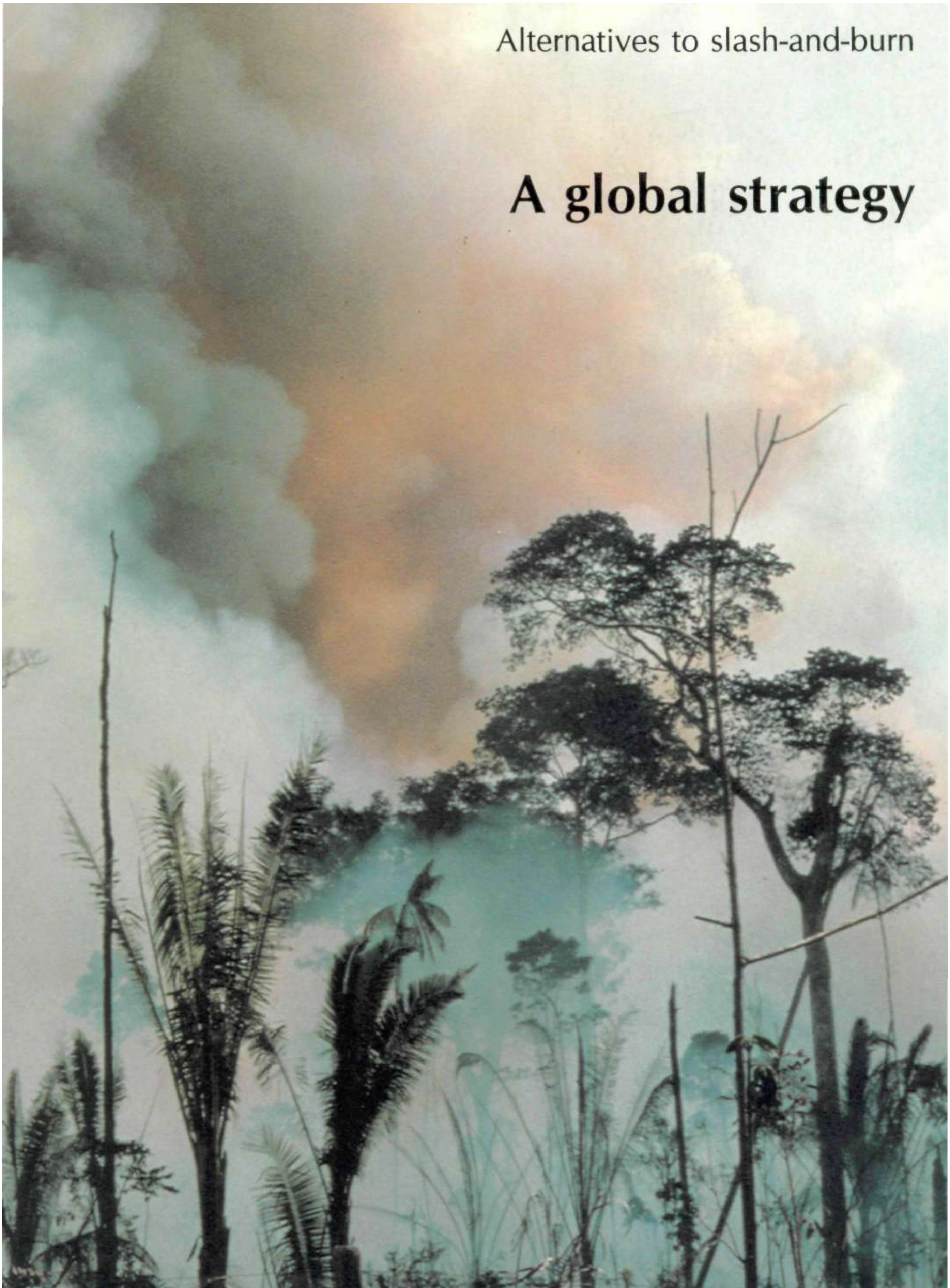
Alternatives to slash-and-burn

A global strategy



Alternatives to slash-and-burn

A global strategy

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EXECUTIVE SUMMARY

It is estimated that shifting cultivation accounts for about 70% of the deforestation in Africa, 50% in Asia and 30% in Latin America of the 14 million hectares of tropical moist forests currently destroyed every year. Tropical deforestation is responsible for 18% of current global warming, for most of the decimation of plant and animal genetic diversity, and for threatening the stability of many watersheds. Landless farmers from crowded areas migrate to the forested areas and attempt to make a living by slash-and-burn, which results in unsustainable agriculture and continuing rainforest destruction. Sustainable alternatives to slash-and-burn would enable millions of poor farmers to make an adequate living without destroying additional forests. Research conducted at several locations for many years shows hope that for eveiy hectare put into promising alternatives, 5 to 10 hectares of tropical rainforest can be spared from the shifting cultivator's axe every year.

Several international centres have decided to join efforts with national research systems (NARS) to formulate a research-and-development strategy that provides viable alternatives to slash-and-burn agriculture worldwide. The strategy focuses on two main targets: (1) reclamation of already deforested lands such as secondary forest fallows and abandoned grasslands and (2) prevention of damage by deforestation itself. The strategy consists of three main components: (1) developing and testing alternative slash-and-burn technologies for small-scale farms, adapted to specific ecoregions within the humid tropics, (2) linking environmentally oriented strategies with socioeconomic policies that provide incentives for such technologies and disincentives to further deforestation and (3) designing effective economically sound and socially acceptable rainforest conservation methods.

The proposed mode of operation

- is a joint strategic research effort of CIAT, IITA, ICRAF, IFDC, IRRI and TSBF at selected benchmark sites on socioeconomic and biophysical aspects of slash-and-burn in partnership with national research institutes and non-governmental organizations

- will validate, test and disseminate options through regional networks, involving public and private organizations and effective policy dialogues in each collaborating country

- will extrapolate global change implications by making the research results available to IGBP-related programmes

- train and strengthen institutions to enhance the capacity of the deforesting nations to build and sustain their efforts to alleviate the crisis.

Selected benchmark sites, two or three per continent, will be selected to encompass the range of biophysical and socioeconomic conditions in the humid tropics. In Africa, one site will be in the equatorial Congo rainforest, which is a zone of rapid demographic, social and environmental change, and one will be in the dystrophic miombo woodlands, where chitemene is practised.

In Latin America, two sites in the Amazon are proposed, one in semideciduous evergreen rainforests with rapid development and another in a typical rainforest with poor infrastructure and migration from the Andean region. A third site in Mexico will be considered.

In Asia, one site is envisioned in the equatorial rainforests, where both primary forest clearing and degraded alang-alang grasslands are abundant, another in the tropical monsoonal region and a third in the hill country of mainland Southeast Asia in an area of extremely rapid deforestation and rapidly eroding slopes.

The level of effort envisioned is on the order of USD 5 million per year per continent for an initial five-year period. This includes strategic research at benchmark sites, direct funding to the host national agricultural research systems, network support, overall coordination and linkages with global environmental efforts. This project builds on existing research facilities and institutions, thereby minimizing capital and administrative costs. It is envisioned that after 10-15 years, the project will have made major contributions toward mitigating major environmental damage and will also have enhanced equity for small-scale farmers in the humid tropics. The immediate beneficiaries will be farmers and consumers of the humid tropics; however, the mitigation of tropical deforestation will benefit every person in the world.

FOREWORD

Representatives of the United Nations Development Programme contacted international centre leaders at International Centres Week in October 1990 to enquire about the feasibility of a concerted effort to develop alternatives to the slash-and-burn system of agriculture. The idea was followed up by scientists from IFDC, IITA, ICRAF and TSBF, who met in Lome, Togo, in June 1991 and formulated the framework of a project, focusing on Africa. Representatives of ICRAF, IFDC, IITA, CIAT, IRRI, TSBF and UNDP met in Diamant, Martinique, 2-3 July 1991, to discuss the possibilities of a global programme. A first draft was the product of that discussion. Contacts were made with potential NARS collaborators, NGOs and members of the global-change scientific community. A visit was made to the head of the Global Environmental Facility on 29 August. The concept was shared with donors, NARS and NGO representatives at an informational lunch during International Centres Week on 29 October, and a seminar, co-sponsored by the Environment and Agricultural divisions of the World Bank, was conducted on 31 October 1991.

Sequentially, the First Global Workshop on Alternatives to Slash-and-Burn, financed by UNDP, was held at Porto Velho, Rondonia, Brazil, 16-21 February 1992, to determine the feasibility of developing a global, coordinated effort on alternatives to slash-and-burn agriculture in tropical rainforest areas. The participants were 26 environmental policy makers and research leaders from eight tropical countries and representatives from five non-governmental organizations, six international research centres, three regional research organizations and six donor agencies. The major conclusions were:

- A global effort is needed.
- The approach for planning and implementing the programme is to be collaborative.
- Socioeconomic policy and biophysical issues are to be emphasized.
- The focus is to be on broad global issues as well as those of specific regional concern.
- Eight locations are to be selected as ecoregional benchmark sites.
- A Global Steering Group (GSG) is to be created to ensure continuity and global coordination.
- ICRAF, as requested, is to continue to play the overall coordinating role.

This proposal is a product of the feedback received from such interactions.

THE PROBLEM

Characteristics of slash-and-burn

Slash-and-burn (or shifting cultivation), the traditional farming system over large areas of the humid tropics for centuries, still remains the dominant land-use practice in about 30% of the arable soils of the world and provides sustenance for an estimated 250 million of the world's poorest people and additional millions of migrants from other regions (Hauck 1974).

Throughout the world, traditional shifting cultivation practices are remarkably similar. Small forested areas are cleared by axe and machete during periods of least rainfall and are burned shortly before the first rains. Without further removal of debris, crops such as com, rice, beans, cassava, yams and plantains are planted in holes dug with a planting stick or in mounds for root crops in Africa. Intercropping is very common, and manual weeding is practised. After the first or second harvest the fields are abandoned to rapid forest regrowth. The secondary fallow may grow for 10 to 20 years before it is cut again (Nye and Greenland 1960, Sanchez 1976).

Traditional shifting cultivation is based on nutrient cycling and weed and pest suppression during the fallow period. In regard to nutrient cycling, burning releases to the soil about half of the nitrogen and phosphorus of the burning biomass and practically all of the other nutrients in the form of ash, which also causes a liming effect. Higher soil temperature following burning also accelerates the decomposition of soil organic matter. These factors provide high nutrient availability for one or two years to grow food crops, depending on the inherent fertility status of the soil (Seubert et al. 1977, Smyth and Bastos 1984, Lai et al. 1986). Burning also helps to control pests and diseases and enables cultivators to clear land quickly and efficiently with minimal labour requirements. (Alternative forms of clearing land are usually too expensive and labour intensive, especially for poor farmers.) As nutrients are removed by crop harvests or lost to leaching, overall fertility declines. Nutrient deficiencies as well as increasing weed pressure impede further cropping, and the fields are abandoned to a secondary forest fallow. The secondary forest grows rapidly, tapping nutrients remaining in the soil, including those released slowly by unburned decomposing forest biomass, accumulating them above ground for 10 to 20 years, until the cycle begins again (Nye and Greenland 1960, Szott and Palm 1986).

