient use efficiency, weed control, and optimizing tillage practices.

Nutrient cycling efficiency

Nutrient cycling must be maximized in all systems in order to minimize the need for external nutrient inputs. The management of crop and root residues is

crucial in this regard. Approaches proposed by TSBF (Tropical Soil Biology and Fertility Programme) on quantifying the nutrient release of organic inputs and the management of soil organic carbon, nitrogen and phosphorus (Swift 1986; Ingram and Swift 1988) are major components of low-input cropping, agroforestry and pasture research. The promising results at Yurimaguas in predicting the rate of nutrients released from leguminous sources (Palm and Sanchez 1990) provide for the first time an opportunity for the quantitative management of organic inputs in a manner comparable to the management of chemical fertilizers.

DEFORESTATION REDUCTION POTENTIAL

For every hectare put into these sustainable soil management technologies by farmers, five to ten hectares per year of tropical rainforests will be saved from the shifting cultivator's ax, because of their higher productivity. Estimates at Yurimaguas for the various management options are given in Table 18.1. These estimates will vary with climate and soils. Such technologies are particularly applicable to secondary forest fallows, where clearing does not contribute significantly to global warming because of the small tree biomass. Nevertheless the use of secondary forest fallows is of very high priority, because in many areas they are a viable alternative to primary forest clearing. Many of the degraded or unproductive pastures or croplands resulting from poor management practices can also be reclaimed using some, but not all of these available technologies.

Table 18.1 Hectares saved from deforestation for various management options: estimates for Yurimaguas in Peru

1 hectare in sustainable management options	equals 'x' hectares saved from deforestation annually
Flooded rice	11.0
Low input cropping (transitional)	4.6
High input cropping	8.8
Legume based pastures	10.5
Agroforestry systems	not determined

Such technologies, however, are useless without effective government policies that encourage, support and regulate them. Likewise, well conceived policies will fail without sustainable technologies. Therefore, the hope lies on a joint policy-technology approach; a worldwide deforestation reduction initiative (Sanchez 1988).

The present situation is analogous to when the world technical assistance community launched the Green Revolution in the late 1960s. At that time sustainable technologies for high yielding rice and wheat production were sufficiently developed to be tested at a large scale. Key government officials were convinced of their importance by leading scientists, and instituted the necessary policies to make massive farmer adoption possible in India, Pakistan, Philippines and other countries. The Green Revolution became a worldwide success during the next twenty years and the goal of arresting worldwide famine was definitely achieved. Unlike the Green Revolution, however, the impact of a Deforestation Reduction Initiative will be gradual and less spectacular. This is because we are focusing on marginal ecosystems, and more complex technological and policy problems.

CONCLUSION

A worldwide Deforestation Reduction Initiative will help directly to improve the livelihood of both developing and developed countries. Sustainable agricultural options for the humid tropics are necessary, but not sufficient conditions to stop tropical deforestation. Coupled with appropriate, conservation oriented government policies the following objectives can be achieved at the same time:

- Increase food and fiber production by farmers now practicing shifting cultivation;
- Reverse the pattern of degradation of many of the lands already cleared of tropical rainforest;
- Preserve much of the remaining tropical rainforests with their rich genetic diversity;
- Alleviate emission of greenhouse gases by as much as 18%.

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