Missing a Moving Target?

Colonist Technology Development on the Amazon Frontier

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ODI Research Study

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Preface

This ODI Research Study was undertaken as part of a three-year (1993–6) Overseas Development Administration (ODA)-funded Rural Resources and Poverty Research Programme. The programme focused mainly on institutional aspects of natural resources management and covered a wide range of sectoral interests including agricultural support services, forestry, water resources and pastoralism. The findings are synthesised in the ODI paper 'Institutional Change in the Natural Resources Sector – Rural Resources and Poverty Research Programme, Summary of Research, 1993–96' by Diana Carney and John Farrington (1996).

This study contributes to the overall objective of the programme of providing policymakers and donor agencies (and in particular the ODA) with guidance on appropriate policy and institutional responses to natural resource management issues involving resource-poor users. The focus of the study was considered to be a high priority area of concern in both the socioeconomic and environmental aspects: how to slow up the rate of conversion of primary forest on the Amazon frontier. This concern has become an important component of ODA's aid programme to Brazil and Bolivia in particular, and is also of major significance in several multilateral initiatives in the region – for example, the G-7 'Pilot Programme to Conserve the Brazilian Rain Forest', and the 'Alternatives to Slash and Burn' research programme (United Nations Development Programme/consortium of international research institutes).

The study therefore brings together recent literature and the author's regional experience to assess the problem of rapid land turnover in colonisation zones in the Amazon Region. It particularly assesses various land use alternatives, including 'slash and burn' farming, by observing field or project experience. The study discusses how institutional factors and market incentives are more powerful determinants of stability than land productivity, and why development efforts need to pay particular attention to the dynamic nature of the frontier. Farmer response to economic and institutional incentives changes as the frontier matures, and projects/technologies have often missed their 'moving target'.

Other ODI publications stemming from this programme have included:

- *Devolution of Management in Public Irrigation Systems: Cost Shedding, Empowerment and Performance* by Hugh Turral, ODI Working Paper 80

- *Changing Public and Private Roles in Agricultural Service Provision: A Literature Survey* by Diana Carney, ODI Working Paper 81

- *Institutional Change within the Forest Sector: Centralised Decentralisation* by Mary Hobley, ODI Working Paper 92
- *Decentralisation and Forest Management and Conservation in Central America* by Michael Richards, Guillermo Navarro, Alberto Vargas and Jonathan Davies, ODI Working Paper 93

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Summary

One of the main characteristics of colonisation in the Amazon has been the high rate of turnover of land holdings. Each new colonist plot usually means new inroads into primary forest. The challenge to reducing deforestation by colonist pioneers is basically one of stabilisation, or reduction in land abandonment. Although colonist farmers are not the most important direct agents of deforestation in the Amazon, stabilisation would limit the access of more important agents – such as cattle ranchers and land speculators – who rarely enter an area until colonist farmers have cleared the land for them, due to the high costs of primary forest clearance away from social and market infrastructure.

The main objectives of this review are to bring together the findings of recent published and unpublished literature in order to increase understanding of the problems faced by colonist farmers, identify the causes of colonist instability, and on the basis of this, assess the appropriateness or otherwise of possible technological, institutional and policy responses to the problem of stabilisation. Chapter 2 assesses the socioeconomic context of colonist technology development, while Chapter 3 focuses on alternative technological and land use options.

Chapter 2 presents a brief history of the colonisation process in the Brazilian Amazon, and then attempts to identify the main causes of colonist instability. The first observation from the case studies summarised in Appendix 1 is the wide diversity of situations and pressures. There are obvious differences between the impacts of official (or directed) and spontaneous colonisation, which have often occurred sequentially in the same area. However the case studies also reveal a certain consistency in their main characteristics, permitting the identification of three main sequential stages in the colonisation process.

In the early pioneer stage of colonisation, there is little social infrastructure or institutional presence and land is cheap. However, over time, market economy institutions (land and labour markets, formal credit, property rights, market infrastructure, etc.) emerge and a second wave of capitalist-type colonists are attracted. This is the stage when most land abandonment occurs. The third stage is often called the closing frontier. This is when there is little or no land left to colonise, although there is usually a still-opening, but increasingly distant, frontier. Land is more expensive due to a stronger speculative element and more developed infrastructure. Land concentration, social differentiation and urbanisation are at a fairly advanced stage.

The study goes on to discuss some of the main factors affecting this process. First, the socioeconomic differences both among pioneer colonists, and between pioneer and second-wave colonists, were critical to success or stability. For example, educational levels influenced the ability to secure property rights and therefore credit, although the presence (or absence) of supporting non-governmental organisations (NGOs) or labour unions was another crucial factor. Several sources emphasise the importance of colonist land market speculation as one explanation of high plot turnover. Many colonists understandably see land 'speculation' as a way of rapidly accumulating enough capital to buy a better piece of land – i.e. better served by social infrastructure – on which they can achieve a reasonable standard of living. Land values are also fundamental in explaining colonist technology choice. Cheap land tends to encourage land-extensive technology (slash and burn and cattle farming), whatever the underlying productivity. Some therefore argue that it is impossible to intensify land use until land values rise in the later stages of the colonisation process. Paradoxically this is when the biological potential of the land is at its lowest point.

Common to most of the colonisation areas have been the institutional problems faced by colonists such as agricultural support services tied to cash monocrops and high-input technology, rather than colonist priorities; bureaucracy and bias in the adjudication of land rights; lack of inter-institutional coordination; and a failure to make the links between policy and technology issues. The Coca project in Ecuador is presented as a case study indicating the potentially positive impact of better-focused institutional support. Other factors analysed include risk, which dominates colonist decision-making, markets, credit, off-farm income and wider political economy influences.

The implications of these factors for 'appropriate technology development' are then discussed. Technology aims at a moving target in terms of microeconomic conditions (moving from labour and capital scarcity towards land scarcity later in the process), colonist objectives and other interrelated factors. Too little emphasis has been put on the importance of the labour constraint. Capital and cattle also play a crucial role in explaining the dynamics of the colonisation process, and have caused some to argue that raising agricultural productivity or providing credit can hasten deforestation. Others take a more positive attitude to technology development, arguing that the role of the land market in explaining colonist land use strategies has been exaggerated. Given the fundamental importance of institutional factors, several analysts have called for a new institutional basis for colonisation zone development. The experience of PESACRE (Agroforestry Systems Research and Extension Group of Acre) in western Brazil appears to present many of the elements necessary for stabilising colonist farming systems, including greater coherence between policy, institutional and technology factors;

inter-institutional coordination (including government and NGO collaboration); inter-disciplinary coordination; and participatory research and extension methodologies.

Following a brief analysis of Amazonian soils, Chapter 3 looks at the 'sustainability' of colonist slash and burn farming and unsurprisingly finds this is dependent on fallow length and therefore land availability. Thence a range of land use alternatives is considered, varying through a continuum from a higher to lower intensity of land use. In the 1970s and early 1980s, it was still believed that high input continuous cultivation of annual crops was a viable alternative for colonists: but after a decade of experimentation at the Yurimungas research station, Peru, it was realised that under frontier conditions the system was not viable, partly due to its institutional demands. Evidence (mainly from Central America) of the use of green manures or cover crops and minimum tillage techniques is much more promising – especially regarding the technology's capacity to generate biomass and reduce fallow periods and its capacity to simultaneously increase returns to land and labour. There are important evolving experiences with cover crops in Brazil and Bolivia, including spontaneous adoption by colonists in the Santa Cruz colonisation zone.

Three important experiences of perennial crop and intensive agroforestry are highlighted: the RECA Project in western Brazil, the El Ceibo cocoa cooperative in eastern Bolivia, and the Tomé-Açu multi-storey agroforestry project in western Amazonia. While all these projects are relative success stories, they indicate a common set of constraints including a level of economic, organisational and institutional complexity difficult and expensive to replicate in colonisation zone areas. More intensive agroforestry has often been regarded as a panacea for small farmers, but the lack of adoption has been based on sound logic in respect of the potential returns and the risks attaching to them. Low adoption is also due to institutional, tenure and marketing constraints. The prioritisation by researchers of intensive over extensive agroforestry is partly the result of weak farmer participation in technology development.

Extensive agroforestry (modification of shifting cultivation) has the potential to work at the crux of the problem of colonist agriculture, which involves increasing the ratio of cropped to fallow years without loss of fertility. However, disappointingly few programmes have seriously focused on this. Fewer still have tried to modify or extract potentially replicable elements of local indigenous agroforestry systems. A major debate in this area is on the 'cultural' constraints to replication or adaptation of indigenous swidden management systems, which are in need of more rigorous microeconomic analysis than has hitherto been the case. Colonists themselves have some important swidden management systems, and have also developed apparently stable farming systems based on fallow length manipulation. These and secondary forest management systems have been too little studied in the region.

Natural forest management appears to have particular potential in the early stages of colonisation, especially where social cohesion is high. There are now a number of embryonic experiences involving colonist farmers in natural forest management, based mainly on timber production, but the organisational, institutional and economic complexity means that these projects will require external support over a considerable period. Such support can be justified on the grounds of the international externality benefits at stake. These projects also require a supporting policy environment that ensures the opportunity cost of forest management is not excessive.

The final policy discussion considers the importance of the macro-level pull and push factors, and on the basis of recent evidence that most colonist deforesters come from within the Amazon region rather than from outside, concludes that the priority for donors is to support efforts to slow down the rate of migration from older to new frontier regions, primarily through a frontier poverty reduction programme.

The evidence presented here asserts the need to align technology development with the microeconomic realities of a moving target; and that technology development is secondary to getting the farm-level incentives right and assistance to the grassroots or secondary-level NGOs providing support services and policy support. The complexity of the factors discussed in this review also indicates that a new and distinct configuration of institutions is needed for each main colonisation area, in order to increase the likelihood that policy, technology and institutional interventions complement rather than contradict each other. Allied to the institutional basis is the issue of participatory methodology. It appears that only on a new institutional and methodological axis is a new set of appropriate policy and technological options likely to emerge which can 'create a legal and economic environment consistent with a new technology and a new social fact: that of retaining farmers on their land' (Almeida, 1992).

Acronyms

ASACODE	Asociación San Miguel de Conservación y Desarrollo (Agricultural Research and Rural Extension Enterprise, Costa Rica)
CAT	Centro Agro-ambiental do Tocantins Araguaia (Agro-environmental Centre of Tocantins and Araguaia, Brazil)
CATIE	Centro Agronomico Tropical de Investigación y Enseñanza (Tropical Agriculture Research and Teaching Centre, Costa Rica)
CCFD	French Catholic Commission
CEBEMO	Catholic Cooperative Organisation for Development, The Netherlands
CIAT	Centro de Investigación Agrícola Tropical (Tropical Agricultural Research Centre, Bolivia)
CICOL	Central Intercomunal de las Comunidades del Oriente de Lomerio (Intertribal Centre of the East Lomerio Communities, Bolivia)
CIFOR	Centre for International Forestry Research, Indonesia
CIPCA	Centro de Investigación y Promoción del Campesinado (Peasant Research and Promotion Centre, Bolivia)
COCAT	Cooperativa Camponesa do Araguaia Tocantins (Araguaia Tocantins Peasant Cooperative, Brazil)
CPATU	Centro de Pesquisa Agropecuária do Tropico Umido (Agricultural Research Centre of the Humid Tropics, Brazil)
CPT	Commissão Pastoral da Terra (Pastoral Land Commission, Brazil)
CRI	Centro Regional de Investigación (Regional Research Centre, Bolivia)
EMBRAPA	Empresa Brasiliera de Pesquisa Agropecuária (Brazilian Enterprise of Agricultural Research)
EPAGRI	Empresa de Pesquisa Agropecuária e Extensão Rural (Agricultural Research and Rural Extension Enterprise, Brazil)
FAO	Food and Agricultural Organisation of the United Nations
FNO	Fundo Constitucional do Norte (Constitutional Fund of the North, Brazil)
FUNTAC	Fundação de Tecnologia do Estado do Acre (Technology Foundation of Acre State, Brazil)

GTZ	Gesellschaft für Technische Zusammenarbeit
IBDF	Instituto Brasiliero de Desenvolvimiento Florestal (Brazilian Institute of Forestry Development)
IICA	Instituto Interamericana de Cooperación en Agricultura (Inter-American Institute for Cooperation in Agriculture, Costa Rica)
IMAZON	Instituto do Homem e Meio Ambiente da Amazôn (Man and the Environment Institute of the Amazon, Brazil)
INCRA	Instituto Nacional de Colonização e Reforma Agrária (National Institute for Colonisation and Agrarian Reform, Brazil)
INPA	Instituto Nacional de Pesquisa da Amazônia (Amazonian National Research Institute, Brazil)
LASAT	Laboratório Sócio-Agronômico do Tocontins-Araguaia (Socio-Agronomic Laboratory of Tocontins-Araguaia, Brazil)
MST	Movimento dos Trabalhadores Rurais Sem Terra (Landless Rural Workers Movement, Brazil)
NFM	natural forest management
NTFP	non-timber forest product
ODA	Overseas Development Administration, UK
PESACRE	Grupo de Pesquisa e Extensão em Sistemas Agroflorestais do Acre (Agroforestry Systems Research and Extension Group of Acre, Brazil)
RADAM	Radar for the Amazon, Brazil
RECA	Reflorestamento Econômico, Consorciado e Adensado (Mixed High-Density Economic Reforestation, Brazil)
USAID	United States Agency for International Development

Glossary

campesinos	Small or 'peasant' farmers
caboclos	Mixed blood descendants of Indians, Europeans and Africans, and who are classed as semi-indigenous due to the time spent in forested areas (in excess of 100 years)
colonists	People who move into areas of colonisation, whether planned or unplanned
ejido	Co-operative landholdings created under the land reform process following the Mexican Revolution (about 1915-1918)
extractivism	Refers to the practice of non-timber forest product management and harvesting, for example by rubber tappers and Brazil nut gatherers
ribeirinhos	River-dwelling people, often *caboclos*
swidden	Swidden management is another term for shifting cultivation, often used in association with indigenous land use practices
terra firme	Land or forest which is not seasonally flooded
varzea	Seasonally flooded forest areas

1 Introduction

Background

> The one thing that can be stated about the frontier with certainty is that it displays enormous variety in all its aspects (Almeida, 1992: 161).