Biodiversity is another unique feature of this form of cultivation. Most indigenous shifting cultivation systems consist of complex polycultures. They have a diversity of crops and species, including trees and food crops in 'traditional' agroforestry systems. This diversity helps to reduce the risk of disease and pests, and it provides a diverse source of foods and products for families. In addition, indigenous systems are usually tied to complex cultural norms and socioeconomic traditions and involve unique cultural knowledge of diverse species. Also, the vegetation of the fallow stage serves as a genetic reservoir for many important plants and is a refuge for invertebrate and vertebrate animals.

In relation to environmental problems promoted by slash-and-burn cultivation, the burning releases half of the nitrogen and most of the sulphur and carbon into the atmosphere, thus contributing to greenhouse gases. Similarly, the accelerated organic matter decomposition associated with intensified agriculture increases carbon loss; the higher nutrient availability can increase gaseous nitrogen emissions.

The fallow period therefore does not improve soil fertility per se. Except for some reaccumulation of carbon in the soil organic matter and fixation of atmospheric nitrogen, fallows mostly accumulate nutrients in the plant biomass, which can be tapped by future crops upon slash-and-burn. The essential mineral nutrients (phosphorus, potassium, calcium, etc.) are extracted from lower soil layers during regrowth and brought to the surface by plants. However, unlike N_2 fixation, this is essentially a slow process, which concentrates nutrients where they can be used to grow a crop but which does not add nutrients to the system. These slowly accumulated nutrients are then removed in the harvested crop, increasing the net loss of nutrients from the whole system.

The traditional systems are ecologically and environmentally sound at low (or very low) population densities. For millions of peoples, shifting agriculture in traditional forms has provided and still provides a basis of subsistence, cultural values and social stability, particularly under low population density. These systems are in various forms, ranging from classic swidden systems to altered forms, such as the taungya system. These systems also have features, such as nutrient cycling and diversity, that are useful for understanding sustainable land uses in the humid tropics.

However, traditional shifting cultivation systems are being rapidly replaced by shifting cultivation in disequilibrium, which turns into unsustainable forms of agriculture. These changes also lead to cultural and social disruption of traditional societies. The unsustainable form of slash-and-burn is practised by migrants from other regions, who are unfamiliar with the humid tropics and ignorant of the sophisticated practices of indigenous cultures that make shifting cultivation a sustainable system. The central concern in this project is unsustainable slash-and-burn, in areas where alternatives are needed, as distinct from the traditional systems practised by indigenous people in forest areas.

Soil erosion is seldom a significant problem in traditional shifting cultivation, because the land area is relatively small and is always covered by some sort of vegetative cover, such as fallen logs, crops, weeds or forest fallows. When shifting cultivation is practised by newcomers to the humid tropics, the land is often devoid of soil cover for considerable time. This can lead to major erosion and siltation of rivers, particularly in hilly areas (Lal et al. 1986).

Shifting cultivation is definitely not sustainable if significant increases in land productivity are required to support higher human population densities and increased demand for food and fibre. Recent increases in population growth, as well as transmigration to poorer, less fertile soils, have placed great pressure on farmers to increase the productivity of limited land resources by expanding the length and intensity of the cropping period and decreasing the fallow period. Migration is less significant in Africa, but major in Latin America and Asia.

As the time available for secondary forest fallow growth decreases, the fertility and productivity of the soils, which are mostly low, continue to decline. Furthermore, when the fallow period is shortened, it generates a disequilibrium of carbon input-output ratios and intensifies nutrient mining. Complex and often adverse ecological changes occur, such as invasion of *Imperata* grasslands and reduction in the number of native seeds left viable for regrowth. Re-establishment of secondary forest fallow vegetation is slowed or stopped, some soil becomes bare and erosion begins. This situation is typified by the so-called derived savannas, which occupy more than three-fourths of the previously tropical moist forest of West Africa. In turn, these declines in productivity contribute to increasing economic hardship and impoverishment for shifting agriculture under conditions of disequilibrium. Moreover, people in these situations tend to lack access to alternative economic opportunities, are isolated from development programmes and in some areas are marginalized further by the expansion of

large-scale producers such as cattle ranchers. The trends towards expansion of the cropping cycle and a decrease in the fallow period are central to the **problem of non-**sustainable production. They are **also** the key trends affecting the contribution of slash-and-burn to global warming. In particular the net reduction in soil organic matter and plant biomass through intensification and modification of traditional systems are the main mechanisms by which slash-and-burn is, if anything, increasingly contributing to the greenhouse effect. The two problems, and their solution, go hand in hand.

Population growth and poverty are not the only causes behind increased rates of deforestation. External forces or processes such as expansion of commercial plantations or farms, ranching, logging and mining also attract or push migrants into slash-and-burn, causing considerable deforestation. In Africa the expansion of cash crops for export (e.g., groundnut, cotton, coffee, cocoa) has considerably reduced land availability for food crops, increasing forest encroachment and reducing the fallow period. Another important cause is the need for fuelwood, estimated to account for half of the wood harvested in the world. Commercial exploitation for high-value logs accounts for much of the deforestation in Central America, Bolivia, Brazil, Nigeria, Cote d'lvoire, Indonesia, Malaysia and Philippines, mainly to supply European, American and Japanese markets.

In Latin America, clearing the forest is a way for settlers to claim title to state lands, encouraging uneconomic forest clearing and land speculation. Construction of roads and other infrastructural facilities supporting development strategies have also contributed to accelerated rates. The recent deforestation in the Brazilian Amazon can be attributed mainly to commercial logging, plantations, speculation and mining, while population pressure by small peasant agriculturalists, clearing land for their own farms, accounts for only about 10% of total deforestation.

Environmental context

Recent estimates indicate that about 18% of global warming is due to the clearing of tropical rainforests, which is occurring now at a rate of **14 million hectares of primary forest** per year (EPA 1990). Most of **the** deforestation is presently occurring **in tropical** America and tropical Asia, accounting for 40 and 37% respectively of estimated net carbon emissions from deforestation in 1980. Tropical Africa ranks third, with 23% of the emissions (Houghton et al. 1987). Deforestation rates have almost doubled during the last decade: from 7.6 million hectares per year in 1979 to 13.9 million hectares per year in 1989 (Myers 1989).

Deforestation from slash-and-burn agriculture in disequilibrium can lead to several negative environmental consequences, including soil erosion and degradation, leaching, watershed degradation and loss of biodiversity. These repercussions at the local level signify resource depletion and declines in production. In addition, diverse forest products are greatly underutilized. At a wider level, the loss of forest cover also contributes to changes in rainfall patterns and climate change.

After deforestation, soil organic matter may act as an additional source of carbon dioxide to the atmosphere or as a sink where carbon dioxide may be sequestered, depending on how the land is managed. There is little reliable quantitative knowledge about fluxes of carbon dioxide, nitrous oxides or methane caused by shifting agriculture. Hard data from well-replicated experiments and surveys are needed to determine the current extent of slash-and-burn agriculture and the process of change in land use, including the extent and nature of the environmental impact of these systems. The contribution of tropical land use to global change is one of the uncertainties in current models (Houghton et al. 1987).

Although every country with humid tropics is undergoing deforestation of primary forests, 12 countries account for over 80% of the total (table 1).

Deforestation rates are expected to increase in the next decades, and the overall contribution to global warming is expected to equal or exceed that of fossil fuel combustion by the second or third decade of the 21st century. If this trend continues, much of the remaining tropical forest will be diminished by the end of the 21st century. Deforestation is also decimating the world's largest depository of plant and animal genetic diversity (Myers 1989). Recent discoveries of rainforest plants as new sources of food, or as ingredients in chemotherapy for certain types of cancer, underscore the need to preseive rainforest biodiversity. Therefore, finding practical ways to preserve tropical rainforests is one of the principal global environmental concerns of our times.

Socioeconomic, policy and equity context

Tropical deforestation by slash-and-burn is also a major human equity concern, because slash-and-burn is largely practised by the poorest, largely displaced rural populations of the tropics. Moreover, poor people usually bear the main costs of environmental degradation. The process of deforestation is driven by a complex set of demographic, biological, social, geopolitical and economic forces, as well as policy pressures (Sanchez et al. 1990). Population growth in developing countries continues at a high rate, while most of the fertile and accessible lands are already intensively utilized.

A variety of governmental policies often exacerbate and contribute to resource degradation, land scarcity and inappropriate land use. For example, land-use policies allow gross inequities in land tenure. These factors result in an increasing number of landless rural people, who essentially have

Table 1. Rates of deforestation and carbon emissions for leading countries

Country	Annual deforestation ('000 ha $year^{-1}$)	Rate (% $year^{-1}$)	$C0_2$ emitted (million t C $year^{1}$)
Brazil	5000	2.1	46
Indonesia	1200	1.4	12
Myanmar	800	3.3	8
Mexico	700	4.2	6
Colombia	650	2.3	6
Thailand	600	8.4	6
Malaysia	480	3.1	5
Zaire	400	0.4	5
India	400	2.4	4
Nigeria	350	14.3	6
Peru	350	0.7	3
Vietnam	350	5.8	3
World total	13860	1.8	140

Source: Myers 1989, estimates for 1989

three choices: stagnate in place, migrate to the cities, or migrate to the rainforests that constitute the frontier of many developing countries. Similarly, land-tenure policies often do not enable people to have secure title to land, which may discourage producers from adopting methods that are sustainable in the long term. Although urban migrations are spontaneous, national policies **in** key countries, notably Brazil, Peru and Indonesia, include colonization programmes, often geopolitically motivated, that encourage the occupation of their tropical rainforests.

Other policy-related factors that lead to unsustainable slash-and-burn agriculture and problems resulting from it include fiscal and monetary policies (e.g., subsidies, incentives and credit), inadequate laws and regulations affecting land use and forests, inappropriate infrastructure, lack of markets for alternative products, weak institutional services such as lack of education and technical assistance, lack of farmer organization, and neglect of farmer participation in research and development programmes. Macroeconomic policies, including the influence of international financial agencies, may underlie the problems as well.

In addition to causing problems, the above policy-related factors constitute socioeconomic constraints for the adoption of more appropriate land-use practices. Densely populated rural environments such as the Andean valleys, Northeast Brazil and Java suffer from ever-decreasing farm size and overuse of steepland areas. This results in widespread soil erosion, siltation of reservoirs and other adverse off-site effects on urban centres.

Migration to the cities in search of a better life results in bitter disappointment and, coupled with limited urban infrastructure, produces unmanageable cities with populations far exceeding their carrying capacity and infrastructure. People migrating to the humid tropics seldom find a cornucopia. The equilibrium of traditional shifting **cultivation, with** its **long** forest **fallows, is broken by the migrants 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 centres increases.

The results 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. Also, deforestation depletes the limited nutrient capital of ecosystems, decimates plant and animal genetic diversity, and accelerates global warming.

Environmental degradation originating from deforestation often affects production and subsistence systems in rural areas. Erosion, flooding, groundwater depletion and silting affect agricultural productivity, decreasing food availability, income and employment. Forests also serve as 'food banks' for poor communities and often are the main source of household energy for cooking; yet, these resources are lost in the degradation process.

Responses

Efforts have been initiated by many institutions in the attempt to alleviate problems from uncontrolled slash-and-bum and other resource degradation. Research programmes, technology and extension projects, and policies have been developed in some regions. For example, a recent change in strategy led the Brazilian government to eliminate incentives to Amazon development, resulting in substantive reductions in deforestation rates.

However, in many cases, these efforts have been constrained or are inadequate in alleviating problems and providing alternatives. Forestry programmes assume that sustained, rational exploitation in suitable areas, using appropriate technologies, should lead to economic benefits. Their assumptions about social institutions, markets, costs, alternative land uses, agro-climatic conditions and available technologies have often been erroneous. Also they sometimes neglect to consider the rates 'beneficiaries' use to discount uncertain future costs and benefits. Equally, they may disregard local social, economic and cultural relationships and constraints, ignoring the way introduced activities compete with others vital for the family livelihood. On the other hand, forestry activities that complement the use of farmers' land, time and other resources in a way that is integrated with other agricultural activities may be more readily adopted.

Moreover, existing institutions undertaking research and extension in this area tend to lack coordination. There is a lack of direct involvement of non-governmental organizations and farmers groups in the research and development activities. In many cases, technology transfer has failed to have an impact in a 'top-down' mode of diffusion. Efforts may be duplicated. These constraints need to be overcome through coordinated and comprehensive research and actions. Lessons can be learned from both the weaknesses and successes of previous efforts, but there is still a great deal of work to be done to alleviate the problems.

The problem addressed by this document therefore has implications for the global environment as well as implications for equity among the poorest of the rural poor, including a major proportion of the migrant populations.

CURRENT STATUS

The search for alternatives to slash-and-burn fortunately does not have to start from zero. There is considerable knowledge about the biophysical and socioeconomic determinants of shifting cultivation.

Technologies

Research on shifting cultivation has been conducted in Africa since the 1920s on replacing chitemene nutrients by sources other than burning. The work in the 1950s by Jurion and Henry (1969) in Zaire and of Nye and Greenland (1960) in Ghana are widely known. The anthropological basis of shifting cultivator cultures has been widely studied in Asia, Africa and Latin America. Long-term agronomic research has been conducted since the 1970s, primarily but not exclusively by four groups: at Yurimaguas, Peru, and Manaus, Brazil, by North Carolina State University (Sanchez et al. 1983, Sanchez and Benites 1987, Sanchez et al. 1987, Szott et al. 1991); at Ibadan, Nigeria, by IITA (Yamoah et al. 1986, Juo and Law 1977, Kang et al. 1990); in north-east India by Ramakhrishnan and associates (Ramakrishnan 1984, Toky and Ramakrishnan 1981, Ramakrishnan 1987); and in Sumatra by AARD and associated institutions (Macintosh et al. 1981, Von Uexkull 1984, Wade et al. 1988). These efforts have provided several kinds of information:

- They have quantified the nutrient transfer process from biomass to ash and into soil and monitored the changes in soil properties upon cropping..

- Analysis of the dynamics of soil organic matter has shown that judicious management of inputs, vegetation cover and harvest residue can result in a sustained level of soil organic matter (SOM).

- They have determined that bulldozer clearing is inferior to traditional slash-and-burn in providing suitable physical and chemical soil properties for planting of food and tree crops. Detrimental effects of bulldozer clearing include topsoil carry-over, soil compaction and the absence of ash as a nutrient-transfer process. Several major colonization projects are no longer based on bulldozer land clearing.

- They have determined that the shift in weed population from broadleaved species to grasses is one of the principal causes of land abandonment and often surpasses the depletion of soil fertility.

- They have determined that crop rotation allows crops to be grown continuously with judicious use of lime, fertilizer and green manures, producing sustainable yields in well-managed systems. With poor management, however, attempts at continuous production have resulted in sharp drops in productivity, soil compaction and erosion, even in flat areas.

- Low-input systems have the highest potential for sustainability in acid, low-fertility soils if they are based on the use of aluminium-tolerant germplasm of annual crops, pastures or trees. Systems based on this principle have shown sustainable production for more than 10 years at research stations, with evidence of improvement rather than degradation of physical, chemical and biological soil properties.

- Keeping the soil surface covered at all times is a key principle for sustainability in the humid tropics. Soil erosion can be controlled with the use of agroforestry systems, including alley cropping on slopes, live fences in pastures, annual crop-tree crop systems and managed forest fallows. The presence of perennial vegetation further promotes nutrient recycling by litter and root turnover. This is particularly effective in pastures and agroforestry systems.

- Current research indicates that shifting cultivation can be replaced by alternative systems that meet the food and fibre needs of the humid tropical farmer while providing for additional income by producing high-value, low-volume crops for export. With these crops (including rubber, palm oil, heart of palm, tropical fruits, pepper, medicinals) the humid tropics have a comparative advantage. Changing consumer values in the First World toward more nutritious and ecologically friendly products may increase this comparative advantage.

- Research on plantation forestry shows that many of the principles applicable to agricultural systems are also appropriate for soil conservation, fertility enhancement, weed control and crop selection in forest management.

The research synthesis shows that some alternatives are possible; there definitely is hope. But research has been conducted on an insignificant scale and primarily at research stations. Such a knowledge base needs to be expanded geographically and adapted to specific climate, soil and socio-economic constraints with different market opportunities. Research needs also to expand from on-station to on-farm testing.

Sustainable management options for acid soils of the humid tropics have been developed to fit different landscape positions, soils and levels of development of the socioeconomic infrastructure (Sanchez 1987). For instance, the principal sustainable management options and alternatives to slash-and-burn for one region, the Selva Baja of Peru, are paddy rice production of alluvial soils, low-input cropping, continuous cultivation, legume-based pastures, agroforestry, perennial crop production (rubber, oil palm) and plantation forestry. Their place in the landscape can be distinguished (fig. 1).

Nutrient recycling must be enhanced in all systems, to minimize the need for external nutrient inputs and maximize their efficiency. The management of crop and root residues is crucial in this regard (Swift

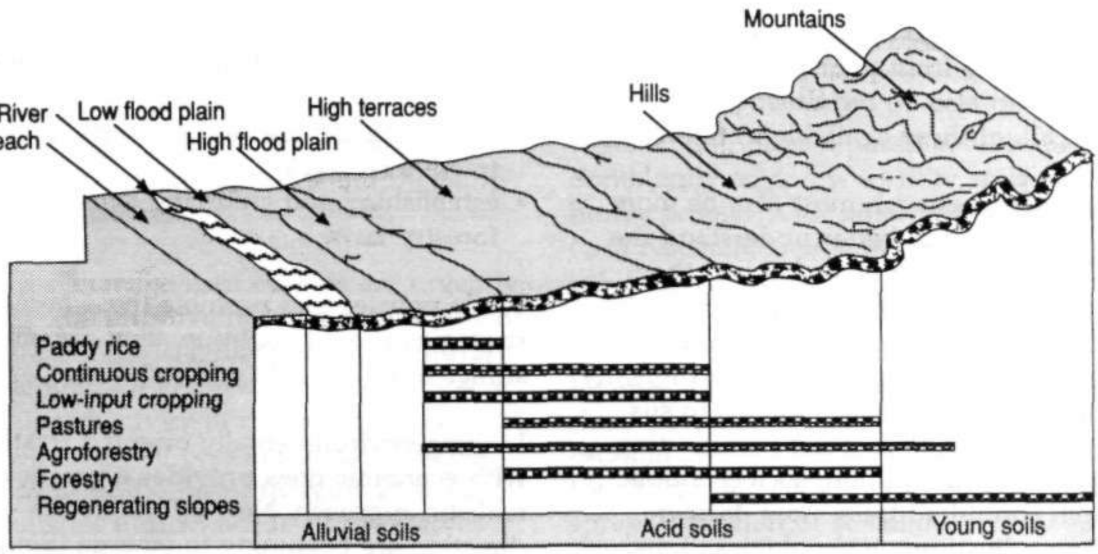

Figure 1. Management options for acid soils of the humid tropics.

1987). Approaches proposed by TSBF on quantifying the nutrient release of organic input and managing soil organic carbon, nitrogen and phosphorus are major components of the research on low-input cropping, agroforestry and pastures. The promising results in predicting the rate of nutrients released from leguminous materials based on their polyphenolic contents (Palm and Sanchez 1991) provide for the first time an opportunity for the quantitative management of organic input in a manner comparable to the management of chemical fertilizers.

However, even in situations where nutrient cycling is possible on a significant scale, it is necessary to employ supplemental fertilizer to maintain productivity. Research conducted by IFDC in Africa has shown that judicious use of fertilizers in combination with a programme of crop residue management is superior to the use of either fertilizers or nutrient cycling alone. Where phosphate rock deposits are available, it may be possible to substitute these agrominerals for commercial fertilizer phosphates.

For every hectare put into these sustainable soil management technologies by farmers, 5 to 10 hectares per year of tropical rainforests will be saved from the shifting cultivator's axe, because of their higher productivity. Estimates at Yurimaguas, Peru, for various management options (Sanchez et al. 1990) are given in table 2. These estimates will vary with climate and soils.

Table 2. Estimates of the impact of soil management technologies on deforestation **for** Yurimaguas and Peru

1 ha in sustainable management options . . .	equals *x* ha 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 are particularly applicable to secondary forest fallows, where clearing does not contribute significantly to global warming because of the small tree biomass. The use of secondary forest fallows is of veiy high priority, because in many areas they are a feasible alternative to primary forest clearing. Many of the degraded or unproductive pasture or croplands resulting from poor management practices can also be reclaimed using some, but not all, of these available technologies.

Furthermore, research must also be more process oriented to better understand the 'why' questions and focus beyond the whats' listed in the preceding section. In particular, there is need to understand the processes that link agricultural and forestry management of these ecosystems to sustainable conservation of the surrounding environment. In addition, socioeconomic research should address 'how' farmers adopt or adjust new technologies, 'how' farmers and communities make decisions on short-term gain versus long-term resource conservation and 'how' the new technologies affect farmer decisions on forest clearance. Finally, research efforts should be more inclusive, with greater participation of NARS, NGOs and developed-country institutions, effectively linked with the global climatic-change community (Bouwman 1990) and biodiversity, aiming at a common research agenda.