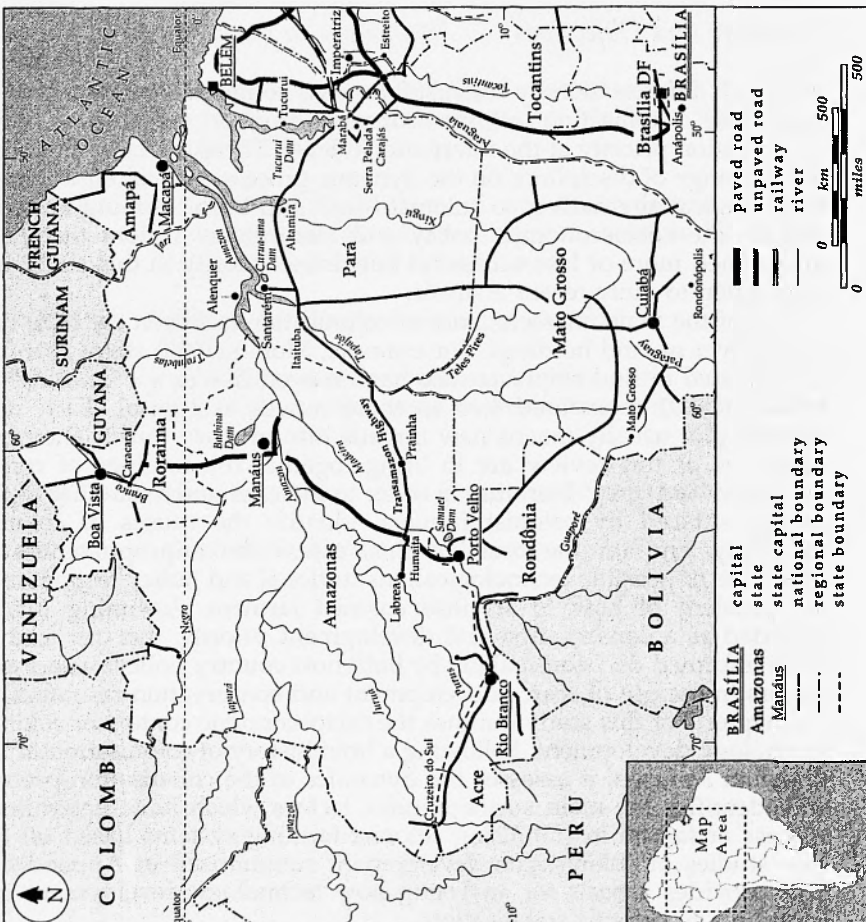
Structure and Objectives

Although deforestation by colonist farmers is sometimes popularly over-estimated, stabilisation of the Amazon frontier remains a major conservation priority at the international level. There is a large literature from a range of disciplines on the dynamic processes of colonisation, on technological alternatives to colonist 'slash and burn' farming systems, and on the socioeconomic, policy and institutional factors that have determined more or less successful outcomes. Priority in this study has been given to more recent analysis.

One of the main characteristics of colonisation has been the high rate of turnover of land holdings. For example, Moran (1989) states that it is not unusual to find colonists who have moved five or six times, while Bakker (1993) considered two to three moves as typical. Each new colonist plot usually means new inroads into primary forest. The main objectives of this review are to bring together the findings of recent published and 'grey' literature in order to increase understanding of the problems faced by colonist farmers, identify the causes of colonist instability, and on the basis of this, assess the appropriateness or otherwise of possible technological, institutional and policy responses to the problem of how to stabilise colonist farmers. Assuming this is regarded as a conservation and development priority, this can lead to more informed decision-making by both host country policymakers and donors in the use of scarce development and conservation resources.

Chapter 2 of this study outlines the socioeconomic context of colonist technology development. Following a brief history of colonisation in the Brazilian Amazon, it assesses the dynamics of the colonisation process and identifies the main socioeconomic factors which have determined success or failure in stabilising colonist farming systems based on the case studies of colonisation development summarised in Appendix 1. This provides a basis for analysing how technology development can contribute to colonist stabilisation.

Map 1 Main cities, roads and development projects in Brazilian Amazonia



Chapter 3 focuses on the alternative technological and land use options for colonist farmers, assesses the basic question of soils, and discusses the sustainability of slash and burn farming. It considers the main technological alternatives, including intensification of shifting cultivation, ranging along a continuum from a higher to lower land use intensity (although this criterion is not strictly followed) and involving the following overlapping categories:

- continuous and semi-continuous cultivation of annual crops
- perennial crops
- intensive agroforestry systems (not based on shifting cultivation)
- extensive agroforestry systems (based on shifting cultivation) and secondary forest management
- natural forest management, including extractivism
- cattle pasture

All these land uses have important implications for such essential aspects of sustainability and colonist stability as risk, land use intensity, returns to labour and capital, external input and credit requirements, storage, processing and marketing aspects, management intensity and the transfer of indigenous or *caboclo* knowledge to colonists, and levels of institutional support. Case studies are presented showing how some of these land use alternatives have fared, and demonstrating the interaction between technical, policy and institutional issues.

The terms 'slash and burn' farming and 'shifting cultivation' are used synonymously in this review. The Food and Agriculture Organisation of the United Nations (FAO) defines shifting cultivation as 'a system in which relatively short periods of continuous cultivation are followed by relatively long periods of fallow' (Robison and McKean, 1992). The term swidden management is also used, usually in relation to indigenous or *caboclo* systems – the difference here is that it implies a more intensive approach involving fallow management and enrichment. The ecological focus is on *terra firme* (non-flooded) humid lowland forest, rather than *varzea* (seasonally flooded) and drier or upland forest areas like the Cerrado on the margins of southern Amazonia. There is also a strong country bias towards Brazil, and to a lesser extent, Bolivia. This partly reflects a bias in the literature, personal experience and UK Overseas Development Administration (ODA) interests.

Colonisation and Deforestation

Moran (1989) defines colonisation as the spontaneous or sponsored settlement of areas of largely unoccupied land. There are three basic types of colonisation. Using Almeida's (1992) terminology these can be classified as 'directed official' or government-managed colonisation, 'directed private' or government-sponsored but privately-managed colonisation, and 'spontaneous' colonisation. Of these the latter has been most important in numbers – for example, Moran (1989) estimates that over two million colonists settled along the Belem–Brasilia highway in less than a decade.

Colonisation areas are usually characterised by their proximity to the forest margin and poor links with national infrastructure. The term 'frontier' cannot be defined in a fixed spatial sense but is the 'transitional process whereby specific new territory is incorporated into an economy' (Almeida, 1992). It can take on a different connotation according to the context – for example, in Brazil it was the area covered by official and directed colonisation programmes in the 1970s, but it is also sometimes taken to mean the area in a colonisation zone in which land rights have not been formalised. Here it is used in a more generic sense to refer to the forest margin areas of colonisation zones, usually characterised by the presence of pioneer or small-farmer colonists. Colonists, unless specified, refer to *mestizos* (mixed blood descendants of European, indigenous and African ancestors) as opposed to indigenous people and *caboclos* – semi-indigenous peoples, often river dwellers, many of whom moved to the Amazon region at the end of the last century at the time of the first main rubber boom.

Almeida (1992) states that the population of the Brazilian Amazon area grew by about 10 million between 1960 and 1980. In the 1970s alone, the Amazon frontier 'absorbed' about three million people, one-third of these in rural areas. It is estimated that there are currently about half a million colonist farmers practising slash and burn agriculture in the region (Homma et al., 1993). The main increases in rural population in the decade were registered in Pará (645,000), Rondônia (208,000) and Mato Grosso (123,000) States – see Map 1. This only partly compensated the net exodus from non-Amazon rural areas in Brazil of almost 3.6 million people,[1] the majority of whom swelled the cities. Official data in Almeida (1992) indicate that there were about 80 million hectares in 'agricultural establishments' on the Brazilian Amazon frontier by 1980, about 18% of the land area of Amazonia, while data in Mahar (1989) implies a total of 144 million hectares , two-thirds of which was pasture.

There is some divergence of views over rates of deforestation, as Appendix 2 indicates, but most sources estimate total accumulated deforestation in the Amazon at 11 to 12%. There is, however, no firm

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1. This excludes the Cerrado frontier along the southern flank of Amazonia, which grew by 234,000 in the decade.

data on the proportion of deforestation caused by small farmer colonists. There are, of course, various agents of deforestation (with inevitable overlaps in their classification):

- ranchers and land speculators
- loggers who cause indirect deforestation by depreciating the value of the standing forest, and building new logging roads
- pioneer colonists
- second wave 'capitalist' colonists
- agro-export farmers
- private and public interests in mining, dams and other development programmes

A sometimes-quoted 'ballpark' estimate for colonist deforestation, as a proportion of total deforestation in the Brazilian Amazon is 30%, and 40% when the synergistic relationship between loggers and colonists is included.[2] Homma et al. (1993) claim that most damage to the primary forest has been done by ranchers, loggers, mining and development projects, and much of the clearance and burning attributed to colonists has been of secondary forest or *capoiera* (four to ten-year-old) fallow. Kaimowitz et al. (1996) report that the main cause of recent deforestation in the Santa Cruz colonisation region of Bolivia has been from mechanised soyabean production. The soyabean area there has been increased from 140,000 ha. in 1989 to 400,000 ha. in 1995, most of it on previously forested land. Mahar (1989) also commented that most conversion was to pasture, and that most, but not all, pasture establishment was on larger holdings.

The challenge to deforestation by colonist pioneers is basically one of stabilisation, or reduction in land abandonment. Partly since it varies greatly from place to place, a large range of plot turnover rates is reported in the literature:

- Almeida (1992) interviewed 400 colonists in 1981 and 1991 from eight official and directed colonisation settlements in Pará and Mato Grosso States, and reported that 36% of the colonists had moved and there was an average length of 13 years on each plot;
- Jones et al. (1992) in a study of 91 colonists in Rondônia found a median length of 10 years on each plot;

2. This estimate is from a survey conducted in Amazonia by the federal agency IBDF (Brazilian Institute of Forestry Development) over the 1966–75 period and reported in Hall (1991): the survey found that 38% of deforestation was caused by ranching, 31% by colonist agriculture, 27% by road building and 4% by logging. However given the interdependence of these agents, any division is bound to be arbitrary.

- Moran (1989) in a review of official and directed colonisation along the Trans-Amazonian highway estimated that between 25% and 75% of the colonists abandoned after five to 15 years of settlement;
- Burford (1993) reported that, in spite of reasonable tenure security, health problems and other factors resulted in less than half the settlers in one area of Rondônia remaining on their plots one to three years after getting their settlement rights;
- Toniolo and Uhl (1995) found that over two-thirds of settlers sold their land during the 1981–93 period in Uraima, located along the Trans-Amazonian highway in Pará State.

Very few of the sources stated what proportion move on to a new plot, as opposed to urban migration, although Toniolo and Uhl (1995) estimated that about half those abandoning move to urban areas.

Justification for Focus on Pioneer Colonists

Colonist farmers are not the main direct agents of deforestation, and colonisation pressures in Brazil have fallen recently, partly due to urbanisation and an ageing population (Almeida and Campari, 1996) – so why the emphasis here on colonist farmers? Some argue that it should shift to the farming systems of those who cause most of the damage, i.e. cattle ranchers, because this would have the most direct effect on deforestation (for example, Serrão, 1995).[3] But this ignores the sequential dynamic of the deforestation process – ranchers rarely enter an area until colonist farmers have cleared the land for them, due to the much higher costs of primary forest clearance away from social and market infrastructure. Stabilisation of the frontier would therefore limit the access of ranchers and land speculators to primary forest. Stable colonists would also be less likely to sell their trees cheaply to frontier logging companies.

Besides the environmental arguments, there are important economic and social arguments for focusing on pioneer colonists. One is that small farmer colonists tend to be more productive in the use of resources than larger farmers; their land use systems are normally less land-extensive and more labour and capital efficient (Cunha and Sawyer, 1992). Also if colonisation is not successful, colonists migrate to other areas where they still need to feed themselves. Away from the frontier, the costs to their respective governments and societies are likely to be much higher.

3. Also improvements in pasture productivity could further encourage ranching as opposed to more intensive land uses.

Therefore effective colonisation can be a cost-effective strategy for tackling poverty, which would have negative environmental effects wherever it was. As Pichon and Uquillas (1995) point out, alleviation of poverty among frontier colonists 'is both a goal in its own right and a precondition for biodiversity conservation'.

2
The Socioeconomic Context of Colonist Technology Development

A Brief History of Colonisation in the Brazilian Amazon

Colonisation was promoted firstly by explicit state policies in the form of official and directed settlement projects. Subsequent spontaneous colonisation resulted from a combination of pull and push factors. The pull factors have included road building, fiscal incentives (although these were aimed at larger-scale enterprises), and development programmes like the Tucuruí Dam and the Grandé Carajas mining project in Pará State.[4] Push factors have included agricultural modernisation in the south, land poverty in the north, inflation and unemployment in the cities, and land distribution policies, among others (see Binswanger, 1989; Mahar, 1989). During the 1970s and 1980s, macroeconomic policies favoured export-led growth in the agricultural sector, and exacerbated what was already a highly unequal distribution of land. A 1986 study by the federal land agency INCRA (National Institute for Colonisation and Agrarian Reform) showed that 30% of rural properties in Brazil were under 10 hectares and occupied only 0.1% of total farmland, while 0.8% of holdings were over 1000 hectares and accounted for 57% of agricultural land (MacMillan, 1996).

Colonisation spread most rapidly along the major new 'highways' opened in the 1970s, like the Pará to Acre Trans-Amazonian Highway, the BR364 Cuiaba–Porto Velho road through Rondônia and Acre States, and the Belém–Brasilia highway (see Map 1). Almeida (1992) observes that the opening of new roads and directed colonisation accounted for a fivefold increase in Rondônia in the 1970s; as a result Rondônia became 'the most important area of Amazon agricultural frontier expansion' (p. 133).