Policy

None of these technologies, however, is likely to be used without significant policy changes that provide adequate market and infrastructure development and at the same time protect the remaining rainforests from being cut. Deforestation is a relatively new field in the policy sciences, but some of its underpinnings are beginning to emerge. Analysts in this field generally cite six or seven major policies to decrease tropical deforestation. These are:

- supporting economic development and market opportunities that are environmentally sound
- establishing more equitable land-tenure systems and securing tenure rights for poor farmers
- encouraging migration to less fragile areas such as the Cerrado of Brazil
- preserving the remaining forests by a vast network of well-protected national parks
- eliminating 'distorted' policies or laws that induce forest destruction
- sustaining the use of the forests as extractive reserves
- establishing and enforcing land-use and forestry laws

While policies that promote these necessary strategies should continue, they are not sufficient to mitigate deforestation.

Linking environmentally oriented strategies with economic ones provides a practical, realistic approach. New efforts in this direction are beginning to emerge (Bouwman 1990, Gillis and Repetto 1988) and have resulted in lively dialogues. A few deforesting countries have developed policies to contain deforestation primarily in response to national and international environmentalist pressures. Some of them are far too radical to be workable. In some cases they backfire, with severe negative effects on the economy, and trigger increasing deforestation in neighbouring countries.

The need for solid policy research on tropical deforestation is as important as biophysical research. This should complement and link with research on technological and socioeconomic options as well. Furthermore, there is a need to assess how economic growth affects rates of forest clearance, how agricultural intensification affects migration and how new technology affects both aspects.

Guiding principle

This review of the status of research, technologies and policy suggests the following principle: control deforestation from slash-and-burn agriculture in situ by eliminating the need to clear additional land and by rehabilitating degraded land and resources.

This can be done by:

- providing sustainable alternatives to slash-and-burn

- reclaiming and managing abandoned and degraded lands that are declining in productivity, including secondary forest fallows and unproductive grasslands
- addressing policy factors that affect slash-and-burn agriculture and the adoption of alternatives

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 forest margins in a way that satisfies human needs and preserves the ecosystem. These options must be compatible with the different socioeconomic needs of specific areas so that they are readily and widely adopted. In addition we should be concerned with how and why deforestation occurs, how the people living in and around forests are affected by deforestation processes, how they react individually and collectively, and what role government policies play. Activities will focus on local interactions of slash-and-burn processes but will also take into account broader processes and systems (zonal, national and regional). In this context, the agroecological foundations of sustainable agriculture will be established as a basis for developing biologically based management systems.

Is such an approach possible with the predominantly 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.

Farmers do not cut tropical rainforest because they like to; they clear them out of sheer necessity to grow more food. Deforestation and the poverty of shifting cultivators, therefore, can be reduced by the widespread adoption of sustainable management practices and policies that permit the use of cleared land and development of diverse, underutilized forest products, on a continuing basis. Such practices also have the potential to reduce emissions of greenhouse gases and increase land available for sustained forest management. 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 in a joint technology-policy approach.

PROJECT PURPOSE

This document proposes a worldwide research and development project with the following goal, objectives, target areas, time frame, and research agenda.

Goal

To significantly reduce the rate of tropical deforestation driven by slash-and-burn agriculture and associated processes, and improve the well-being of dwellers of the forests and forest margins by means of a joint technology-policy approach aimed at developing feasible land-use alternatives.

Objectives

- Assess the socioeconomic processes leading to deforestation, including decision-making patterns of farmers practising slash-and-burn.

- Identify and develop improved production systems that are economically feasible, socially acceptable and environmentally sound alternatives to current slash-and-burn systems at key benchmark sites in the humid tropics.

- Identify policy options and institutional management issues that facilitate adoption of such systems and at the same time discourage further deforestation.

- Validate and transfer through adaptive networks in Asia, Africa and Latin America successful experiences in prototype technologies and policies.

- Quantify the contribution of slash-and-burn and its alternatives in the tropical forest zone to global environmental changes.

- Train professionals and strengthen institutions to build a sustained research and policy infrastructure.

Target areas

The forests and forest margins within major humid tropical areas of Africa, Asia and Latin America, where deforestation is extensive and accelerating at present.

Time frame

The time frame is 15 years, given the long-term nature of the work, with an initial phase of 5 years for consideration by the Global Environmental Facility or other donors.

Biophysical and policy research agenda

The objectives, activities and expected outputs for both the biophysical and policy research are outlined in table 3.

- Characterization of the biophysical and policy evironment will be undertaken at each of the proposed study areas. Specific emphasis will be given to an analysis of conditions under which farmers have already started to modify slash-and-burn systems and intensify land use. Such information will be derived from prior studies of land-use systems and from more specific reviews of farms within these systems.

- Using outputs from biophysical, socioeconomic and policy research, a regional, geographically referenced database will be developed for the purpose of synthesizing regional information and identifying key socioeconomical and biophysical determinants and processes leading to slash-and-burn agriculture and deforestation. The regional GIS database will provide the global framework under which the research will be conducted and have potential impact.

- For both biophysical and socioeconomic reasons, not all land-use systems currently practised as alternatives to slash-and-burn are sustainable. To evaluate the sustainability of these systems, it is important that criteria be developed against which the systems can be assessed. These criteria will be established by **a** global working group consisting of participants from the three regions and other experts from relevant research areas. The criteria will be tested in a few selected areas.

- Based on the information gathered regionally and synthesized globally, and utilizing the sustainability criteria, potential alternatives to slash-and-burn agriculture will be identified and documented in a geographically referenced database. This database will provide a global reference point for sharing and transferring information for regional and local research initiatives, and the potential relevance and introduction of new alternatives.

- To provide a focus for research and intervention, and based on agroecological and socioeconomic criteria, priority identification domains will be named in each study area. Given the wide spectrum of potential interventions, this activity will maximize the chances for the adoption and impact of sustainable alternatives through the identification of priorities for technology development and system improvement.

Table 3. Summary of the biophysical and policy research agenda

BIOPHYSICAL RESEARCH	POLICY RESEARCH
Objective 1 To assess and prepare diagnosis of the biophysical processes leading to slash-and-burn and deforestation.	**Objective 1** To assess and prepare diagnosis of the socioeconomic factors and policy environments that influence the practice of slash-and-burn agriculture.
Activities 1. Characterization of the biophysical environment of target areas by collecting and collating and digitizing existing information on soils, climate, vegetation, agricultural practices, land use and environmental degradation in target areas. 2. Synthesis of data derived from the biophysical and policy characterization of the target areas. 3. Integration of characterization data to develop preliminary models of the processes influencing slash-and-burn and deforestation.	**Activities** 1. Characterization of the socioeconomic factors and policy environment in target areas. • Collection of existing information on infrastructure, international trade patterns, export-import subsidies, monetary policies and demographic patterns. • Analysis of present and past population policies regarding migration and resettlement. • Analysis of population dynamics, ethnic composition and traditional land-use systems and their impact on land management. • Analysis of land-tenure policies and land-use laws and their impact on land-management practices.
Expected Outputs 1. A georeferenced interactive database and information system for each target region. 2. Prototype models of the key biophysical and policy determinants of slash-and-burn and deforestation.	**Expected Outputs** 1. A georeferenced interactive database and information system for each target region. 2. Prototype models of the key biophysical and policy determinants of slash-and-burn and deforestation.

Table 3. Continued

BIOPHYSICAL RESEARCH

Objective 2
To determine the key biophysical constraints to agricultural production, environmental quality and sustainable land use.

Activities

1. Investigation of component interactions on weed dynamics, pest-parasite dynamics, soil fertility, resource competition and soil erosion.

Expected Outputs

Identification of key biophysical constraints in the multistrata, improved fallow and silvopastoral systems.

POLICY RESEARCH

Objective 2
To determine the key socioeconomic and policy constraints to the adoption of slash-and-burn alternatives.

Activities

1. Analysis of legal and institutional constraints that influence local processing of products.
2. Conduct of market surveys to determine local,regional and international market commercialization and consumer preference.
3. Assessment of the legal and institutional constraints to farmers' access to modern inputs.

Expected Outputs

1. Improved understanding of producer group organizations for processing products.
2. Comparison of local market commercialization with national, regional, and international markets.
3. Identification of levels of accessibility to modern inputs.

Table 3. Continued

BIOPHYSICAL RESEARCH

Objective 3

To evaluate existing and potential land-use alternatives to slash-and-burn and reclamation of degraded lands that are environmentally sound, economically feasible and socially acceptable.

Activities

1. On-station and on-farm research on rehabilitative systems that incorporate ecologically integrated resource management practices—agropastoral systems, multistrata systems, enriched fallow systems and agroforestry systems.
2. Development of integrated soil and nutrient management practices through component systems research.
3. Selection, collection and evaluation of germplasm for the prototype systems.

Expected Outputs

1. Selected components (plant species, management, spatial and temporal arrangements, etc.) for prototype alternative systems to slash-and-burn agriculture.
2. Component technologies on soil, water and nutrient management that can be incorporated in the design of potential prototype systems.

POLICY RESEARCH

Objective 3

To develop alternative policies for encouraging the adoption of sustainable agriculture.

Activities

1. Evaluation of land-tenure and resource-use policies for management interventions on land rehabilitation and soil fertility.
2. Documentation and analysis of indigenous knowledge as a basis for the development of alternative systems to slash-and-burn agriculture.
3. Identification of institutional policies that will accelerate investment in agricultural research and improvement of technologies.
4. Identification and evaluation of market, credit and other policies that will facilitate farmer access to modern inputs through incentive policies and technical assistance.
5. Identification of migration and resettlement policies that will prombte sustainable use of land resources.

Expected Outputs

1. Incentive policies for adoption of alternative production systems to slash-and-burn agriculture by farmers.
2. Policies to promote investments in natural resource conservation by national and international agencies.
3. Land-tenure and land-use policies that will improve the v/elfare of the small-scale farmers and promote better management of forest and agricultural land resources.

Table 3. Continued

BIOPHYSICAL RESEARCH

Objective 4

To determine the sustainability of the alternative systems in terms of their biological productivity, economic importance, risk reduction, nutrient cycling and soil conservation potential.

Activities

1. On-station biophysical monitoring and investigation of component processes that contribute to agricultural productivity and sustainability (weed pressure, soil fertility, resource competition, soil erosion, etc.).
2. Evaluation of the performance and impact of the improved technologies over a wide range of environments.

Expected Outputs

1. Analysis of the performance and sustainability of the alternative production systems in terms of biological productivity, economic importance, risk reduction, nutrient cycling and soil conservation.
2. Predictive models for performance and impact of the improved technology under different biophysical and management conditions.

POLICY RESEARCH

Objective 4

To assess and develop mechanisms for effective implementation of alternative policies and the adoption of the alternative technologies.

Activities

1. Enhancement of human resource capacity for informed decision making and development of awareness on the alternatives to slash-and-bum.
2. Participation of farmers and national policy advisory institutions in the design and technology evaluation.
3. Information dissemination and exchange to enhance decision making for improved resource management.
4. The gathering of information on mechanisms used in other countries to make decisions on the implementation of policy alternatives.
5. Evaluation of the policy decision-making processes and intervention points for policy implementation.

Expected Outputs

1. Analysis of the policy decision-making processes and identification of the critical intervention points for policy alternatives.
2. Identification of relevant successful policy experiences from other countries.
3. Enhancement of the human resource capacity to make decisions.
4. Dissemination of information on alternative technologies and policy networks at national and global levels.

Table 3. Continued

BIOPHYSICAL RESEARCH

Objective 5
To quantify the contribution of slash-and-burn to major features of global change, such as loss of biodiversity, emission of greenhouse gases and soil degradation, in comparison with the alternative systems.

Activities
1. Monitoring and quantification of greenhouse gas emissions.
2. Analysis of soil organic matter (SOM) dynamics, cycling of carbon, phosphorus and nitrogen through the system.
3. Analysis of the effects of soil erosion on organic matter loss.
4. Quantification of changes in biodiversity above and below ground under slash-and-burn agriculture compared to alternative systems.

Expected Outputs

1. Quantification of losses and storage of carbon associated with deforestation and subsequent land use in relation to global warming.
2. Biodiversity assessments of species, ecosystems, land use and landscapes.

POLICY RESEARCH

Objective 5
To assess the socioeconomic costs and benefits associated with slash-and-burn and deforestation as opposed to those of the alternatives to slash-and-burn agriculture.

Activities
1. Analysis of socioeconomic and environmental benefits and costs of slash-and-burn agriculture to individuals and society.
2. Analysis of costs and benefits of alternatives to slash-and-burn (e.g., analysis of the socioeconomic and environmental costs and benefits associated with rehabilitation of degraded lands. Evaluation of opportunity costs and benefits of alternative land-use production practices with conserving biodiversity).

Expected Outputs

1. Assessment of the 'value' of slash-and-burn systems and their alternatives.
2. Social impact analysis, indicators to include nutritional status, household welfare, gender and labour market.

- At each study area, candidate systems will be evaluated under field conditions in priority recommendation domains, and their relative sustainability will be determined utilizing the sustainability criteria. Such evaluations may occur both on-station, or where appropriate, in farmers' fields, and will include systems currently practised in the study area and sustainable systems practised in other ecoregions but of potential relevance to new situations.

- Based on the perceptions and aspirations of farmers in priority recommendation domains and the biophysical and socio-economic factors affecting their decision-making processes, key interventions for the improvement of components will be identified. The potential of such improvements to contribute to enhanced system sustainability and productivity, and the principles governing their function, will be evaluated through strategic, process-oriented on-station research. Such research is essential to provide the basic understanding required to predict performance and impact of improved technology over a wider range of environments. Such studies may include agroforestry or legume-based systems with specific studies on components and processes such as nutrient cycling, management of crops and soil organic matter, weed dynamics and management, multipurpose tree improvement and management, and resource sharing or competition for light, water and nutrients.

- Strategic research on improved components and their interactions will generate information that allows the design of improved or new production systems. These systems must be evaluated on a long-term basis and their productivity, sustainability, environmental soundness and social acceptability will be monitored and assessed. Such research will be undertaken both on-station, where the emphasis will be on biophysical monitoring, and on-farm, where the focus will be on assessing the social acceptability, potentials and constraints to adoption. This on-station and on-farm research will provide a sound framework for studies on the emission of greenhouse gases and on land degradation and for identifying policy interventions that would enhance both the adoption and the sustainability of improved alternatives to slash-and-burn agriculture.

- This project would provide a framework, through support facilities and staff, for GCTE to undertake research on the impact of land-use change, through slash-and-burn agriculture, on biodiversity. GCTE's approach is first to investigate the implications of loss of biodiversity on ecosystem function (nutrient cycling, carbon fluxes, etc.). Then studies of the interactive effects of global change, particularly land-use change, on biodiversity and ecosystem function will be undertaken. GCTE's programme will also emphasize research on the viability of isolated populations. This is particularly appropriate for slash-and-burn as this activity normally leaves forest remnants of various sizes and configurations.

- As part of its effort to determine the effects of land clearing and agricultural intensification on quantities and pathways of carbon and nutrient loss (and their regulation) in the humid tropics, GCTE will measure emission of greenhouse gases ($C0_2$, CH_4 N_20) to the atmosphere, from slash-and-burn and associated land-use systems. Emission-controlling processes, such as the effects of cattle grazing on soil structure and the effects of an altered microclimate following land clearing on fire frequency and on litter decomposition in residual forest fragments, will be quantified; associated microbial processes will also be measured. The work on emission of greenhouse gases to the atmosphere will be undertaken in collaboration with the IGBP International Global Atmospheric Chemistry (IGAC) Core Project, with this project providing well-characterized sites arid support facilities, where appropriate.

- One of the major aims of this project is to determine the extent and type of soil degradation associated with slash-and-burn practices. Particular emphasis will be placed on understanding the dynamics of soil organic matter and the cycling of nutrients, particulary nitrogen and phosphorus, through the system. The key issue in the latter is to determine the quantities and pathways of nutrient loss from the system. Another important aspect of soil degradation that will be studied is the physical loss of soil material through hydrological pathways and by water erosion. GCTE can add a further global change component to this work by investigating soil organic matter dynamics under elevated CO_2 and by determining soil erosion potentials under altered rainfall regimes.

- To maintain the holistic nature of the project and to keep the multiplicity of issues and linkages in perspective, the following procedural mechanisms will be adopted for conducting policy research:

  - Factors and policies will be considered at local, regional, national and international levels.
  - Research will be conducted as much as possible with the participation of the farmers.
  - Policy research will be conducted in continuous interaction with the biophysical research aimed at technology development.
  - A multidisplinary approach will be used in the implementation of research activities.
  - Consideration will be given to intersectorial and intrasectorial linkages and to the relationships among on-site and off-site factors.

- Important items to be included in the specific and more focused policy research are:

  - fiscal policies (taxes, subsidies, etc.)
  - trade and market policies (imports and exports regulations and taxes)
  - monetary policies (credit, interest rates)
  - organization policies (farmers' associations and participation, NGOs)
  - tenure and property rights policies (land, trees, water, biodiversity)
  - regulatory policies (regulations on use of land and natural resources)
  - processing and marketing (agricultural products and inputs)
  - services (extension, transport, education, health, communications)
  - population growth and related policy issues
  - gender and family issues
  - international institutions (development organizations, donors, etc.)
  - indigenous cultural and rights issues
  - valuation of environmental benefits and costs
  - Off-the-land alternatives for economic activity and employment
  - labour and employment issues

The matrix presented in table 4 shows the levels at which socioeconomic and policy research activities will be conducted to achieve the objectives of the project.

OPERATIONAL FRAMEWORK

Conceptually, an operational framework should not only involve institutional mechanisms but should also be looked upon as the process for setting priorities process for ideas for research within the activities originates from a number of sources:

- The process should be bottom up, in which research is driven by farmers'

Table 4. Matrix of policy research objectives and levels of analyses

Objectives	Levels of analysis			
	Global	National	Regional	Local
1. To assess and prepare diagnosis of the socioeconomic and cultural factors and the policy environment affecting decision-making processes leading to slash-and-burn and deforestation				
2. To design and evaluate policy alternatives to eliminate or reduce the practice of slash-and-burn and deforestation, promote the establishment of sustainable agriculture and protect the environment		x	x	x
3. To develop methodologies and tools for policy evaluation to facilitate the decision-making process for the implementation of policy alternatives	x	x	x	x
4. To identify and adapt successful policy experiences from other countries and locations to the circumstances that characterize the areas where slash-and-burn is practised and field research is conducted	x	x	x	x
5. To assess the policy decision-making processes and identify critical intervention points and means to promote implementation of policy alternatives	x	x	x	x

needs, i.e., a demand-driven approach evolved through an ex-ante assessment.

• At the same time, ideas for research should originate with the scientists, or flow up from the field.

• In addition, the regional and global implications need to be considered as the research relates to the rest of the world, i.e., a commonality focus as in Global Warming and Biodiversity.

The framework also involves joint efforts among three groups of institutions:

• The consortium of international centres will serve as a resource pool of expertise not available in developing countries.

Eight developing countries with designated national research institutions have endorsed the project and will host primary sites representative of major agroecologies where slash-and-burn systems are widely used and where improved systems can be developed and evaluated.

A network of national research institutions from additional developing countries will be engaged in practical field evaluation of policies and technologies identified in the project.

Committee structure: three-tier system

LOCAL STEERING GROUP

Local Steering Groups (LSGs) will be constituted at each of the eight sites.

For Latin America:
Porto Velho, Rondonia, Brazil
Yurimaguas, Peru
Merida, Yucatan, Mexico

For Africa:
M'Balmayo, Cameroon
Kasama, Zambia

For Asia:
Bogor, Indonesia
Chiang Mai, Thailand
Claveria, Mindanao, Philippines

LSG membership

Representatives from farmer producer associations, community leaders, state governments, national government, non-governmental organizations, public and private universities, and participation of local, national and international research and extension staff.

Tertns of reference for LSG members

- Problem identification and prioritization
- Activity planning, implementation and evaluation
- Financial requirements including counterpart funding
- Preparation of activity reports

REGIONAL STEERING GROUP

Three Regional Steering Groups (RSGs) will be constituted, one each for Latin America, Africa and Southeast Asia. An ecoregional approach will be followed; CIAT, IITA and IRRI will be the coordinating institutions for their respective regions.

RSG membership

- Chairman from the LSG
- Representatives from the Slash-and-Bum consortium
- Representatives from regional organization and institutions
- One NARS representative from each benchmark site
- Global coordinator

Terms of reference for RSG tnembers

- Activity appraisal, endorsement and approval
- Resource allocation: counterpart, grant and cofinancing
- Regional coordination, monitoring, evaluation and dissemination of results
- Identification of institutional responsibilities
- Setting regional research priorities
- Preparation of annual reports

GLOBAL STEERING GROUP

Global Steering Group (GSG) membership

- Chairman of RSGs
- Benchmark site country representatives
- International Consortium on Slash-and-Burn
- Representatives of NGOs
- Donor agency representatives
- Global coordinator

Terms of reference for GSG members

- Setting of global research priorities
- Project activities and budget approval
- Project monitoring and evaluation
- Receipt of annual reports from RSGs and concurrence on a comprehensive annual report
- Dissemination of information

International centres

This project brings together the experience and expertise of five CGIAR centres, an affiliated centre and two international programmes as follows:

- *ICRAF*. The International Centre for Research in Agroforestry, headquartered in Nairobi, Kenya, has global responsibilities for mitigating deforestation in the humid tropics and massive land depletion in subhumid and semiarid tropics in a sustainable way so that farmers' needs for food, fibre, browse and firewood are met without depleting the resource base. ICRAF's senior scientists include leaders in developing alternatives to slash-and-burn in research conducted in the Amazon and Southeast Asia. ICRAF scientists currently operate in 14 African countries, many of which practice slash-and-burn in their humid tropics.