The 1970s colonisation policy was based on the idea of 'bringing men without land to land without people' according to an unfortunate phrase (many of the areas were occupied by indigenous and *caboclo* peoples) attributed to Brazilian President General Medici. However these migratory flows were in both directions. There was a reverse flow in the late-1970s as most of the large, land-speculation-driven private colonisation schemes collapsed when government support was

4. The area of influence of Grande Carajas extends to 10% of Brazil.

withdrawn due to low colonist productivity and macroeconomic pressures. However by the mid-1980s many of these areas were reinvaded and became INCRA land settlement schemes.

Almeida (1992) discusses the differences between the colonisation processes in eastern (Pará State and the Trans-Amazonian highway) and western Amazonia (Rondônia, Acre and Mato Grosso States), showing how pre-colonisation societies were reproduced on the frontier. In southern and western Amazonia, following a first migratory wave from the poor north-east and northern Brazil, many of the colonists were from southern Brazil. They migrated at a time of rapid modernisation and land concentration in the southern agriculture sector (especially from the exploding coffee frontier in Paraná State) as capital substituted labour, and when land prices were at a peak. Many were therefore able to bring considerable capital with them, as well as experience with modern farming methods. Areas in Mato Grosso State were subjected to both official and private colonisation, much of it in the form of large holdings producing coffee, rice and pasture. The colonists employed poor north-easterners, who had migrated earlier, as farm labourers. This frontier spread north to Roraíma and Amazonas along the new highways.

Eastern Amazonia has sometimes been referred to as an extension of Maranhão's (north-east Brazil) frontier. The latter became saturated and exhausted by the end of the 1960s. North-easterners had traditionally come to the Brazil nut polygon area of eastern Pará on an itinerant basis. The vicious circle of slash and burn technology, subsistence and itinerancy – never intended to be sustainable – reproduced itself in Pará. Schmink and Wood (1992) state that colonisation policies have reproduced the urban ecology of metropolitan Brazil at the frontier by promoting a rapid process of integration into the cash economy. Surviving colonists quickly turned into urban businessmen, while the failures returned to the cities, worked as hired labourers, or moved to the next frontier. By the 1980s, the 1970s colonisation zones were well advanced on the path of urbanisation, land concentration and social differentiation (see Appendix 1).

In most colonisation areas, yields have increased[5] and real living standards become higher than in many other rural and urban areas in Brazil (Schneider, 1994). In some of the state-directed colonisation programmes like Altamira in eastern Pará, markets proved competitive and good prices enabled colonists to invest in permanent crops, diversify, and accumulate capital. However Almeida (1992) observes that the best soils in Amazonia were all claimed by the end of the 1970s. The 1985

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5. Almeida (1992) reported that maize yields increased by 50% and rice yields by 29% in a survey of 400 colonists in eight colonisation zone areas from 1981 to 1991.

National Programme for Land Reform was set up to redistribute unproductive land to new colonists, and colonists were encouraged to invade privately-owned holdings in the hope that government would intervene on their behalf (MacMillan, 1996). This policy did not have adequate political support and faded out towards the end of the decade. There were increasingly violent land conflicts throughout the decade as colonists squatted on the unoccupied better quality soils, and collectively organised themselves, often in the form of rural labour unions, against those with previous land claims and federal and State institutions. They increasingly took the law into their own hands and defied technocrats, entrepreneurs and politicians to carve out a life on the frontier.

There have been great political and policy changes since 1985, when the Brazilian military regime ended. The late 1980s saw the rise of rubber tapper unions amidst the land violence of western Amazonia, extractive reserves, the ending of ranching incentives, and the curbing of multilateral-funded dams and roads. But despite all these changes, the main thrust of Amazonian policy has remained developmental. One of the main recent changes, according to Schmink and Wood (1992), has been democratisation – more political channels are now open to grassroots movements, with new forms of political organisation and alliances within and outside Brazil, especially with environmental and indigenous rights groups, and new sources of information and finance have become available.

Spontaneous colonisation has proved both more effective and cheaper for the government than directed or official colonisation. This was partly because colonists selected themselves and showed greater initiative than average, and due to a lower government presence which reduced land speculation pressures and tenure protection for other actors (Moran, 1981, 1989; Schneider, 1994). Now almost all colonists are 'spontaneous' – as few as 1% live in 'planned colonisation projects' (Jaenicke and Flynn, 1992).

The Causes of Colonist Instability

Appendix 1 summarises selected case studies of colonisation zone development, according to the emphasis put on the various processes by the different analysts. A better understanding of these factors is basic to identifying and prioritising appropriate interventions and policies to promote colonist stability. The first observation from these case studies is the tremendous diversity of situations and pressures. There are the obvious differences between official or directed and spontaneous colonisation, which often occurred sequentially in the same area. However, the case studies also reveal a certain consistency in analysis about the dynamics of colonisation zone development: for example, the importance of differences in the social and economic characteristics of the colonists; the question of land values and speculation; and institutional (support service) aspects. This has permitted the development of some generic scenarios (Tables 1 and 2), which attempt to summarise the underlying processes of colonisation.

The Three Main Stages of Colonisation

One of the main characteristics of colonisation is change. In most situations, the resource-poor colonist comes to an undeveloped frontier where land is cheap and abundant, usually following road construction. This is termed the 'early pioneer stage' of colonisation. Typically there will be little institutional presence or social infrastructure, and a high level of forest cover. At this stage there is usually little interest in land rights, unless the land has been previously occupied and abandoned, for example following a failed directed colonisation programme.

However, over time, social infrastructure and market opportunities gradually improve, formal government arrives, land tenure becomes more formalised, and land prices increase. These factors bring about the transition of the frontier into a market economy system. One of the main characteristics of the 'emerging market economy' stage is that as market economy institutions (land and labour markets, formal credit, property rights, market infrastructure, etc.) are put into place, a second wave of capitalist-type colonists are attracted. If it is in a former area of directed colonisation, this will include past landowners returning to re-establish land rights. This is the stage (typically 5 to 15 years after the frontier is opened) when most land abandonment occurs, according to Moran (1989).

Table 1 Colonisation zone conditions associated with high instability

	Early pioneer stage	**Emerging market economy**	**Closing frontier**
Colonist characteristics	Individualist and speculative attitudes; pre-colonisation itinerancy cultures of N.E. Brazil; big differences in initial financial and human capital: 'broker' and 'client' relationships; very risk averse; small family/young children.	Lack of literacy proves handicap in land claims; slow to adapt to new market and institutional opportunities; lack of prior entrepreneurial experience proves constraining.	Colonists unable to make socio-cultural adaptation to capitalist frontier economy; become landless labourers, migrate to frontier or return to cities.
Land tenure and distribution	Not usually an important issue since land abundant, but there may be land claims from earlier abandoned directed colonisation.	Government defends land claims of earlier claimants or second-wave colonists causing land conflicts; second-wave colonists do not have to occupy land to secure tenure.	Increasing concentration of land in hands of second-wave colonists.
Role of land value and speculation	Cheap land encourages land-extensive farming regardless of soil quality; colonists aim to maximise return to scarce family labour and capital; land value can often be tripled by conversion to pasture.	Rising land values with market-economy institutions: second speculative wave arrives; increasing indebtedness, tenure insecurity and rising land prices encourage sale by pioneers.	Higher land values encourage more intensive and commercial farming systems by survivors – mainly capitalist colonists.
Government/ other institutional interventions	In directed/official colonisation: support services do not reach resource-poor farmers; incentives/ credit tied to cash crop monocultures; negative 'invisible institution' problems; absence of NGOs, or labour unions slow to develop.	Increasing indebtedness due to induced emphasis on inappropriate cash crop monocultures; government agricultural support services and tenure support go to second wave colonists; weak NGO/labour union support for pioneers.	Formal government withdraws and local institutions/NGOs take over but land concentration and social differentiation is well advanced.

Table 1 *(continued)*

	Early pioneer stage	**Emerging market economy**	**Closing frontier**
Credit	Mainly non-monetary mercantile credit with high interest rates – indebtedness forces labour/ subsistence crisis.	Formal credit arrives but depends on land title, and is tied to inappropriate cash crop monoculture – inducing indebtedness.	Credit tied to unsustainable land use management.
Off-farm income	Lack of opportunities for off-farm income to provide alternative means of accumulating capital and ease capital constraints.	Increasing off-farm wage opportunities can accelerate conversion and abandonment if speculative element is dominant.	A developed labour market – client colonists are absorbed as hired labourers, and other factors encourage land abandonment.
Farming systems	Subsistence crops, manual farming methods and destumping by family labour, fire as key management tool.	Increasing clearance for pasture, market orientation, use of hired labour and some external inputs.	Dominated by pasture, reliance on hired labour, occasional mechanisation.

Table 2 Colonist farming systems: the moving target

	Early pioneer stage	Trends with maturing frontier
Colonist objectives	Survival, subsistence and if possible capital accumulation; but little economic or social incentive to remain unless tightly knit social group.	More income-orientated and greater incentive to remain due to better social infrastructure, market opportunities and higher land values.
Tenure	Insecure, although tenure is often uncontested at first.	If land rights are not protected by labour unions or NGOs, increasing insecurity.
Risk	Very high, especially due to loss of former social institutions.	Risk falls with better health infrastructure, stronger labour unions or community structures.
Colonist farming experience	Experimental phase, often with an initial burst of clearing; minimal support services.	Accumulated experience and increased institutional support.
Land values	Low, but higher when converted to pasture.	Increasing.
Resource scarcity	Scarce family labour and capital; relatively abundant land.	Dwindling forest reserves means land becomes scarcer; off-farm income, credit and hired labour can ease other resource scarcities.
Micro-economic incentives	To maximise returns to labour and capital, and maximise use of land.	Increasing incentive to intensify land use.
Credit	Mainly non-cash mercantile credit, often with high real interest rates.	Better access to formal credit for those with land title.
Off-farm income opportunities	Limited – capital accumulation depends on farming.	Developing labour market provides capital accumulation alternative.

The third stage is often called the 'closing frontier'. This is when there is little or no land available in the area to colonise, although there is usually a still-opening, but increasingly distant, frontier. Land use systems, although still in a process of change, are more stable with cattle farming dominant. Land is more expensive due to a stronger speculative element and more developed infrastructure. Land concentration, social differentiation and urbanisation are at a fairly advanced stage.

Social and Economic Differentiation between Colonists

All the main analysts have emphasised the differences between colonists. Colonists do not start out equal; differences in initial capital, management experience, experience with credit and entrepreneurial orientation are critical in terms of their ability to stabilise. Colonists with low financial and/or human capital (education, farming knowledge, entrepreneurial skills, etc.) are always fighting against the odds.

Moran (1981) divided pioneer colonists into two main types: 'broker' and 'client' farmers. Brokers were entrepreneurial-type farmers who came with some capital and appropriate skills, and were more market/cash-orientated. Subsistence-orientated client farmers rapidly came to depend on the brokers for credit and other services. Moran further subdivided clients into labourers and artisans according to their previous experience. As Appendix 1 shows, broker colonists have tended to absorb the clients in the process of land concentration.

Regional differences, and associated social and economic characteristics of colonists, were emphasised by Almeida (1992). Southerners, who moved to western Amazonia (especially Rondônia), brought skills and resources superior to the north-easterners, who moved more to Pará State. For the north-easterners, itinerant (unstable) agriculture was almost a way of life. A vicious circle of short-term but low input technology, subsistence and 'itinerancy' (land abandonment and movement to another plot or area) is described. Almeida (1992) also emphasises family size and age structure – accumulation was difficult for smaller families with young children since most available labour was absorbed by subsistence activities.

Toniolo and Uhl (1995), Schneider (1994) and others found that the key difference was between the pioneer colonists and second-wave settlers. The latter, often termed capitalist colonists, came with strong urban connections; they often held political or civil service positions, owned urban real estate, and ran small businesses. They were essentially speculators with only a secondary interest in occupying the land for farming: 'as real estate appreciation pushed pioneer farmers out of older frontiers and into new ones, the deforested land accrued to a new constituency that was considerably better off than those who left. Many were probably not really farmers at all, but merchants, public servants and other city dwellers' (Almeida, 1992: 27).

Land Tenure Issues

The interaction of social differences with land security is particularly emphasised by Schneider (1994). Illiteracy can be a very serious handicap for early colonists to press their land claims, in contrast to more educated and influential colonists, ranchers or land speculators, with whom urban-based officials have more cultural affinity. Early informal tenure is precarious, usually involves some cost to the colonist, and does not provide access to bank credit. Typically, in the early stages, a wave of speculator colonists and ranchers move in to buy up or lay claim on land opened up by new roads, but then move on. In Brazil this was greatly encouraged through fiscal incentives. However, much of this land was soon abandoned when farming was found to be unprofitable due to the high transport costs. The unoccupied land was then re-invaded by pioneer colonists, especially in the late 1970s.

As the frontier matured, government tended to come in and take over land rights adjudication – usually coming to the defence of the absentee owners. This meant that speculators were able to hold on to the land without needing to farm it, and thus without needing to clear and farm it for very little economic benefit (due to the high costs of clearance and marketing). They were able to hold the land until its value, market access and profitability improved. Also they could earn more from urban-based activities. Meanwhile the pioneer colonists, with much lower opportunity costs (i.e. the lack of an economic alternative), could only defend their land rights by occupying, farming and degrading the low value land. This process naturally hastened land abandonment by pioneer settlers (Schneider, 1994).

Those who secured land rights were also able to get access to formal credit, which was cheaper than informal credit. The various economic and legal disadvantages of untitled pioneer colonists make it difficult for them to hold out, and they were gradually bought off – if they were not forced out. It was only in situations where NGOs, like the Movement for the Landless (MST) and the Catholic Pastoral Land Commission (CPT), or strong rural labour unions were formed as in the Marabá region of Pará, that this process could be resisted.

Another problem for pioneer colonists in Brazil has been the ambiguity and confusion of land rights. For example, in Pará State's 'Brazil nut polygon' area, usufruct rights to local elites for exploitation of forest products were originally granted by the federal government – land was classified as neither public nor private property. Since 1950, four separate government institutions have been charged with allocating and regulating land titles in this area (MacMillan, 1996). From 1959 to 1963 the Pará State government sold 5.6 million hectares illegally, and then a review in 1964 revoked all previous titles and placed land titling in the hands of the State Secretariat of Agriculture. Later, in 1975, the State Secretariat for Land issued special permits permitting the repurchase of land acquired irregularly before 1964. Relatively few colonists in the area have absolute title (*titulo definitivo*). Conversely, Thiele (1995) points out how the ambiguities of state support to *large* farmers help explain the persistence of smaller colonist farmers in the Santa Cruz region of Bolivia.

Land Speculation and Colonist Capital Accumulation

There are two important types of land speculation: firstly, 'speculation' by colonist farmers as an effective form of capital accumulation; and secondly, by outsiders who rapidly raise land values so that colonist, or even capitalist, farming cannot compete.

Most authors recognise the strong incentive for colonists to view increasing land values as a means of capital accumulation. Many colonists understandably see land 'speculation' as a way of rapidly accumulating enough capital to buy a better piece of land on which they can achieve a reasonable standard of living. This means obtaining land with lower transport costs to market, better served by health and education infrastructure, and having enough money left over to buy some cattle. Forest clearance was also a condition for receiving credit and fiscal incentives in Brazil. The process has been well-studied in the Marabá colonisation zone of eastern Pará by LASAT/CAT (Socio-agronomic Laboratory of Tocantins Araguaia/Agro-environmental Centre of Tocantins and Araguaia). Land values could be tripled by clearing the forest and sowing to pasture, in anticipation of the buyer's needs (LASAT/CAT, 1995). Forest clearance for pasture increased land values for several reasons: firstly, by making it easier to establish land rights and obtain formal credit; secondly, land market values tend to at least partially reflect market product potential, and cattle have the least transport and market constraints in frontier areas (Bakker, 1993). Pasture was also the cheapest means of occupying cleared land (Fearnside, 1992).

Toniolo and Uhl (1995) report that land along the Trans-Amazonian highway costing from US$10 to $50 per hectare in the 1970s was worth in excess of $150 in the 1990s. While there were great variations in the increase in real land prices – Almeida (1992) found an increase of only 15% overall between 1981 and 1991, but variation between sites of –15 to

200% – land was clearly the best investment in stagflating economies such as Brazil's and Bolivia's in the 1980s. A calculation by Mahar (1988) estimated that a colonist 'speculator' could get $9,000 profit from buying 14 ha of frontier land, farming it for two years, planting pasture and selling it.

In other situations, the colonist speculative element is even more transparent. In eastern Bolivia, several sources have pointed out how highland colonists retained highland plots when they came to the lowland frontier. Buying and reselling land, once deforested and sown to pasture, was the most effective way of rapidly raising urgently needed capital to intensify production on their small highland plots (Davies, 1994).

On the second type of speculation – from outside – Rudel (1995) has astutely pointed out that 'the more valuable a resource becomes, the less likely it is that indigenous peoples or smallholders will retain control over it' (p. 191). High land prices can be associated with high natural resource or mineral values, or with government development projects. Rudel (1995) contrasts two areas of mainly spontaneous colonisation – southern Pará State, Brazil, and Morona Santiago in south-east Ecuador (see Appendix 1). Morona Santiago is a relatively stable colonisation zone where colonists have developed common property resource management rules to protect their land rights. In contrast to southern Pará, there were few valuable natural resources, no big development programmes (like Grandé Carajás), no resident commercial elites, and a passive state policy towards colonisation. There was only a very brief initial burst of land speculation. Thus the absence of formal government and projects, although it reduced off-farm income possibilities as an alternative means of capital accumulation, greatly reduced competition for land.

Land Values and the Microeconomics of Colonist Land Use

Most analysts consider that the price of land, relative to other inputs, is fundamental to colonist technology choice. Low land prices and high input prices stimulate land-extensive technology (slash and burn without fallow enrichment, and clearance for pasture), while high land prices relative to labour and other inputs stimulate land-intensive technology. Relative product:factor prices further determine the technology, but land prices are normally more important according to a comparison of rice yields, rice prices and land prices in different colonisation zones by Almeida (1992).

Schneider (1994) posits that whatever the underlying productivity or income potential, as defined by soil fertility, when land is cheap the rational response is nutrient mining, clearance for extensive land uses and early land abandonment. However, as the frontier closes land values rise, social infrastructure improves, institutional support improves, property rights become secure, and capital more available – and there is consequently a much greater incentive to intensify land use. Toniolo and Uhl (1995), in their study of land use intensification[6] in an old frontier region around Paragominas in eastern Pará, compared rising land prices to changing agricultural practices. They found that many surviving (mainly capitalist) farmers grew labour- and capital-intensive vegetables on raised beds, and most grew perennial crops like black peppers and oranges. Significantly, the most intensive farmers were urban businessmen. Toniolo and Uhl (1995) concluded that it is impossible to intensify land use in the early frontier stage when land is cheap.

Paradoxically, when the economic incentive to intensify is highest, the capacity of the land for intensification is at its lowest point. Declining productivity is compensated, wherever possible by bringing new lands into production, and the cycle begins again (Pichon and Uquillas, 1995). Intensification in the closing frontier stage therefore implies improving the productivity of open or degraded areas. Mattos et al. (1992) from the Paragominas area of Pará State found that ranchers have been prepared to reinvest about $260 per ha to achieve a three to fourfold increase (possibly sustainable) in liveweight production per hectare with a 13–16% return on investment. Productivity is increased by removing debris, ploughing, fertilising and reseeding with improved forage varieties.

Schneider (1994) argues that both smaller and larger ranchers in this closed frontier region have pursued this path as a result of the prevailing scarcity and cost of land; ranchers who need more land have been unable to find it at a price which is less than the equivalent cost of pasture rehabilitation.[7] He even goes on to hypothesise a mathematical relationship. If pasture rehabilitation can cause a threefold increase in productivity, it is only worth buying more land when its price is less than half the cost of this rehabilitation; by buying two more hectares at $130 per ha, the rancher will have three hectares at the lower productivity which are equivalent in economic terms to one hectare at the higher productivity.

But these are over-simplifications. As Almeida (1992) explains, the issue of agricultural technology in the Amazon cannot be reduced to relative factor and product prices. Firstly, there is always a period of adjustment as colonists respond to economic changes; some take rapid

6. Intensification here is taken here to mean the fuller use of natural resources, external inputs and/or labour resulting in an increase in gross land productivity.

7. This ties in with LASAT's (1995) observation that there is a land productivity and income crisis in the later stages of colonisation (Appendix 1).

advantage of new opportunities at the frontier, while others persist with old practices from their areas of origin. Also the quality of institutional support, and how rapidly colonists respond to it, is very variable.

Finally, initial land prices can be very important for a colonist farmer with limited capital. The high land prices in directed (private) colonisation schemes in the 1970s proved crippling for many colonists. Another case where high land costs and insecurity made it difficult for farmers to adopt more intensive land use systems was in north-east Ecuador (Hiraoka and Yamanoto, 1980 – see Appendix 1).

Institutional Factors

Most accounts of colonisation emphasise a range of institutional problems, many associated with government agencies involved in official or directed settlement programmes. For Moran (1981), a key failure of official colonisation along the Trans-Amazonian highway was its failure to appropriately support poorer colonist farmers in the early stages of colonisation, when the loss of previous social institutions caused difficulties in the areas of risk and labour sharing. During the first five years, the main priorities of the colonists were market access (roads), health infrastructure, schools, and local adaptive agricultural research and extension. However the government's (national level) priorities were to integrate the colonist into the national cash crop economy as rapidly as possible.

Official priorities were essentially based on green revolution high input–output technology – as Pichon and Uquillas (1995) point out, resource-poor farmers gained less as official research and extension efforts favoured the commercial farm sector. Associated with green revolution technology were a host of problems for appropriate colonist technology development – for example, the emphasis on land productivity, centralised research stations, the technology transfer extension model, market dependency etc. (Pichon and Uquillas, 1995).

The main policy instrument of INCRA was to tie credit, tenure and support services to rice production. As Collins (1986) has pointed out, this caused colonists to invest their energy and spare capital in a technology that was not appropriate for most of the region's soils. Shorter rotations and declining yields resulted in increasing indebtedness, and in a relatively short time client farmers were bought out by broker farmers (in Moran's terminology).

Norgaard (1984), in an interesting analysis, observes how a monoculture and 'temperate-zone approach' was doomed to failure. Drawing on what he terms a 'coevolutionary' (between social and natural processes) explanation of development, he finds that

> the failure of planned development in the Brazilian Amazon . . . can be characterized as a classic sociosystem and ecosystem mismatch. The key characteristics of the ecosystem are incredible species diversity, a highly specialised system of nutrient recycling, uncertain succession responses, and rapid rates of growth. These characteristics suggest that an initially compatible social system would emphasize (i) multiple-product, regional, near-subsistence economy, (ii) participation of native peoples with knowledge of the natural system, (iii) technologies that evolved in the tropics, (iv) formal and informal risk-sharing, and (v) decision-making power in the hands of people close to the dynamic ecosystem (p. 533).

Another aspect of this mono-vision approach to colonisation was a lack of interdisciplinarity and inter-institutional coordination between policy, support service and technical issues (Schmink, 1992, and Vosti, 1993). This contributed importantly to an unsupportive policy environment and ill-directed research and extension service.

In a statistical analysis, Almeida (1992) found that access to institutional assistance – of which technical assistance and support in tenure claims were most important – had most influence on variation in current incomes of colonists. The institutional influence was found to increase over time as the influence of colonists' areas of origin weakened. Toniolo and Uhl (1995) also found that the main obstacles, after land values, to a transformation from extensive slash and burn farming to more intensive farming methods were institutional: lack of social organisation, technical and market information, and capital. Another common problem implying a lack of microeconomic planning was the lack of storage for crops, which caused much of the produce to rot in the fields.

Moran (1981), Smith (1982) and Schmink and Wood (1992) all emphasise the failure of government agencies to provide services they had promised to settlers, and the inattentiveness of government agencies and other institutions to the realities of the frontier. Information feedback from the field was poor, and the institutions proved inflexible to the needs of the frontier colonist – which were effectively defined at the central level. The presence of a supporting NGO (usually Catholic-based) or development of a rural labour union could be critical for stabilisation – for example, in the case of the RECA Programme (Box 6) in Rondônia, the early support of the Pastoral Land Commission was crucial (Allegretti, 1994). This is now regarded as a model programme in technology development, based on high value perennial tree crops.

Moran (1989) also brings out a series of negative 'invisible institution' problems associated with the incentives and attitudes of those working in public service (these can range from apathy to patronage and graft). Extension workers sent to the region did not work effectively with those they perceived to be of a lower social status. They were also frequently inexperienced in local conditions. The bureaucracies of the federal land agency (INCRA), the banks and other institutions were inflexible, making it difficult for colonists to obtain inputs, credit and extension services at the time they were required. An example of the effects of a bureaucratic system of land tenure in north-eastern Ecuador (Hiraoka and Yamanoto, 1980) is presented in Appendix 1. Bakker (1993) comments on the problems of bias and snobbery by civil servants, who often regarded farmer organisations as subversive. This also contributed to very low levels of consultation and participation with colonists in the design of support programmes, and reinforced the tendency of colonisation programmes to respond to national economic policy priorities rather than colonist priorities (Moran, 1989). Bakker (1993) also discusses corruption problems surrounding credit distribution in official colonisation programmes.

Institutional factors have also been of paramount importance in situations where greater colonist stability has been achieved. Box 1 focuses on the Coca Agroforestry Programme in Napo Province in north-eastern Ecuador. This was a mainly state-managed programme of research and extension using participatory methodologies which have resulted in the development of various agroforestry-based technologies by colonists over a large area. The key institutional components listed in Box 1 contrast with the approach taken in the official (INCRA) Brazilian Amazonia colonisation programmes.

Thiele (1995) traces the persistence of colonist settlement on the Santa Cruz (Bolivia) frontier to 'ambiguities in state support for the large farmers, the lack of dynamism in commercial agriculture, different spatial patterns of expansion of peasant and commercial farming[8], the occupation of land by peasant farmers in legally recognised agrarian unions, and the Andeanisation of the frontier with the extension of a distinctive social and economic space originating in highland Bolivia into the lowland environment' (p.273). An important institutional factor affecting land security was the role of the National Colonisation Institute, which maintained land registers in the colonisation projects to try and ensure each settler received only one parcel – this effectively precluded the entry of large farmers.

Another source (Painter and Partridge, 1989) reported on the stabilising influence of a church-based NGO which provided pre-colonisation orientation and training in one of the Santa Cruz settlement

8. Small and large farm expansion occurred in different geographical directions; the main expansion of commercial farming has been in lower rainfall areas suitable for soyabean cultivation, while small farmers gravitated to the higher rainfall areas suitable for rice.

Box 1

The Coca Agro-forestry Research and Extension Project, North-east Ecuador

(based on Peck, 1990, and Ramirez et al., 1992)

In the Coca (River) Project in Napo Province in north-east Ecuador, an effective agroforestry research and extension programme has been developed since 1984. It was started by the government in one of the most active areas of Amazon colonisation, due to the 1970s oil boom, and from 1973 to 1989 some 16,000 colonist families settled in the region. By 1984 some 3,300 families had moved onto 50 ha plots in the project area. The Project's success has been based on a combination of small-scale technologies which responded to farmer needs and an effective institutional strategy. Also many of the colonists were indigenous, which proved advantageous in the organisational aspects of the project. The Quichua communities were organised in regional indigenous associations and *comunas* with large blocks of communal hunting lands.

The project initially focused on improved germplasm and agroforestry practices within existing swidden farming and coffee and pasture production systems. Commercial timber and other tree species and legume cover crops like *desmodium ovalifolium* have been introduced simultaneously and at little financial or opportunity cost to the farmer. Technology development has taken account of labour as the main constraint, for example the *desmodium* only has to be sprinkled on bare ground around the tree species; cattle also help to spread the seeds by digesting and fertilising them. Such practices as cover crops to reduce weeding costs, selective cleaning of coffee trees, pruning to improve the future harvest of coffee, better use of shade and measures to reduce the incidence of the coffee bean borer, have been adopted and increased the return to labour, according to an economic analysis by Ramirez et al. (1992).