- *IITA.* The International Institute for Tropical Agriculture, headquartered in Ibadan, Nigeria, has worked on slash-and-burn agriculture since the early 1970s. IITA currently focuses on developing alternative practices that greatly prolong the fertility of tropical soils and reduce the need for bush fallow and the clearing of new land for permanent agriculture. Primary focus for its strategic research on alternatives to slash-and-burn is the new IITA Humid Forest Station at M'Balmayo, 40 km south of Yaounde, Cameroon, in typically deforested land in the Congo Basin-

- *IFDC.* The International Fertilizer Development Center is headquartered in Muscle Shoals, Alabama, USA, with its Africa Division located in Lome, Togo, and an Asia Division in Dhaka, Bangladesh. IFDC has extensive expertise in the efficient use of fertilizer; in developing and testing alternate fertilizer materials; and in the manufacturing technology, marketing and distribution of fertilizer. With scientists outposted in Asia, Africa and Latin America, IFDC is therefore heavily involved in nutrient efficiency research throughout the tropics. IFDC scientists have considerable expertise in modelling, socioeconomic and policy research. IFDC is placing high priority on nutrient cycling in major agroecosystems.

- *TSBF.* The Tropical Soil Biology and Fertility Programme, headquartered in Nairobi, Kenya, focuses on the maintenance of soil productivity through the manipulation of organic inputs (mulches, residues, green manures, etc.) and soil organic matter. Its principal investigators, located throughout the world, have extensive expertise in nutrient cycling under humid tropical conditions and seek to maximize nutrient-use efficiency through the combined use of inorganic and organic inputs.

- *IRRI.* The International Rice Research Institute, headquartered in Los Banos, Philippines, is placing priority on rice-based upland cropping systems in Southeast Asia. Its goal is to rehabilitate upland ecosystems and increase the stability of upland rice farming systems. IRRI senior scientists have expertise in this subject and coordinate effective research networks in the region.

- *CIAT.* The Centro Internacional de Agricultura Tropical, headquartered in Cali, Colombia, is the first CGIAR centre to have adopted a full-scale ecoregional approach. In this context it is implementing a land-use programme (focusing on the relationships between policy, land use and sustainable agriculture compatible with natural resources and preservation of the environment) in three Latin American and Caribbean agroecosystems programmes, relevant to this project, for the tropical forest margins, the savannas and the hillsides. Unique among the IARCs is CIAT's geographic information system on climate, soils, vegetation, cropping, physical access to the land, population and other biophysical, political and social variables, which will be a strategic input to this project. The centre has a team on soil-plant relations, currently working on the pasture-crop complex on acid tropical soils; and on pasture-based reclamation of degraded deforested land. It also features the largest collection of acid-soil-tolerant germplasm of forage and food crops used in shifting cultivation. On interinstitutional work the centre has long-standing experience for large-scale collaborative research with NARS in the humid forests of Latin America.

- *IFPRI.* The International Food Policy Research Institute, headquartered in Washington, DC, USA, focuses on identifying and analysing policies for meeting food needs of the developing countries, particularly the poorer groups within those countries. IFPRI has recently been reviewing its potential contribution to socioeconomic policy research in the area of natural resource conservation and management. Major issues reviewed in development of its new research agenda focus on finding ways of optimizing land use among small-scale farmers, including shifting cultivation, the distribution and growth of populations, and opportunities for alternative land-use strategies that incorporate trees or other perennial crops. IFPRI pursues its research in collaboration with about 100 institutions, most of them in the developing world. IFPRI's collaborative activities are intended to build the capacity for policy research in the national research systems of developing countries.

- *CIFOR.* The Centre for International Forestry Research, headquartered in Bogor, Indonesia, is a recently created research centre with a global mandate for forestry research focused on conservation and improved productivity of forest ecosystems. Currently, CIFOR is developing its strategic plan proposing a set of four common disciplinary objectives, which are (1) understanding the biophysical and socioeconomic environments of present and potential forestry systems and their functional relationships; (2) creating the potential for sustainable improved productivity of forest systems for the benefit of people in developing countries; (3) providing analysis information and advice to assist in making sound policy decisions in relation to forest and land use; and (4) strengthening national forestry research capacity. CIFOR will operate with a decentralized research agenda interlinking with regional modes in Africa and Latin America.

NARS and strategic benchmark sites

Strategic research will be conducted at eight key benchmark sites in full collaboration with the relevant NARS. Each selected site will be representative of the range of biophysical and socioeconomic conditions where slash-and-burn is important. We call them ecoregions because they represent humid tropical situations in specific geographical areas with contrasting socioeconomic conditions, at both the macro (policy) and the micro (farm) level.

Researchers at all candidate benchmark sites for each ecoregion are conducting studies on alternatives to slash-and-burn. Although the scale of research is insufficient, all sites have significant strengths in research facilities and staff, and some have long-term research plots where changes in soil properties and crop yields have been monitored for years, representing an invaluable research resource. The proposed choice of sites for Africa is based on the recommendations of a Rockefeller Foundation-funded soils study group, which included scientists actually working in four of the collaborating international centres (Sanchez et al. 1991). The proposed sites in Latin America and Southeast Asia include those where NARS and bilateral partners are currently conducting long-term research. A short description of the proposed ecoregions and major research thrusts follows.

AFRICA

Two contrasting benchmark sites for Africa are proposed. One is to be located in the equatorial rainforest of the Congo Basin and the other in the adjacent acid miombo woodlands.

Congo Basin

The remaining tropical rainforests of Africa are concentrated in Central Africa, starting in eastern Nigeria and covering most of southern Cameroon, southern Central African Republic, most of Gabon, northern Congo and northern Zaire. Food production is still largely dependent on shifting agriculture but with ever-shortening fallow periods. While tree crops represent the highest potential for the area in the long term, their use will be possible only under circumstances of adequate food import from the surrounding savanna zones, where food production potential is greater. In the short term there is a pressing need to alleviate a growing food deficit in an agroecological zone where the transfer of conventional, high-input technology has failed badly in the past and where the rate of degradation of the environment is high.

Considering the severe logistical constraints of countries such as Zaire, which has the largest area in this zone, and Madagascar or eastern Nigeria, which have the highest urgency as they approach total deforestation, southern Cameroon seems the best location for a long-term initiative on strategic soils research in looking for alternatives to slash-and-burn. There has been no systematic research eliorA. orv acid soils oi Africa since the Belgians left Yangambi, Zaire, in the 1960s.

A possible benchmark site for this ecoregion is M'Balmayo, about a 1 -hour drive south of Yaounde. This is the location of a new 11TA research station, operated in collaboration with the Institute de Recherche Agronomiques (IRA) of the Government of Cameroon. M'Balmayo was selected as an acid-soil, forest location for the IITA resource management research team. It is also the location of the continuing programmes in plantation forest management of the Cameroon Organisation Development Agricole et Recherche Environment et Foresterie (ONADEF) with the UK Overseas Development Administration (ODA) and the Institute of Terrestrial Ecology (ITE). Laboratory and office facilities have been completed at the research station site of IRA at Nkolkisson just north of Yaounde. The core of the project in Cameroon will be a partnership between IITA and IRA with additional collaboration from ICRAF, GCTE and other international organizations. M'Balmayo would act as host station for scientists posted to Cameroon. This joint effort would make M'Balmayo a central focus of research and training for the equatorial rainforest zone of Africa.

Soil management requirements for this acid-soil, humid rainforest zone are based on two main imperatives. The first derives from the particular socioeconomic circumstances of this agroecological zone, which is characterized by a heterogenous, mosaic population, which includes patches with the highest number of people per unit area in Africa. The area is dominated by small-scale farmers, most of whom still practise shifting cultivation in varying forms. Alleviation of the increasing food deficit in this zone in the short to medium term can be achieved only by increasing productivity per unit area as population pressures increase and the availability of land for follow decreases. Moreover, increased productivity can only be realistically attained by incremental improvement of organic and inorganic management practices in the research agenda.

The second imperative derives from the particular soil problems characteristic of this zone, i.e., high acidity and aluminium toxicity together with relatively low nitrogen reserves and extremely low availability of phosphorus. Improved productivity in the presence of these constraints cannot be achieved by organic management alone. The utilization of inorganic fertilizers and amendments must also be considered as necessary components of soil management.

Miombo woodlands

The Dystrophic Miombo Woodlands of southern Africa are a large, contiguous agroecological zone, covering about 100 million hectares east of the Congo rainforest and south of the East African highlands. It is a woodland savanna with typical broadleaf 'miombo' vegetation but is situated on red, acid soils, most of which are classified as Ultisols and Oxisols. Rainfall during the wet season is reliable, temperatures are cool because of the 1000-m elevation, and much of the topography is favourable to agriculture. Soils, vegetation, climate and topography are remarkably similar to the woodland savannas of the Cerrado of Brazil, which lie directly west of the miombo across the Atlantic. This zone has a low population of indigenous large animals, probably because of the low calcium and phosphorus levels of the soils as compared with those of adjacent areas with higher base-status soils, where game is abundant. The hazard of erosion is substantially less than in other zones because of the generally favourable topography with long gentle slopes and low erodibility of the main soils. There are, however, steep slopes and severe erosion in some areas, such as parts of northern Malawi.

The acid miombo woodlands are best expressed in the northern half of Zambia and adjacent Shaba province of southern Zaire. They extend well into northern and central Malawi, parts of southern Tanzania, large areas of northern Mozambique and a large part of Angola.

This agroecological zone is not readily identified on most maps, and thus it is difficult to delimit its western and eastern borders. Vegetation maps with the notation of Dystrophic (i.e., acid) Miombo Woodlands dominated by the genera *Brachystegia* and *Julbemardia* area probably the best source (Huntley 1982). This excludes Eutrophic (i.e., nonacid) Miombo woodlands, which are located primarily on sandy Alfisols and Entisols to the south.

Two particular kinds of shifting cultivation are the main land-use system of this region: *chitemene* and *fundikila.* The natural resources are relatively well conserved. The acid soils have conventionally been regarded as low in agricultural potential. Modern research, particularly on comparable soils and climate in the Cerrado of Brazil has, however, revealed high sustained productivity potential under appropriate cropping systems and management practices. The zone is therefore ideal for the establishment of a long-term programme for development and adaptation of soil management practices. The existence of traditional organic-based farming systems provides the base for innovative research with the aim of developing transitional and sustainable technologies. This agroecological zone is among the highest in Africa in its potential for food production, because it is largely devoid of drought-induced soil degradation and its biodiversity is not at risk as is the case with rainforests. The large increases in sustained crop production in the Cerrado of Brazil (Abelson and Rowe 1987, Goedert 1983) lend credibility to its potential.

A possible benchmark site is the Misamfu Regional Research Station of Zambia's Agricultural Research and Extension Programme (ZAREP) in its Ministry of Agriculture, located in Kasama, Northern Province. The present staff and capabilities of this centre are considerable, having an adequate infrastructure supported by NORAD, the Norwegian Agency for International Development.