The key institutional components of the project listed by Peck (1990) were:

- use of multidisciplinary teams and a farming systems approach to prevent a narrow, specialised approach
- use of local extension officers, who were stable and had a good rapport with the farmers
- an adaptive research and extension approach which responded to individual farmer needs
- a built-in auto-evaluation system
- linkages with national and international research centres for additional technical support
- presence of national institutions ensuring continuity
- secure tenure and good market and credit access

By 1987, there were over 200 on-farm demonstrations (1–12 ha in size) promoting 27 native tree species in mixed associations. Once the on-farm demonstration effect was achieved, the project has relied successfully on spontaneous expansion.

areas (see Appendix 1). Another positive example detailed in Appendix 1 comes from south-east Ecuador, where non-formal institutions in the form of a common property resource management system to protect colonist land rights was developed in a more remote colonisation area (Rudel, 1995). At the same time, these Andean colonisation zone examples indicate that there were some different dynamics operating, some related to indigenous influences, which once again highlights the danger of generalisation - especially across cultures.

Risk and 'Imediatismo' on the Frontier

The importance and role of risk in frontier economies is another reason why institutional response to the needs of colonist farmers is critical. Risk dominates the lives of colonist farmers. Among many others, there are risks to individual and family health, challenges to land rights, crop pests and diseases, and fluctuating input and output prices. As Vosti and Witcover (1994) point out, risks do not necessarily come one at a time. Isolation greatly increases risk. The absence of roads linking more distant communities to social infrastructure, especially health facilities, tends to further encourage short-term cash crop farming and clearance for livestock in order to purchase cattle, since this combination makes it easiest for colonists to respond to a crisis – typically of illness. Moran (1989) also points out that improved health facilities and roads are usually the early colonists' main priorities. Institutional support to replace the colonists' lost social institutions, can play a major role in reducing risk. As the case studies in Appendix 1 show, the development of rural labour unions or the presence of an NGO can have a major impact.

For Schneider (1994), the explanation of what he terms the frontier culture of *'imediatismo'* (looking to the very short term) is found in terms of high personal discount rates[9] of colonists, due both to risk and high interest rates in the economy. This means that new investments or more sustainable technologies have to be very much more profitable or attractive than traditional low investment practices to stand a chance of being adopted.

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9. The discount rate is the inverse of the interest rate (1/r) and is used to calculate the present value of future income flows. The higher is the discount rate, the lower is the present value.

Markets, Credit and Off-farm Income

Marketing problems were commonly cited as a major constraint to colonist stability. For example, Fearnside (1992) found that market opportunities and fluctuating prices limited colonist planting of cocoa in western Amazonia. The depressed nature of markets for the main colonisation zone crops of eastern Bolivia (Santa Cruz region) – rice, maize and cassava – has greatly limited colonist accumulation strategies (Painter and Partridge, 1989).

Access to credit, and the impact of different forms of credit, is also considered an important determinant of stabilisation by many analysts. Almeida (1992) emphasises the importance of traditional mercantile-usuary forms of credit imported into Pará State by north-easterners. Credit is provided in the form of food, inputs and other necessary goods; payment and interest are through advance purchase of the harvest, often involving usuary interest rates, depending on supply and demand considerations.

An important aspect of this system is the dynamics between family size and age structure and the credit system. Increasingly the 'brokers' forced 'client' farmers into producing cash crops like rice, placing an enormous pressure on scarce family labour resources. The crisis comes when there is insufficient family labour for the families' subsistence needs left over from debt-related cash crop production. Thus plot abandonment can be due to a labour, rather than land exhaustion crisis, although the 'debt labour' system also leads inevitably to land-extensive farming and deforestation. Escape from increasing land or labour indebtedness can also come from off-farm income earning possibilities, if these exist. Lack of off-farm income in the early and middle phases, combined with limited credit opportunities, hastens plot abandonment, as indicated in Table 1.

Political Economy Viewpoint

Finally there is a significantly held viewpoint that the failure of the small farm system as a viable option is predetermined by national and international vested interests, and the pressure of the international market economy (Schmink and Wood, 1992; Redclift, 1986). For colonist farming to succeed, it would have to be at the expense of the short-term economic interests accruing to the economic and political elites. Fearnside (1992) argues that this is a reason why technological, rather than policy or economic, options are more commonly supported: an agroforestry programme is unlikely to affect the underlying incentives and interest groups.

Implications for Appropriate Technology Development

What is Appropriate Technology?

Technology can be defined as appropriate according to, on the one hand, the colonist farmer's objectives and needs – which involve some combination of risk reduction, family subsistence and cash needs, stability and capital accumulation – and on the other hand, society's need for non-degrading natural resource management (authors like Anderson (1990) and Dubois (1990) emphasise the role of nutrient recycling, natural succession and so on). Clearly many of these objectives are interlinked. Low productivity causes colonists to mine their natural resources, since low farm incomes put great stress on the farming system to meet cash objectives. High risk and time preference (high personal discount rates) in colonist situations means that technologies need to produce early returns on any labour or capital investment. But lack of ecological sustainability will mean that it will only be a matter of time before colonists have to move on.

Therefore technology development aimed mainly at meeting subsistence needs is not likely to be adopted. Farmers questioned in early frontier settlements in the Marabá area of Pará State revealed that 60 to 70% of annual crop production was needed for cash requirements. Higher productivity and income generating technology are therefore normally essential from both individual and societal viewpoints. Vosti and Witcover (1994) argue that technology development must aim for 'overlap technologies' that satisfy both productivity/income and sustainability criteria.

Hitting a Moving Target

Any technological response must pay extremely close attention to the microeconomic determinants of colonist land use, particularly the relative opportunity costs of land and labour and product:factor price ratios. Thus technology development should correspond to labour and capital constraints in the earlier stages of colonisation, switching to land as forest cover is reduced and land values increase. Table 2 shows that technology, institutional and policy responses are aiming at a moving target in terms of microeconomic conditions, colonist objectives and many other interrelated factors. It is important to note that Table 2 assumes that the pioneer colonists survive as the frontier matures –

obviously second-wave colonist objectives and conditions are quite different.

The prevailing economic incentives make any kind of colonist investment (of labour or capital) unlikely in the early stages. But if the process is left too long, the problem becomes one of open land rehabilitation – in which case the options are greatly reduced. Therefore land use intensification should probably aim at an intermediate stage of colonisation when there is still enough forest left on the plot to assist nutrient recycling, and land values are increasing. But even at this stage, technological response needs to assess carefully the opportunity costs of labour and land.

The Importance of Labour

Most attempts at developing sustainable technology for colonists have viewed the central problem as how to intensify land use, for example by satisfying subsistence and cash requirements from a smaller cleared/cropped area through fallow enrichment or by increasing the cropping period. While this is a vital aspect of colonist sustainability, the problem is that it has tended to focus technology development on land productivity.

Simple microeconomic theory indicates that while land is cheap and labour and capital scarce, colonists will prefer technologies which attempt to maximise the returns to capital and labour. Low-input but land-extensive slash and burn farming, and conversion to pasture, is therefore a predictable response to prevailing microeconomic incentives. Thus Schneider (1994) argues that in newer frontier areas, land-extensive farming and early abandonment are rational responses to cheap land regardless of the underlying suitability of the soil.

Various examples from the literature show that it is often a labour, rather than land, crisis which causes abandonment. The early pioneer stage mercantile credit system increases the emphasis on the productivity of family labour, as discussed above. Also Maxwell's (1979) pioneering analysis in the Bolivian Amazon showed that it was mainly a labour crisis (interacting with land and capital constraints) that normally caused land abandonment. As fallow periods were reduced, there was an increasing labour cost of weed control. If the farmer did not have enough capital to hire labour or use herbicides, the increasing family labour burden would cause abandonment. As Thiele (1991), in the same context, has pointed out, the ratio between the cost of labour and the price of rice was also crucial to the land intensification or abandonment decision.

Labour-efficiency is also central to the rationale for burning, which represents a major constraint to land intensification (for example, preventing the introduction of perennial crops in fallow areas). Burning is a labour-efficient means of controlling weeds and releasing nutrients from the above-ground biomass. An exciting development in Central American colonisation areas over the last decade, and more recently in Amazonian areas like the northern Santa Cruz colonisation area of Bolivia, has been the spontaneous adoption of green manures and cover crops with minimum tillage techniques (see Chapter 3). One of several reasons for this is that it is a technology with the potential to increase returns to labour and capital, as well as land, and represents a labour-efficient alternative to burning. The Coca Agroforestry project (Box 1) also shows how focusing on a number of low investment labour-saving technologies has successfully fostered small farmer interest in agroforestry and land use intensification. Conversely the lack of interest of colonists in labour intensive agro-forestry technologies like alley-cropping, for example when briefly promoted in the Marabá area by CAT (Centro-agroambiental do Tocantins Araguaia), is predictable.

The Role of Capital and Cattle, and the Case against Increasing Colonist Productivity

A widely-held viewpoint is that colonists will only adopt more land-intensive technology when land values are rising (as the frontier matures and closes), especially when the main colonist motive is capital accumulation through the land market. According to Schneider (1994), data from various sources show there is no relationship between land productivity/incomes and permanence on the plot. Yields have increased in most colonisation areas – for example, Almeida (1992) reported that maize yields increased on average by over 50% and rice yields by 29%. Jones et al. (1992) found no statistical relationship between income and permanence in their longitudinal (20-year) study of 91 farms in Rondônia, while Thiele (1995), in assessing the relative stability of small colonist farmers in the northern Santa Cruz colonisation zone in Bolivia, found that 'peasant displacement has not been noticeably different than in areas with good soils, and we can conclude that soils do not appear to be a major influence on the persistence of settlement' (p.275).

Others argue that providing credit to colonist farmers can increase the rate of land degradation, since it allows them to move more quickly into cattle farming – without credit they are more likely to have land- and labour-intensive farming systems in which farmers are prepared to work at 'sub-capitalist' labour rates (Thiele, 1990).

Another aspect of this is that colonists who invest surplus income in cattle are merely responding rationally to a powerful economic rationale. Hecht (1992) points out the inexorable logic of cattle for colonists, based on a series of interlinked biological and economic factors. These include the cost of marketing when roads and crop storage facilities are inadequate; lower price fluctuation and economic risk; flexibility – cattle can be sold in a crisis; cattle are inflation-proof (high inflation has been a major incentive); the ability to occupy large areas with little labour to prove tenure and gain access to credit; and high returns to labour. In Rondônia, which has the highest level of recent deforestation in Amazonia, there has been an expansion of cattle numbers by 3,000% from 1970 to 1988 (Hecht, 1992). These views imply that cattle should figure in any realistic approach to stabilising colonist farmers, for example as part of a silvipastoral approach.

A minority viewpoint in the socioeconomic literature emphasises attitudinal problems which seem to go beyond economic rationality. For example, Fearnside (1992) believes colonists have 'a virtually insatiable demand for goods: the areas cleared and planted are limited not by humble ambitions but rather by the amount of labour and capital available to the farmers for expanding their agricultural activities. Increasing yields would have little negative effect on clearing rates. Profits from more intensive farming would probably be invested in rapid deforestation for other land uses such as cattle pasture' (p. 213). To support this, Fearnside cites the re-investment in cocoa farming of cocoa profits in Rondônia.

The main implication of this analysis is that the most popular policy response to the colonist problem, i.e. trying to raise productivity and income through technology development, could be mistaken – and even make things worse. Schneider (1994) cites data showing that land turnover has been faster in situations with increasing yields and incomes. Some argue that intensification will only occur when land values are high enough to provide the underlying incentive (Toniolo and Uhl, 1995) – implying that technology development should be delayed until a later stage. One problem with this view is that, by this time, most of the target pioneer farmers will have already been pushed off by capitalist type colonists to a new frontier – or back to the cities.

More Positive Attitudes to Technology Development

On the other hand, much of the social science-based literature implies there is an important role for improved (higher productivity and more sustainable) land use technology, for example Hecht and Posey (1990) who emphasise the potential for adapting *caboclo* and indigenous soil management principles to colonist farmers, and Homma et al. (1993) who argue that appropriate technology can radically reduce the rate of new clearance.

A generally more optimistic picture comes from sources who see institutional, human capital and more straightforward microeconomic incentives (prices, markets, credit, etc.) as the major constraints to adoption. Collins (1986) emphasises the interrelationship between institutional and biological problems – government insistence on rice cultivation leading to falling yields and indebtedness as colonists are forced into inappropriate production systems – as an explanation for colonist failure. Colonists will adopt more sustainable technology if institutional support is effective, and markets are accessible. Accessible credit and off-farm income can also help. In these situations, 'improved' technology productivity can lead to on-farm capital accumulation.

Sources like Collins (1986) and Moran (1989) disagree with the view that capital accumulation through the land market is the overriding driving motive of most abandoning colonists, claiming that the latter prefer to accumulate capital through cattle and transport investments and transactions, which enable them to remain on the land. Other important forms of capital accumulation have been through seasonal employment in the informal gold mining sector, selling standing timber to logging companies and working as hired labourers. Land clearance is a 'last resort' approach normally caused by indebtedness. Many colonists in the early stages of colonisation live in communities where social cohesion is high, due to family or religious ties. In these situations, there is a genuine desire to remain and pursue alternative methods of capital accumulation than through the land market. Also older colonists, especially those who have moved before, are less keen to go down the land market route – 'this is our last chance' was a typical sentiment in the Marabá colonisation area (author's field notes).

One reason for the many different viewpoints is the diversity of situations and variables which determine how a colonist responds to different types of intervention, whether the intervention involves economic incentives, and other institutional or technological factors. Colonist response is always somewhat unpredictable since they 'differ in objectives and ambitions, capacity and competence. They also differ as to the stage each one has attained in the family life cycle; their initial resources, knowledge and prior experience; the fertility, size, and location of their plots; and in many other ways' (Almeida, 1992: 160–61).

Institutions, Methodologies and Participation

The importance of institutional factors for appropriate technological response has been discussed. Research and extension activities have often been designed at a national level with little or no consultation, been poorly focused, and divorced from policy development. Vosti and

Witcover (1994) argue for a new inter-disciplinary framework for research and extension with clear and common goals, and capable of adopting a systems approach encompassing technology, policy and institutional aspects, and in which there is no separation between those working on poverty, growth and sustainability issues. This should be a 'start to finish collaborative research approach' ending with a series of policy implications presented to policymakers.

Cleary (1992) regards the PESACRE (Acre Agroforestry Systems Research and Extension Group) project, presented in Box 2, as an inter-institutional and inter-disciplinary model which donors would do well to study. The key achievement of PESACRE has been the 'creation of a network of people in local institutions, government organisations and NGOs with a common research and policy agenda, and the technical capacity to carry it out' (Ibid. p.157). Decentralisation and government/NGO partnership are also important in terms of developing sufficient institutional capacity at the local level.

The World Bank is helping pioneer an innovative institutional and methodological approach in four of Brazil's States, on the basis that participation must be stepped up to an operational level for progress to be made in colonisation areas. The US$138 million Land Management

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Box 2
PESACRE – Case Study of an Appropriate Institutional Response
(based on Schmink, 1992)

The Acre Agroforestry Systems Research and Extension Group (PESACRE) evolved as a 'political ecology' response to the problems of colonist farmers. Since 1986, the Universities of Acre and Florida have been working towards 'a coherent institutional strategy within which technical, social and political issues can be addressed over the long term' (Schmink, 1992). PESACRE has the active participation of both federal and State organisations like EMBRAPA/CPATU (Brazilian Enterprise of Agricultural Research/Agricultural Research Centre of the Humid Tropics – the federal agricultural research agency), FUNTAC (Technology Foundation of Acre State, Brazil – a parastatal rural development agency), the universities, the State extension agency and a range of NGOs and private sector groups, including the National Rubber Tappers Council. PESACRE has been primarily funded by the United States Agency for International Development (USAID) and the Ford Foundation.

Key reasons for the success of PESACRE (now an NGO) have included a strong emphasis on training in participatory research methods (especially in agroforestry), the use of 'issue-orientated' and inter-disciplinary working groups, information networking, and support from the Acre State governor. Schmink (1992) emphasises the importance of informal connections as several PESACRE staff moved into key decision-making positions in the State, and posits that sharing a common vision was more important than formal linkages. However, replication of PESACRE may not be easy. It was pioneered by a group of dedicated scientists with good links to external funding, and sound knowledge of the local area and institutions.

Project, including a World Bank loan of $63 million, involves the development of Microcatchment Land Management Plans. These Plans, which consolidate individual farm plans and community-level plans, have to be approved by Microcatchment Committees of local farmers, and then by Municipal Committees, regional and State-level committees. Peer monitoring is to be used to ensure an equitable and transparent use of the funds (Pichon and Uquillas, 1995). The UK Overseas Development Administration has also helped promote an innovative methodological approach in the Chimalapas Campesino Biosphere Reserve in Oaxaca State in southern Mexico, involving the use of Geographical Information Systems in community-level resource use planning and monitoring (Barry Pound, Natural Resources Institute, UK, personal communication).

Stabilisation of colonist farmers also takes time. Almeida (1992) argues that inconsistency and lack of continuity in settlement programmes have been a major cause of colonist failure in the Brazilian Amazon. She points out that it takes time for ingrained 'itinerancy' attitudes to change to a desire to settle, to respond to new institutional opportunities, for agronomic experimentation and for capital accumulation from consistent economic incentives (access to markets, good prices and credit). For the latter, some market protection may be necessary.

Finally, Moran (1989) has pointed out how stronger and broader grassroots institutional arrangements are essential for defending tenure, to achieve effective representation to obtain a fairer share of development resources, and to negotiate prices with opposing stakeholders, for example loggers. An example of this approach is provided by the ODA-supported Agro-environmental Centre of Tocantins and Araguaia (CAT) in Pará State, in which the main emphasis is on building the capacity of the rural labour unions to support their members through appropriate technology and marketing development.

3
Technological Issues and Review of Land Use Alternatives

Soils in the Amazon Region

Soil is the primary biological determinant of any land use. There is a somewhat confusing ambiguity in the literature about the potential of Amazonian soils for farming. There is a widespread view that the soils are not generally appropriate for continuous cropping. For example, Hecht (1992) states that 'Amazonian soils are for the most part extremely poor'. It has been estimated that 90% of the region's soils have a nitrogen (N) and phosphorus (P) deficiency, 78% have a potassium (K) deficiency, and 73% suffer from an aluminium (Al) toxicity problem (Cochrane and Sanchez, 1982). In addition, 24% of the soils are subject to flooding. Almeida (1992) also reports that from official remote-sensing data that only 1–3% of Brazilian Amazonia's soils are 'suitable for colonisation'.

But several sources think the area of extremely poor soils is regularly over-estimated. Cochrane and Sanchez (1982) estimate that 70–75% of the Amazon region is composed of oxisols and ultisols which are similar to soils in the south-east of the United States: well-granulated, deep, but acidic and deficient in nutrients. There are also large areas of entisols, inceptisols, and alfisols (*terra roxa*). Only 3% of the Amazon is covered by 'infertile' or sandy soil, and only 4% of the soils are laterites, according to Sanchez et al. (1982). Plinthite, laterite and spodosols probably cover less than 10% of the Amazon region (Bakker, 1993). Meanwhile the topography, temperatures and moisture conditions are generally excellent for plant growth.

On the basis of more detailed assessment of the official RADAM (Radar for the Amazon, Brazil) data, from remote sensing and photo-interpretation techniques, Almeida (1992), while admitting there is some discussion about the validity of the data, reveals four main soil groups according to the type of technology and potential for accumulating capital:

- **Group 1** 3.3% of the area has soils suitable for annual and perennial crops at 'low' (shifting cultivation) and 'medium' technology levels: on these soils farmers can begin with rudimentary techniques and evolve in time into permanent crops and improved management.

- **Group 2** 14.6% are soils suitable for annual and perennial crops at the low technology level: farmers can become established with low input technology but the soils are not suitable for higher levels of management – capital accumulation is therefore limited.

- **Group 3** 23.8% are soils suitable for annual and perennial crops at the medium technology level only: these soils permit capital accumulation, but only if colonists can start off with medium-level technology.

- **Group 4** 58.3% are soils unsuitable except at 'high'-level technology: these soils can only be worked by farmers with considerable amounts of capital.

An idea of soil quality in official colonisation programmes is provided by a breakdown of the soils in INCRA settlements. In a 1984 analysis, 0% were in Group 1, 16% in Group 2, 19% in Group 3, and 64% in Group 4 (Alameida, 1992). One interpretation of the RADAM data is that about 18% of the soils are capable of supporting low-level (extensive slash and burn) technology with a reasonable level of productivity, and up to 42% is within the range of better-off pioneer colonists. But another analysis from the same original data concluded that less than 1% of the region could sustain small farmers' capital accumulation strategies starting from low and medium technology levels (Almeida, 1992).

But these figures do not say how much of the suitable land has already been farmed – the best soils were taken for commercial agriculture in the 1970s. Almeida (1992) reports that the best land in Rondônia, Acre and Mato Grosso was occupied by medium technology farmers who could have used land of lesser quality.

An important clarification is the difference between *varzea* (seasonally flooded) soils and *terra firme* (dryland) areas. The former soils are generally much more productive, since repeated flooding helps restore soil fertility and control the weeds. The only really clear conclusion for the *terra firme* soils is that the main problem of the soils is chemical (fertility and acidity) rather than physical. Therefore Hecht's (1992) view is correct in terms of soil fertility.

The Sustainability of Colonist Slash and Burn Farming

A global review of views on shifting agriculture by O'Brien (1993) found that most sources were 'detractors' who regarded slash and burn farming as ecologically destructive, wasteful, inefficient, etc., often referring to the 'psychological backwardness' of the users. However Moran (1981) has claimed that 'slash and burn agriculture is emerging in the literature, not only as an effective agronomic practice for tropical regions, but also one based on sound economic considerations'.

Main Biological Characteristics

Slash and burn farming followed by fallow is essentially a strategy for fertilising and sanitising the soil and controlling weeds. The main effect of burning is to release large quantities of nutrient ions (carbonates, phosphates and silicates) from the standing vegetation and litter layer. The increased cation exchange capacity increases the availability of all nutrients to the plants except nitrogen (Nye and Greenland, 1960). Fertility and the better conditions for plant growth balance the losses of carbon, nitrogen and sulphur. Burning also drastically increases the soil pH, aids nitrification and reduces the dangers of aluminium toxicity. Apart from weeds, burning also kills parasites, nematodes and pathogenic bacteria.

There is a popular misconception that burning incinerates all or most of the biomass. Cochrane and Sanchez (1982) found that only 20% of it is normally turned to ash. The remaining organic matter, much of it underground, helps maintain soil quality through nutrients stored in living micro-organisms and dead organic matter (Jordan, 1991), ensures restoration of forest vegetation (as long as it is not destumped or mechanically cleared) and conservation of physical soil properties, and limits erosion. However with repeated burning, nitrification of bacteria can occur, and nitrogen fixation is impeded. Burning also prevents the introduction of many useful perennial species for enrichment of fallow areas.

During the cropping period there is a decline in soil fertility as carbon and organic matter drops, and nutrients are taken off by the crops and lost through leaching and erosion. Soils slowly return to the acidic state, and there is a decline in soil physical properties, resulting in increased bulk density, decreased infiltration and water holding capacity (Nye and Greenland, 1960). But during the fallow period, there is a net increase in nitrogen and carbon in the soil and the total system, as the deeper root systems in the fallow intercept leached nutrients from the subsoil. Many harmful weeds are eliminated and there is a reversal of the physical soil properties (Robison and McKean, 1992).

'Sustainability' and the Fallow Period

At this stage it is useful to review the concept of sustainability. A useful working definition of the technical/financial aspect of sustainability is provided by Cunha and Sawyer (1992): combining production of a flow of goods and/or services with preservation of the resource base at a non-increasing cost. Vosti (1993) argues that a technology must both increase resource productivity (ideally land and labour) and have a poverty focus – if technologies are unable to ameliorate family poverty, farmers will not be able to afford 'sustainability'. For Anderson (1990), sustainability implies some degree of utilisation of natural ecosystems and natural regeneration. Uhl et al. (1990) and others argue that some level of natural succession is vital to recycle nutrients and protect fragile soils. Other important aspects of sustainability concern the effect on risk and labour utilisation.

From almost all these points of view, shifting agriculture is an ideal production system – assuming the colonist has enough land. Adequate fallow maintains the ecosystem, provides food products and construction materials, and entices game. This interwoven versatility has proved the most difficult aspect of the system to replace or maintain – natural succession is complex with different species showing vigour depending on the weeds with which they must compete (Robison and McKean, 1992). However the longer the fallow period, the lower is the overall land productivity, and thus sustainability, of the system.

Thus the slash and burn system is only sustainable if the land area is large enough. Toniolo and Uhl (1995) estimate that in the Amazon basin this would mean an area of about 100 ha per family without intensification. But, according to the same source, almost half the holdings in the Brazilian Amazon are less than 20 ha, and as a result of demographic and economic pressures, fallow periods have shortened in most colonisation zones. Shorter fallows and repeated burning decrease nutrient stocks and biological diversity, expose the soils to heat and erosion, and result in increased weed invasion and pest problems. Where larger areas are cleared and distance from the forest increases, pioneer weeds and grasses like *Imperata* sp. replace woody regrowth.

Continuous and Semi-continuous Cultivation of Annual Crops

High Input Continuous Cultivation

The best documented high input continuous cultivation approach has been the research at the Yurimungas Research Station in Peru. The theory was that the key to overcoming the soil fertility problems was through fertilisers and crop rotation. The research, begun in 1971, gradually incorporated local farmers on poor soils. A rotation of rice/maize/soya/groundnuts (three crops per year) was introduced, and repeated continuously. To achieve this, one ton of lime, 80–100 kg of N, 25 kg of P and 100–160 kg of K were required annually per hectare, along with pesticide inputs. These inputs produced good returns and a threefold increase in income over traditional techniques (Nicholaides et al., 1985). This led Sanchez et al. (1982) to claim that 'it is economically viable over a wide range of crop and fertilizer prices, capital levels and labour force compositions'.

Fearnside (1987) in particular mounted a critique of the Yurimungas technology. While he admits that the research shows that it is *technically* possible with a high intensity of extension support and credit, the Sanchez et al. claim was overblown since there were hidden subsidies and it operated in a favourable economic (for example, market access) and institutional environment. Under frontier conditions, the system was not viable since these kinds of support levels were not realistic, and it exposed small producers to unacceptable levels of risk. In fact most participating farmers opted for a lower input variant (Fearnside, 1987).

Another high input alternative is mechanisation – but where this has occurred, as amongst the Mennonite groups in eastern Bolivia, it has tended to be on better soils (Maxwell, 1979). Again the main problem is the accessibility of the technology for the vast majority of colonists, and the problems of input supply, machine maintenance, and institutional support. Pichon and Uquillas (1995) also point out that intensification through the use of chemical inputs, mechanisation, etc., can be unsustainable due to negative long-term biotic effects, for example soil impoverishment, soil and water pollution, compaction and salinisation.

Evolution of Yurimungas: Lower Input Continuous Cultivation

The architects of the Yurimungas technology also came round to the view that these input and institutional levels were not realistic in frontier situations. Sanchez and colleagues have since developed variants of the Yurimungas technology with lower input technologies for ultisols and oxisols, based on short fallows, locally adapted crop varieties, and greater use of organic inputs (Sanchez and Benites, 1987). More recently they have put further emphasis on managing soil organic matter, mulching, and developing fallow systems with cover crops like *kudzu*.