The station recently doubled its land area and has improved its laboratory and computer facilities. The Soil Productivity Research Programme includes teams working on soil surveys, soil fertility, soil microbiology and agroforestry. In addition, its Adaptive Research Planning Team, working with smallholder farmers throughout Northern Province, includes agronomists, socioanthropologists and economists. The goal of the station is to find alternatives to the present and highly complex local shifting cultivation systems: chitemene and fundikila. Research is published in annual reports and technical bulletins, which provide an unusually up-to-date record of activities (Lungu 1987, SPRP 1987, 1988).

Research areas include soil surveys, soil

physics, soil fertility, soil biology, agricultural anthropology, economics, agroforestry, ecology, focusing on the gas-emission consequences of chitemene and fundikila and on soil-plant laboratory development. **Trainers and research** scholars will come **primarily from Zambia,** Malawi, Zaire, **Tanzania, Angola,** Mozambique, Congo **and Madagascar.**

The expertise **of** headquarters-based scientists at the international institutions will be tapped as needed to provide short-term on-site advice or to serve as advisers for junior scientists working in their various disciplines.

LATIN AMERICA

The Amazon constitutes the largest deforesting area in the world and therefore efforts in Latin America will concentrate there. The Amazon is undoubtedly one of the world's greatest reservoirs of plant and animal genetic diversity and holds one of the largest carbon stocks in its vegetation and soils. This region is rapidly being penetrated by roads, not only from the Brazilian side, but also across the Andes in neighbouring countries. The major penetration road of the 1980s, BR 364, connecting Sao Paulo with the states of Rondonia and Acre, links Brazil's major economic centre with excess population to a population vacuum. By 1988, however, 24% of Rondonia's area and 13% of Acre's land area was deforested (Mahar 1988). This road will be linked to the Peruvian road system shortly, further enhancing the threat of deforestation. The Amazon is characterized by two main agroecological zones within the humid tropics: the typical tropical rainforest with little to no dry season and sandy to loamy Ultisols and the semideciduous forests with a short but pronounced dry season and predominantly clayey Oxisols. The rainforests predominate roughly west of Manaus, Brazil, while the other zone is more common east of Manaus. The main causes of deforestation are cattle ranching and food production under extensive and intensive shifting cultivation systems, which lead to land abandonment, primarily in the form of **degraded** pastures or degraded secondary **forests** called 'juquira' (Hecht 1979, Serrao et **al.** 1979).

Two benchmark sites are proposed, one for each major agroecological zone of the Amazon: the semideciduous forest and the humid tropical rainforest. The first zone is in Brazil and the other in the Andean region.

Semideciduous forests

Recent changes in the EMBRAPA structure have assigned Manaus the leadership role in agricultural research for much of the Brazilian Amazon. In March 1989, two adjacent research stations merged into a single unit, the Centro de Pesquisas Agroflorestais da Amazonia (CPAA), headquartered at Manaus. Its mandate is to coordinate, both technically and financially, all agroforestry research centres in Rondonia, Acre and Roraima. CPAA inherits quality baseline information on management of the individual agroforestry components.

Agroforestry is one management option for the humid tropics because it provides many ecological and economic advantages compared with other management options. Among other services, trees provide a continuous soil cover, protecting the soil from erosion, and they recycle nutrients from the subsoil, preventing leaching. In addition, trees can provide many products for on-farm use, such as mulches, fodder, fruits and fuelwood; many of these products can also be sold throughout the year, giving the farmer a year-round source of income. Of course, there are major obstacles to harnessing the potential benefits of the system. In depleted acid-soil areas, there will be few nutrients to recycle. Woody perennials may cause excessive shading and compete for water and nutrients. Woody perennials may also have adverse allelopathic effects on food crops and may even host pests that cause damage to the associate crop (Lai 1991).

Agroforestry systems relevant to the Amazon are divided into three broad categories: agrosilvicultural, which combine trees and crops; silvopastoral, which combine trees and animals, and agrosilvopastoral, which combine trees, crops and animals. Many of these systems would be readily adopted by Brazilians because of their strong tradition and well-developed markets in native fruits and beef.

For many years CIAT has been conducting collaborative research with various Brazilian entities, especially with EMBRAPA, on pastures, rice, beans and cassava, and it is recognized as one of the main sources of expertise in such components.

In September 1990, EMBRAPA and North Carolina State University (NCSU) initiated a project titled 'Agroforestry Alternatives to Slash-and-Burn in Western Amazonia' with support from the Rockefeller Foundation at the rate of USD 0.3 million annually for the three years. NCSU has stationed a senior scientist (a soil scientist/agroforester) and several graduate students to work in the States of Amazonas and Rondonia on tree selection, soil fertility, socioeconomic surveys and greenhouse emissions from.potentially sustainable alternatives to slash-and-burn starting from virgin rainforests and from degraded pastures.

This proposed project can therefore build on existing strengths by adding senior staff positions in the areas of nutrient cycling, weed management, anthropology and silvopastoral systems. Preliminary contacts between EMBRAPA and ICRAF scientists indicated a strong interest from EMBRAPA in developing a collaborative research project on slash-and-burn with the inclusion of the international centres that are represented in this project. Emphasis will be in Manaus, Rondonia and Acre. CPAA headquarters could be used as a regional training centre for Amazonian scientists in collaboration with the PROCITROPICOS programme of IICA.

Rainforests

The other half of the Amazon, the true tropical rainforest region, is well exemplified by the Yurimaguas Research Station of the Instituto Nacional de Investigaciones Agropecuarias y Agroindustrial (INIAA) in Peru. This is where North Carolina State University and INIAA have been conducting a sustained strategic research effort on alternatives to slash-and-burn on acid tropical soils since 1972. Research seeks to develop, refine, extrapolate and validate soil management technologies suitable for changing land currently under shifting cultivation into agronomically, ecologically and economically sound agricultural production systems. Investigations have focused on

- soil characterization in relation to landscape and constraints to crop production
- clearing methods for both primary and secondary forest vegetation, their consequences and correction in subsequent cultivation
- long-term dynamics of physical, chemical and biological soil properties with time of cultivation under various production systems
- selection and evaluation of tree, crop, grass and legume germplasm for tolerance to acidity and low nutrient reserves
- comparisons of cropping systems involving intercropping, continuous crop rotations, agroforestry, mulching, green manuring and composting
- management of fallows derived from natural regeneration or introduced species and their effects on subsequent cultivation cycles
- watershed hydrology
- compatibility and persistence of grass-legume associations under variable grazing pressure trials
- recuperation of degraded pastures
- economic interpretations

Current resources at Yurimaguas include a well-mapped 135-hectare station, laboratory facilities capable of analysing 10 000 soil samples and 2500 plant samples annually, facilities for monitoring soil moisture, compaction and erosion plus a biological laboratory capable of quantifying root dynamics, mineralization, microbial biomass, soil faunal biomass and other TSBF methodologies. The most important asset is the existence of well-monitored, long-term plots on continuous crop-rotation (since 1972); legume-based pastures (since 1979); low-input transitional systems with managed fallows (since 1980); agroforestry systems (since 1982); plus a systematic comparison between some of the these systems with shifting cultivation and secondary forest fallows (since 1985). These long-term plots represent an invaluable resource for sustainability studies.

The preliminary scope of work remains to be discussed in detail, but it is likely to include the following areas:

- socioeconomic analysis of slash-and-burn alternatives
- nutrient cycling efficiency and biological soil management
- breeding of key high-value, low-volume tree crops
- integrated pest management
- silvopastoral systems
- export market development

Peru is currently experiencing severe economic and security problems. Although research continues at Yurimaguas, alternative sites in the Amazonian region of Ecuador may be considered.

A third potential site in Latin America is rapidly deforesting regions in Central America (Nicaragua, Panama, Honduras) in collaboration with CATIE or in Mexico (Chiapas, Yucatan).

SOUTHEAST ASIA

Deforestation is largely limited in Southeast Asia to three agroecological zones: equatorial rainforests, the hill country in mainland Southeast Asia and a tropical monsoon zone.

Equatorial rainforests

The equatorial rainforests are located primarily in Indonesia and Malaysia. Indonesia is the second largest deforesting country, because of extreme population densities in Java and vast underpopulated rainforests in the outer islands. The current primary forested area is 109 million hectares, deforestation rates are estimated to be about 1.2% per year (Kartasubrata 1991).

The source of deforestation is mainly traditional shifting cultivation. This practice is considered an adaptation of existing limited resources and low-level technology to the fragile local environment. As long as the fallow period is of sufficient length (15 to 20 years) the practice is deemed ecologically sound. However, if the fallow period becomes shorter, and in some areas it has been reduced to 1-3 years, formation of extensive unproductive alang-alang *(Imperata cyclindrica)* grasslands takes place, in particular when accompanied by fires (Kartasubrata 1991). There are approximately 20 million hectares of alang-alang in the outer islands of Indonesia.

The shortening of the fallow period is brought about by increase through transmigration of the local population, the opening of logging roads and logging camps, the clearing of large plots facilitated by using mechanical means such as chain saws, ready markets for selling agricultural products, and fast-growing cities. Deforestation by shifting cultivation is estimated at 500 000-750 000 hectares per year.

Agricultural development schemes, such as estate crops and smallholder crops, besides transmigration, have also brought about deforestation. It is recommended not to clear primary forest but to utilize unproductive forest for continuation of the programme. Logging operations and forest industries, though having contributed much to the economic development of the country, have brought about damage to the forest condition in several localities. Logging operations do not cause outright deforestation; however, the new network of logging roads has increased accessibility to forest land for shifting cultivation and migrants. Moreover, after the large marketable trees, clearing of smaller trees becomes easier for shifting cultivators.

The government of Indonesia has embarked on various programmes to stop deforestation. Most are directed towards rationalization of shifting cultivation. During the 1970s the programme was in principle directed to move shifting cultivators into resettlement areas. Because of many constraints, technical as well as cultural, a new in-situ approach is directed toward rationalizing the system itself (Kartasubrata 1991). Research on alternatives to slash-and-burn has been concentrated around various transmigration regions in West and South Sumatra, where tall primary dypterocarp rainforests are cleared and after cultivation a considerable amount becomes converted into alang-alang pastures. Appropriate crop rotation schemes have been devised, based on upland rice, cassava and grain legumes with moderate fertilization (Macintosh et al. 1981, Wade et al. 1988). A novel approach of implanting a managed *Pueraria phaseoloides* fallow right after slash-and-burn has been used to stabilize relatively large clearings for state crops, capturing the nutrients in the ash and allowing unburned vegetation to decompose until the planting materials are available (Von Uexkull 1984). The reclamation of alang-alang grasslands is being researched with promising results (Kartasubrata 1991, Sajise 1980, Von Uexkull 1990), primarily through agroforestry techniques with trees that outcompete and outshade the grass.

Sitiung, West Sumatra, and several sites in South Sumatra and Kalimantan may be suitable locations. Regardless of the sites chosen, this project should focus on the following topics:

- systematic investigation on reclaiming alang-alang degraded grassland
- long-term changes in soil properties and greenhouse gas emissions upon conversion of dypterocarp virgin forests
- nutrient cycling and organic input management of selected systems, with emphasis on agroforestry ones

Hill country of mainland Southeast Asia

The second site in Asia will represent the totally contrasting region that includes the vast northern tropic hill country of the interior of mainland Southeast Asia. This region encompasses a continuous belt from Assam, India, through northern and eastern Burma, to northern Thailand, Laos, Vietnam and southern China. The climate is strongly monsoonal with long dry winters that are slightly cooler. Shifting cultivation is still the prevalent agricultural system. Major land degradation has occurred as a result of agricultural intensification on the steep terrain. Possible sites with infrastructure suitable for intensive research are located in northern Thailand and southern China. Potential collaborating institutions in northern Thailand are Chiang Mai University and the Departments of Land Development, Agriculture and Forestry. In southern China the Red Soils Institute is a potential collaborating institution.

Tropical monsoon zone

The third benchmark site in Southeast Asia is to represent the mid-tropical monsoon latitude belt including the Philippines and southern Thailand. In that region, population densities in the uplands are rapidly increasing. This has resulted in steep terrain being clean cultivated in short grass fallows and incipient permanent annual crop systems being established on strongly acidic or shallow calcareous soils. A possible benchmark site is the Eastern Visayan island of Leyte, in collaboration with the Visayas State College of Agriculture (VISC-A) and the Departments of Agriculture and of Environment and Natural Resources.

We shall have to develop a list of criteria for making a definitive choice of site. The above sites are relatively favoured if the selection is based on current research infrastructure upon which to base strategic and applied research, accessibility, logistical support and living environment for expatriate staff. The availability of efficient NGOs and extension agencies must also be assessed when finally considering sites. Myanmar and Laos should definitely be network research sites, but they do have major limitations for strategic research. Vietnam is still said to be enforcing a ban on all foreign access to the uplands.

Extrapolation from benchmark sites

The research proposal has concentrated on analysis of the problem and identification of benchmark sites. The sites will provide the main research thrust, with intensive study of traditional and alternative systems and practices. The programme must initially take account of the variation in environmental and socioeconomic conditions and management practices within the agroecological zones in which benchmark sites are situated. This will be covered by two approaches:

Characterization of the distribution of major soil, climate and physiographic conditions within the agroecological zone and of the distribution of major areas of forest, shifting and permanent cultivation. This will be obtained at a low level of resolution using a combination of existing information, for example, the UNEP GRID, and remote sensing. The information will be integrated into a GIS system associated with each benchmark site and used for both research and planning. CIAT has already started characterization of Latin America through the use of extensive databases, but further analysis of social, demographic and economic data are needed. In addition, IITA and ICRAF in Africa and IRRI in Asia have made some progress on characterization of their ecoregions.

- A limited programme of observations will be undertaken at a selected range of sites within each agroecological zone. Most of these sites already have relevant research under way within each zone, often by NARS and other institutions. The project will undertake a coordinated set of measurements related to intensive studies at the benchmark sites to assess the effect or influence of site-specific environmental or social variables.

To best prepare for extension of beneficial research findings, NGOs and farmers should be invited to join systems research planning meetings.

These approaches will constitute **a** relatively small part of the overall programme, but they are designed to involve regional organizations and experience to provide tests for the extrapolation of results from benchmark sites and to initiate **a** framework for subsequent development of **the** programme.

Extension

The aim of this project is not extension but to maximize the potential for extension (i.e., the adoption of beneficial research findings). To accomplish this, links with extension agencies must be formed at the earliest opportunity.

Dissemination through networking

Established research networks supported by one or more of the international institutions are the logical vehicle for validating technology and for training and policy dialogue, as appropriate. These networks include, for example, AFNETA (IITA/ICRAF/ILCA), AFRENAS (ICRAF), IFDCs in West Africa and, TSBFs worldwide; RISTROP, CATIE and PROCTROPICOS in Latin America; F/FRED, the Asian Rice Farming Systems Network, the International Network for Sustainable Rice Farming and IBSRAM in Asia and Africa. Such networks cover most of the tropical deforesting countries.

The strengthening and expansion of regional and interregional networks will greatly facilitate training, data exchange and synthesis, standardization, the development and comparison of research methods, and the discussion of research extension experiences. We found that suitable networks already exist—in part, through NGOs, the academic community and commodity areas.

Linkage with related institutions

Collaboration is anticipated with appropriate developed-country institutions with expertise in alternatives to slash-and-burn. This would be primarily on-campus and through graduate student research at strategic sites. Examples include Reading University and ITE for Africa, North Carolina State University for Latin America and Madagascar, CSIRO for Southeast Asia and the Edinburgh Centre for Tropical Forests for Africa and Asia.

Collaboration is also envisioned with national, developed-country research bodies like CIRAD and with other CGIAR centres: IFPRI on policy, IPBGR on germplasm conservation, and the emerging forest research institute on forestry research. Collaboration is also envisioned with FAO's land-resource evaluation and the tropical forestry action plan. The non-CGIAR international organization IBSRAM will collaborate with IFDC as needed.

Linkages with the private sector

In some regions the private sector is becoming increasingly interested in assisting research, from both a funding and an implementation perspective. Where possible, maximum collaboration with the private sector will be sought.

Linkage to global environmental programmes

This project will contribute significantly to global environmental research through collaboration with several components of the International Geosphere-Biosphere Programme (IGBP). In particular, there is varied scope for close collaboration with the Global Change and Terrestrial Ecosystems (GCTE) Core Project of the IGBP. GCTE will undertake research on the global environmental impact of slash-and-burn (biodiversity-related research, soil degradation and greenhouse gas emissions). In addition, collaboration with GCTE will link this project to GCTE's developing expertise on understanding the dynamics of 'complex' (multispecies) agricultural systems and the global change impacts upon them; it will also contribute research results of direct relevance to GCTE's international programme. The Alternatives to Slash-and-Burn project will interact with GCTE at three levels:

LEVEL 1

Direct contributions to GCTE

Work characterizing and evaluating the environmental soundness of alternative agricultural and agroforestry systems in the humid tropics will contribute directly to GCTE's international programme:

- biogeochemical (nutrient) cycling
- mitigation of soil erosion
- weed dynamics and management
- interactions between components: **multi-**species systems

In addition **to** these specific areas of **mutual interest, the thorough and standardized site characterization will offer baseline** data **to** assist **in monitoring and detecting** global change.

The linkages of these activities to specific elements of the GCTE programme are listed earlier in the project description.

LEVEL 2

Additional collaboration

There is an opportunity for additional research that will benefit both this project and GCTE. In particular, research on the hydrological pathways of nutrient loss from present and alternative production systems would be useful. In these cases, a joint GCTE/Alternatives to Slash-and-Burn proposal would be submitted to relevant agencies for additional funding.

LEVEL 3

Framework for GCTE research

One of the objectives of the Alternatives to Slash-and-Burn project is to determine what slash-and-burn and associated land-use practices contribute to global environmental problems. Research on global change itself is beyond the scope of this project. However, Alternatives to Slash-and-Burn will provide an excellent framework, through well-characterized sites, extant agroecological research and support facilities, where appropriate, for GCTE to undertake the research, which will include:

- relationship between loss of biodiversity and ecosystem function
- global change impact on biodiversity
- measurement of greenhouse gas emissions from present and alternate production systems (with IGAC, see below)
- addition of the component of global change to ongoing agroecological research, for example, impact of elevated CO_2 on soil organic matter dynamics, crop-weed competitive interactions and erosion risk under changed rainfall

Although this third level of work will be undertaken in close collaboration with Alternatives to Slash-and-Burn, GCTE is ultimately responsible for organizing, securing funding for and conducting the research.

In addition to GCTE, there are links to other components of IGBP.

International Global Atmospheric Chemistry (IGAC). Measurement of greenhouse gas emission, to be undertaken jointly by GCTE and IGAC, will contribute to the IGAC effort to quantify the global carbon cycle.

Biospheric Aspects of the Hydrologic Cycle (BAHC). The emphasis on the global change impacts on regional hydrology of changes in land use will link BAHC and this project.

Global Change System for Analysis, Research and Training (START). The START programme is establishing a system of regional research centres and associated networks of experimental sites in all the major biomes of the world. The centres will be used for analysis, interpretation, modelling and training in addition to collecting data. Initial emphasis is on three regions: Latin America, Africa south of the Sahara and Southeast Asia. There are obvious advantages for the benchmark sites of the Alternatives to Slash-and-Burn project to be linked to the START network.

Data and Information Systems (DIS). The project should collaborate with IGBP-DIS, which will develop global databases on land-use and land-cover change and on biophysical and ecological characteristics of the earth's surface.

EXPECTED OUTPUTS

The first five years of this project will put in place a concerted worldwide effort on mitigating tropical deforestation by alternatives to slash-and-bum. Strategic research at the benchmark sites will be well under way and initial results from the technological innovations, training, institutional strengthening and policy research will begin to be validated or adapted by networks composed of most tropical deforesting countries. Valuable ground-truth data will be exchanged with the global environmental community, which in turn may help sharpen the focus of this project. Major impact on tropical deforestation can be expected after several years once technologies are fully developed and validated and governments put into practice the appropriate policies.

The ultimate beneficiaries of this project are farmers and consumers in developing countries. The farmers will benefit through the adoption of technologies that provide sustainable crop yields and sufficient firewood, fodder and fibre, plus increased income and improved living standards. Consumers will benefit through greater availability of produce at lower prices.

On national and global levels, the benefits derived through decreases in deforestation and soil degradation will be a major contribution to the environment. Society in general will be the main beneficiary of the long-term benefits of the project because of the conservation of natural resources, the preservation of biodiversity and the reduction of greenhouse gases.

IMPLICATIONS FOR RESOURCES

The collaborative nature of this project builds upon already available resources of the international research centres, the NARS, existing networks and advanced developed-country institutions. No new 'bricks and mortar' institutions are envisioned. Resource needs therefore are basically incremental funding to existing institutions.

It is envisioned that the NARS that accept the responsibility of hosting the benchmark strategic research sites will receive incremental funds directly from the donors to support such international initiatives. International centres, likewise, would receive incremental funds for their input to the sites and network coordination, training and linkages with the environmental community. Bilateral funding agreements could provide complementary funds for advanced developed-country institutes. A small budget for informal programme coordination will also be included.

Initial funding estimates for the first five years is in the order of USD 5 million per year per continent (Southeast Asia, Latin America and Asia). A five-year total of USD 75 million, without major capital and administrative costs, will result in a definitive step in reducing slash-and-burn and the destruction of the remaining tropical rainforests of the world.

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