Green Manure/Cover Crop-based Systems in Humid Forest Areas of Central America

It is reported by Pasos et al. (1994) that green manures and other cover crops, in combination with minimum tillage techniques,[10] are now found in all the main humid forest/colonisation zones in Central America. This is not a new technology – it has been practised for up to 50 years by some 40,000 small farmers in northern Honduras, as well as in humid areas of Mexico and Guatemala (Flores and Estrada, 1994). The most popular species have been velvet beans (*Mucuna pruriens* and *ensiformis*), jackbeans (*Canivalia ensiformis*), lablab beans (*Dolichis lablab* or *Lablab purpureus*), cowpeas (*Vigna* spp.) and pigeon peas (*Cajanus cajan*), but many other species have been found to be appropriate in different situations, according to management objectives and the soil's physical and chemical properties.

Flores and Estrada (1994) have documented a typical system in a humid area of northern Honduras (rainfall over 3,000 mm) – presented in Box 3. Roland Bunch[11] has commented that 'to our amazement, these (cover crop and minimum tillage) systems, virtually all of them in the supposedly infertile humid tropics, allow farmers to plant maize every year for decades, with productivity increasing over time up to 4 tons/ha.

In other words, these farmers have found an answer to slash-and-burn agriculture' (Bunch, 1995). The spontaneous spread of this technology in Central America has been astounding – for example in Nicaragua, the Farmer to Farmer extension programme has extended the use of velvet beans to more than 40 municipalities (Pasos et al., 1994); by 1993, at least 30 NGOs in Honduras were promoting it (Flores and Estrada, 1994); in Honduras's Rio Platano Biosphere Reserve at least 600 farmers in a

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10. In-row tillage which leaves turf between the rows – amongst other things this has been shown to reduce pest incidence.

11. Former Director of World Neigbours in Central America, and author of *Two Ears of Corn*, a bible for sustainable rural development in Central America and beyond over the last decade.

Box 3
Traditional Use of Green Manures in Northern Honduras
(Flores and Estrada, 1994)

Mucuna pruriens (velvet bean) is typically planted one to two months after maize (planted in December–January). It climbs up the doubled-over maize stalks, dries out and covers the soil. Left throughout the dry season, it is chopped with a machete the following December, creating a mulch of up to 20 cm. The next maize crop is planted (in December) through the mulch. In the second year, *Mucuna* seeds volunteer themselves to begin the cycle again. Maize yields are typically 2–3 tons per ha, in comparison with 800 kg/ha without green manures. Costs per ton of maize were 30% lower in the velvet bean system than in neighbouring high-input systems.

World Neighbours programme had adopted this technology and stopped annual burning in little more than a year (Richards, 1996). Why has this happened and what relevance does it have for Amazonia?

Benefits of green manure/cover crop and minimum tillage technology
Based mainly on Central American evidence, intercropped cover crops or green manures can produce 50–140 tons green biomass per ha, as well as 90–100 kg of nitrogen from fixation. As explained in Box 4, this level of biomass production appears to have the potential to greatly shorten the length of fallow to restore the fertility necessary for annual cropping. But the biomass/nitrogen fixation effect is only one of several reasons behind the dramatic adoption of this technology in Central America and beyond:

- It suppresses weeds, and when left through the dry season, provides a labour-efficient weed control alternative to burning. This can critically permit farmers to intensify or enrich fallow areas through the introduction of fire-resistant trees.

- When left through the dry season it protects the soils from the sun, thereby lowering soil temperature, and reducing nutrient 'burn-out' loss and evapotranspiration. This provides better conditions for decomposition and mineralisation of the organic matter (Pretty, 1995).

- It can simultaneously increase the return to labour and land. A low return to labour has been the single main cause for non-adoption of a range of much-touted agroforestry technologies, including alley cropping. It involves minimal labour: there is no moving, layering, etc.

of the mulch; it is not necessary to incorporate it into the soil;[12] and suppression of weeds reduces net labour costs.

- The land opportunity cost of introducing green manures is at, or close to, zero (Bunch, 1995).
- It can prevent or greatly reduce soil erosion on slopes up to 40% in a more labour efficient way than live barriers or terraces (Bunch, 1995).[13]

Box 4
The 'R Factor' and Green Manures
(based on data in Pasos et al., 1994)

Arguably the key to farming in the humid tropics is management of the biomass, because of its importance in soil regeneration through nutrient recycling. The soil regenerative capacity of biomass can be calculated, according to soil scientists at the International Centre for Research in Agro-Forestry (ICRAF), especially Young (1989), from a simple formula called the 'R factor':

R% = years cultivated/(years cultivated + years in fallow)

Thus permanent cropping would have an R of 100%. Various researchers have estimated that an R factor of 17–33% is necessary to ensure an equilibrium of organic carbon and agroecological sustainability. Nye and Greenland (1960) estimated that a 25–30 year fallow was necessary to get the R factor low enough. But only amongst indigenous groups in forested areas are such R factors likely to be maintained, for example an R factor of 23% was found among Pech Indians in the Rio Platano Biosphere Reserve of Honduras.

It has been calculated that biomass in virgin forest in Costa Rica is about 380 tons per ha. Other research shows that a 30-year fallow returns this level of biomass, but only 75% of this level is necessary to achieve the required carbon equilibrium – about 285 tons of biomass per ha, equivalent to a 25-year fallow. *Mucuna pruriens* produces annually at least 30 tons of biomass per ha which can increase humus levels by half an inch in cultivated areas. This is three times the biomass from fallow. Theoretically it can reduce from 25 to 10 years the time necessary to achieved the desired carbon equilibrium. If an area is cultivated for four years continuously with *Mucuna*,

R = 4/(4+10) = 28.5%

This is within the range suggested by Nye and Greenland (1960).

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12. In fact it is probably better not to incorporate it, due to the benefits of mulching, and because a certain amount of nitrogen volatisation is beneficial since it prevents acidification of the soil's A horizon (Thurston et al., 1994).

13. Although personal observation in Honduras indicates that superficial rooting on steep slopes can make hillside farming less stable.

- The mulching effect of green manures also allows plants to take up phosphorus fertiliser applications when fed through the mulch (Thurston et al., 1994) – phosphorous is a key nutrient deficiency in the Amazon. When soils are acidic, any phosphorous application becomes almost instantly tied up, whereas feeding it through the mulch avoids this problem.

Bunch (1995) points out how green manure/cover crop technology has several characteristics in common with natural succession or regeneration, and in complete contrast to technologies adopted from temperate areas and typically pushed by official development agencies. These characteristics include maximising organic matter production, keeping the soil covered, minimum or zero tillage, maintaining biological diversity and feeding plants through mulch.

Adoption of green manure/cover crop technologies in the Amazon Region

While the above observations stem mainly from Central America's humid forest zone region, there is increasing evidence that cover crop/green manure technology is catching on in Amazonia. Colonists in several parts of the Santa Cruz colonisation zone in eastern Bolivia are spontaneously adopting cover crops without any obvious institutional encouragement: farmers in the San Julian, Berlin and Bajo Paraguay areas are using *mucuna*, *lablab*, *Canivalia* and other cover crops in fallows, for forage, for weed control, and in association with both annual (rice, maize and other crops) and perennial crops. The cover crop is normally left to cover the ground in the dry season. In the Beni area of Bolivia, *kudzu* grass is being used in fallows in a recent colonisation area (Elizabeth Ditchburn, ODA agronomist, personal communication).

The Centre for Tropical Agricultural Research (CIAT), Bolivia, in coordination with the UK Natural Resources Institute, has also been experimenting with various cover and annual crop combinations in the Santa Cruz colonisation zone; Barry Pound (consultant agronomist, personal communication) believes that one of the promising combinations is cowpeas (indeterminate variety) and rice. The cowpeas are cut, and then the rice sown through the mulch. This avoids competition between crops for soil nutrients – a particular problem for rice. It is relatively easy to weed out the 'volunteer' reseedings. The work at CIAT has also been influenced by the *Campesino a Campesino* (Farmer to Farmer) Movement in Nicaragua (Penny Davies, European Union Agricultural Frontier Programme, Panama, personal communication).

In the Coca Agroforestry Research and Extension Project (Box 1) in the Ecuadorian Amazon, Ramirez et al. (1992) report that cover crops have reduced the weeding costs of coffee and improved soil fertility, while *Desmodium ovalifolium* combined with the pasture *Brachiaria humidicola* has been found to be effective in the restoration of degraded pasture after herbicide use.[14] Also a technique using *Desmodium* has been found to establish trees in pastures (this is normally very difficult). In over 100 field trials, trees have been planted next to protective natural barriers like stumps and fallen trunks, the vegetative material of lechero (*Euphorbia cotinfolia*) – disliked by the cattle – introduced in the rainy season around the tree, and *desmodium* sprinkled around the base of the tree (Peck, 1990). Loker (1995) also reports from the Peruvian Amazon that several farmers are experimenting with pasture legumes like *Stylosanthes guiensis* in abandoned pastures to accelerate the recuperation of exhausted pasture, and to enrich fallows.

Box 5 reports on a very successful experience in southern Brazil: the EPAGRI (Agricultural Research and Rural Extension Enterprise) Programme in Santa Catarina State. Commenting that he has visited some 160 agricultural development programmes, Bunch (undated) considered this project to be the finest of its size in Latin America.

Box 5
Use of Green Manures in Southern Brazil
(Bunch, undated)

In a high erosion area on sloping farmland, commercial inputs were worsening the situation before the advent of green manure-based technology. Together with the Santa Catarina State Agricultural Research and Extension Service, cooperatives and private organisations, an NGO called EPAGRI (Agricultural Research and Rural Extension Enterprise) helped stimulate small farmers (with an initial subsidy) to work with green manures in all areas of the State. A recent survey revealed that more than 100,000 farmers were cultivating green manures on an area of more than 300,000 ha. The green manures were planted between maize and tobacco, but developed after harvesting the main crops, protecting the soil against rain and solar radiation. In some areas, non-leguminous cover crops were planted during fallow (winter) like oats and turnips.

After four continuous years of green manures, farmers have been able to stop ploughing. Farmers underwent a high opportunity cost building up organic matter in order to achieve zero tillage sooner – this ties in with Furuoka's approach in *The One Straw Revolution* (1978). The result has been reduced soil compaction, better soil structure, higher fertility and reduced cost. Maize yields have typically risen from three to five tons per ha.

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14. However some colonists found *Desmodium* too aggressive and that it complicated coffee harvesting.

Perennial Crop-based Systems

Almeida (1992) points out that permanent crops are crucial to the stability of small farmers on the frontier, but that only 1–3% of Brazilian Amazonia's soils are appropriate for them. However, there have been some important success stories, for example the development of coffee in Ecuador, Peru and Rondônia State, Brazil. Cocoa has also been successfully established in Rondônia, although Fearnside (1992) says that its promotion has resulted in the clearing of natural forest at two stages: in anticipation of high cocoa yields on newly-cleared land (the nutrient mining effect), and investment of the ensuing profits in cattle farming. It can therefore be dangerous to overstimulate perennial crop options, because of the temptation to use forested land with its free or very cheap (according to land price) nutrient capital available at the outset.

Organisational aspects are exceptionally important for the development of high value perennial crops. This is because of problems both at the growing and at the processing/marketing stages. For example, in the Marabá colonisation zone, 70% of the cupuaçu (*Theobrama grandiflorum*) crop delivered to strategically located freezer stations in 1994 was rejected by the colonist marketing cooperative due to deterioration in transit. One of the causes was poor washing of the cupuaçu pulp by farmers. Transport and other marketing costs have also been very high due to organisation and management problems (COCAT, 1995).

Such problems have to a large extent been overcome in the two case studies presented here involving the development of cocoa production in the Beni area of Bolivia, and cupuaçu and other crops in the RECA project in Acre State, Brazil. Another important experience, that of Tomé-Açu in Pará State, Brazil, involving the production of black pepper, acerola, oil palm, cupuaçu and passion fruit, is presented under the section 'Intensive Agroforestry Systems', since it involves a complex high intensity agroforestry system rather than a more traditional plantation approach (although the RECA technology is not a typical perennial crop system either).[15] These three case studies have much in common, but above all their high level of organisational, institutional and economic complexity.

15. Perennial crops, whether trees or not, tend to be grown in monocrop plantations. Other typical characteristics are an export market, the need for prompt processing, and a large fixed capital investment (Tiffen and Mortimore, 1990).

The RECA Project, Acre State, Brazil

The RECA Project is regarded as a model project in hostile colonisation conditions. From small beginnings in the late 1980s, by the end of 1994 RECA involved some 274 farmer members in 14 groups. RECA's members had evolved from landless peasants to a situation in which they had enough food, and each family had at least a cow and draught animal (Allegretti, 1994). RECA had also started working on health and education problems in the communities.

As shown in Box 6, there were a number of factors which made the RECA experience difficult to replicate, although at least three other projects in nearby areas were trying (Oliveira and Oliveira, 1994). These factors included the organisational complexity, a charismatic leader, the institutional linkages, the high cost and credit implications, and the market constraints. The organisational strengths of RECA have included the ability to form effective partnerships with different institutions, a clear division of responsibilities, management rules which are respected, transparency, and social cohesion between members (Allegretti, 1994).

But RECA confronts a series of critical problems according to Oliveira and Oliveira (1994): in spite of proximity to a major highway (the BR364), it has been difficult for cupuaçu to penetrate the national market; financial dependency – eight RECA employees were being paid by the Dutch Catholic Cooperative Organisation for Development (CEBEMO) donation in 1994; over-dependence on credit; and difficulties created by the federal FNO (*Fundo Constitucional do Norte*) credit scheme which provided incentives for conversion to pasture.

El Ceibo Cocoa Cooperative, Bolivia

The cocoa growing and processing cooperative El Ceibo, presented in Box 7, grew out of the remains of a failed state programme. This experience is again notable mainly for the institutional aspects – especially the linkages with national and international agencies; the establishment by a grassroots organisation of an effective research and extension programme; the prolonged external financial and technical support (it has benefited from 16 years of economic and technological assistance from the same organisation); and for the development of an integrated planning process involving government and NGOs (Trujillo, 1993). Other factors favouring its success include its isolated location, which discouraged competing private capital in cocoa farming, and specialisation in a high value, low volume export crop (Bebbington et al., 1996).

Box 6

Evolution and Development of the RECA Project, Acre State

(based on Allegretti, 1994, and Oliveira and Oliveira, 1994)

The Reflorestamento Econômico, Consorciado e Adensado (RECA) Project evolved from an abandoned government-sponsored settlement programme on the border of Acre and Rondônia States. About 12 families, who did not wish to return to their areas of origin, embarked on an analysis of the local eco-system and why their own farming system had been unsuccessful: lack of infrastructure, poor soils and endemic malaria. Gradually the group started to experiment with native plants on land they had earlier planted with beans, rice and maize. Their charismatic leader convinced others to plant cupuaçu shaded by pupunha (*Bactris gasipaes*). Brazil nut (*Bertholletia excelsa*) trees were planted between the other species – and the plantation began to look more like a forest. This led to the name RECA (Mixed High-Density Economic Reforestation), and formalisation of the institution in 1988 by a group of 84 farmers.

Outside institutional support was very important at this early stage from the well-established Catholic Pastoral Land Commission (CPT), and through close collaboration with government institutions and NGOs. Interest-free credit to plant the cupuaçu was provided by a Dutch NGO called CEBEMO. Other sources of finance included the regional Catholic Church, the Ministry of Agriculture, and a donation from the French Catholic Commission (CCFD) which permitted the opening of a cupuaçu processing factory in mid-1993. Government agencies assisted with the purchase of vehicles, freezers and depulping machines. Research, training and extension support came from PESACRE and the federal agricultural research institute INPA.

RECA developed strict conditions for membership including a period of pre-selection in which an aspiring member could join a branch and help keep the area clean. An important criterion was the ability of the person to work with others. Leadership was decentralised to the community level – each community Coordinator represented his/her group on RECA's Central Commission. Others in the group had to compensate the Coordinator for lost production time. Allegretti (1994) comments that usually those giving most service were selected. An important role of this Commission has been to mediate on credit issues between RECA members, NGOs and banks. The emphasis in training and organisation has been on developing the individual skills each member needs to make their own technical decisions.

Diversity of income source and tree crops has been an important element of the success of RECA. Thus the market problems of cupuaçu have been compensated by the better than expected market for pupunha seeds. However cupuaçu still represents over half the trees planted, and CCFD and INPA are encouraging a greater diversity of timber and fruit tree species. By the end of 1994, the project had planted 872 ha of cupuaçu, pupunha palm and Brazil nuts in combination with other species. In 1994, 600 tons of cupuaçu were produced, and 40,000 pupunha seeds sold.

Box 7
El Ceibo Cocoa Cooperative, Bolivia
(based on Healy, 1987; Trujillo, 1993; Bebbington et al., 1996)

El Ceibo (Regional Centre of Agricultural Industrial Cooperatives) is a federation of cooperatives in the Beni area of Bolivia, where 7,000 Indian settlers grow cocoa. In 1964, the government formed the Alto Beni Cooperative Ltd in a top-down fashion. This was disbanded in 1971 after a series of administrative and political problems, but the experience in organisation led to the formation of independent cooperatives to defend members against cocoa middlemen, whose prices reflected a monopoly control of transport to distant markets – a two to three-day journey on bad roads to La Paz.

In 1977, 12 coops formed El Ceibo, mainly for processing, marketing, and the supply of inputs, credit and education. There was vital early support from Caritas, a Catholic NGO, and the Inter American Foundation. Technical assistance was not included due to the continued presence of State extensionists – although there was some grassroots pressure to do this. Further deterioration of State technical assistance led to the formation of El Ceibo's own Department of Agricultural and Educational Cooperation. The public sector programme was in a state of near paralysis due to administrative, political and financial problems. El Ceibo tried to fill this gap, drawing on support from national institutions.

Following 16 years of military rule, the new civilian government provided an opportunity for popular action. In 1982, the transport monopoly was broken by a programme of road blocks led by El Ceibo, and from this time the organisation grew in strength, so that by 1987 it owned 18 trucks, supplied 80% of Bolivia's cocoa and was exporting chocolate to Europe. El Ceibo's strengths have been a cohesive and dynamic organisation; leaders with vision; egalitarian social structures; and the participatory management of its programmes. In 1989, bi-monthly meetings of 10 organisations were instituted, including government organisations, NGOs and farmer organisations. Its research and development programme involved a number of national and international collaborators, including CATIE (Tropical Agriculture Research and Teaching Centre) and IICA (Inter-American Institute for Cooperation in Agriculture) of Costa Rica. It successfully courted international support (Swiss and German aid). El Ceibo now has a Development Projects Office, which seeks loans rather than grants.

Intensive Agroforestry Systems

Agroforestry can be defined as a temporal or spatial mixing of woody perennials with cultivated crops or pastures. Harwood (1994) presents the following classification:

- Agrisilviculture: the interplanting of crops and trees, including shrubs and vines. This includes shifting cultivation, forest gardens, trees on farms, alley cropping and windbreaks, as well as multi-storey mixtures of plantation crops.

- Silvipastoral systems: combinations of pastures with trees, including cut-and-carry fodder production, living fences, fodder trees and hedges, and trees in pasture land.

- Agrisilvipastoral systems: combinations of food crops, pastures and trees, including home gardens and woody hedges to provide browse, mulch, green manure and erosion control.

- Rotational agroforestry: rotation of trees, either naturally occurring or introduced, and other woody species with annual crops in shifting cultivation systems.

Intensive agroforestry systems are defined here as those which attempt to intensify land use through the association of tree and annual crops, other than through modification of shifting agriculture-based systems (covered separately below). Intensive agroforestry systems often involve the substitution of native vegetation with exotic species, sometimes in plantation form, and tend to require external inputs and more labour to maintain fertility and control weeds, pests and diseases. They can be technically complex and are usually market orientated, although traditional intensive agroforestry systems involving home gardens may be more subsistence-orientated.

Intensive agroforestry is regarded by some researchers as the panacea for colonist farmers. It has several attractions – by promoting a higher person:land ratio it provides a cushion against increasing demographic pressure; is potentially ecologically sustainable; reduces risk; can result in a better spread of income over the year; can combine subsistence and commercial needs; has advantages for livestock; can build on traditional agroforestry practices; and is adaptable to smallholder needs.

Fearnside (1992) argues that too much has been expected of intensive agroforestry. Two main problems have limited farmer uptake. Most colonist farmers are at least initially more concerned with returns to labour than land, and few agroforestry technologies increase returns to labour – although an exception to this is provided by the Tomé-Açu experience. The second problem is market demand. As soon as regional demand is satisfied, farmers face the thorny difficulties of export markets – like fluctuating prices, demand for homogeneity and continuity of supply.

The Tomé-Açu Experience

The classic case study of a high intensity agroforestry system in Brazilian Amazonia is provided by the Tomé-Açu experience. Box 8 describes how a dynamic immigrant population succeeded on poor soils with a capital- and labour-intensive[16] system (although land was not constraining) based on a multi-storey agroforestry system in which there was a complex and

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Box 8
The Tomé-Açu Cooperative, Pará
(based on Subler and Uhl, 1990, and Penny Davies, personal communication)

The Japanese settlers at Tomé-Açu came to Brazil in the 1920s but many emigrated following the failure of an earlier farming system of vegetables, rice and other crops brought with them from Japan, and also due to malaria and yellow fever. By 1942, only 98 of the original 353 families were left. Around this time, black pepper was discovered as a valuable cash crop. This became the first area to produce significant quantities of black pepper. The Cooperative was founded 1949, and is now composed of 280 families.

The cropping sequence is as follows: perennial and annual crops are planted together after the first clearing; overstories are created of rubber (*Hevea brasiliensis*), mango, Brazil nut (*Bertholletia excelsa*), andiroba (*Carapa sp.*) and other species valued for timber or fruit; and understories by shade-tolerant trees – coffee, cocoa, guarana (*Paullinia cupana* var. *sorbilis*) and cupuaçu. Vines of vanilla and other species range between the stories. The system is integrated with fish, chicken and pig production. The waste or by-product of one operation forms the mulch or fertiliser of another.

The system was developed sequentially and in response to market incentives. For example, rubber was planted into a black pepper plantation as the bottom started falling out of the pepper market; cocoa was grown under rubber shade as State subsidies for rubber became available.

Subler's PhD work highlights the importance of organic matter management in this system. It shows the importance of the system in terms of nutrient recycling through lateral interception by extensive root systems and the high litter fall. The organic matter, microbial activity, effective cation exchange capacity and phosphorous availability have all increased over time (Toniolo and Uhl, 1995). However, it is not completely self-sufficient in terms of nutrients – both organic and chemical fertilisers are used but in declining quantities as the multi-storey system matures. The lack of a leguminous component contributes to poor ground cover.

According to Subler and Uhl (1990), the keys to success have been overcoming the nutrient, leaching, weed and pest problems which plague annual cropping systems; the diversity of high-value low volume market products; and the high quality of cooperative management, which has processed and marketed the products, provided access to inputs and credit, and ensured effective research and technical advice.

The last point indicates the limited replicability of the model. All the cash crop components require fairly sophisticated marketing and processing know-how, and the economic viability of the system is mainly dependent on a relatively sophisticated fruit pulp factory. A high volume of output is needed to justify hiring the refrigerated trucks which take the fruit juice to southern Brazil. This system also depends on the know-how of a young Japanese who spent seven years in southern Brazil learning about fruit juice processing.

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16. Six to eight workers per 20 ha farm.

synergistic mixture of perennial tree and vine crops with annual crops, including black pepper, cocoa, passion fruit and up to 30 other species, mainly high value cash crops (Subler and Uhl, 1990). It has proved very profitable – in an economic comparison, Anderson (1992) quotes net returns to land and labour far in excess of other Brazilian Amazonia land use systems:

	Extractivism[a]	*Varzea forest management and agroforestry*[b]	*Tomé-Açu*
Net return per ha	2.35	70.77	339.27
Net return per day	4.38	4.18	16.46

[a] Mainly rubber extraction from Cachoiera Extractive Reserve, Acre State.
[b] Natural forest management, cocoa (understorey) and açai (*Euterpe olerala*) palm extraction by *ribeirinhos* on Combu Island, Amazon estuary, Belem.

Is Tomé-Açu replicable? Unfortunately its technical complexity and cultural uniqueness suggest that it is not. In fact, many Brazilians in surrounding areas grow passion fruit and/or black pepper, but there is 'no indication they are adopting the types of crop systems and management techniques employed by the Japanese' (Subler and Uhl, 1990). The explanation may not be merely cultural; the Japanese have enjoyed secure tenure and good access to credit. As in the other cases of high value perennial crops, market access has been essential – the area is close to Belém. There are now visible cracks in the system as a result of increasing marketing problems and as younger settlers have questioned the values of the original settlers (Penny Davies, personal communication).

Extensive Agroforestry Systems and Secondary Forest Management

Extensive Agroforestry

Extensive agroforestry systems revolve round the manipulation of successional systems involving shifting agriculture. Systems that come closest to the structure and functioning of natural forest succession are likely to be ecologically most sustainable, since successional species are least nutrient demanding, protect the soils and can provide steady yields (Uhl et al., 1990; Jordan, 1991). Extensive agroforestry is more likely to involve native trees and maintain high levels of biodiversity. The drawback is that it is by definition less land-intensive and therefore only appropriate where land is not limiting. But it needs emphasising that in most of Amazonia land is not particularly limiting – many colonists have 100 ha plots. Also extensive agroforestry is more intensive than extractivism – a rubber-tapping family requires 300 to 500 hectares (Fearnside, 1989).

Extensive agroforestry has the potential to work at the crux of the problems of colonist agriculture, which involves increasing the ratio of cropped to fallow years – either by increasing the number of years in cultivation or reducing the fallow period necessary to restore fertility. Fearnside (1992) points out the need to focus on ways to improve nutrient recycling and the use of light, water and soil inputs, reduce pest and disease risks, maximise labour complementarity, increase subsistence uses and lower market risk. He suggests an emphasis on high unit-value products with relatively low nutrient demands like oils, latex and resins. Surprisingly few research programmes have responded significantly to this challenge, but the ODA-supported Centre for Tropical Agricultural Research (CIAT) based in Santa Cruz, Bolivia (Box 9) is regarded as the main source of appropriate agroforestry technology for colonists in lowland Bolivia and beyond. More recently, the Brazilian National Institute for Research in the Amazon (INPA) in Manaus has started a research programme on the most promising agroforestry systems, including indigenous ones, in the region, then testing them in controlled trials. However this is too recent for analysis.

Indigenous Agroforestry Practices: How Replicable are They for Colonists?

Reviews of indigenous swidden management or agroforestry (Clay, 1988; Hecht and Posey, 1990) reveal sophisticated systems by Amerindians and *caboclos* characterised by highly differentiated resource use, i.e. with high local variation in small and highly diversified fields/gardens, and based around successional management which prolongs use of the cleared area after an initial intensive phase. But relatively few agroforestry programmes have taken as a starting point existing local indigenous swidden management practices. One exception was the Coca Project (Box 1), where the land use practices of the remnant lowland indigenous groups in the area were an essential basis for the programme's technology development (Peck and Bishop, 1992).

'Cultural' constraints. There seem to be two main aspects to the oft-mentioned 'cultural' constraints to colonist adoption of indigenous management practices. These refer firstly to the complexity problem associated with folk soil taxonomies and the detailed local knowledge

Box 9

Agroforestry-based Research at CIAT, Bolivia

(based on Garcia et al., 1995; James Johnson, ODA Agroforester, personal communication; and personal observations)

Since the late 1980s the Centro de Investigación Agrícola Tropical, Santa Cruz, has developed a strong agroforestry research programme which aims to stabilise colonist farmers. CIAT has developed several systems based on multi-purpose leguminous trees and bushes established by direct sowing. Leguminous trees like *Flemingia*, *Erythrina* and *Gliricidia* spp. have been found to successfully mimic the functions of secondary forest but are insufficient alone to ensure recuperation – there is a need for dense soil cover at the start of the regeneration process through cover crops.

The emphasis has been on maximising flexibility so that the system can respond to farmer needs and objectives – thus the farmer can move rapidly from annual cropping to a range of tree-based production systems: for example into forage alleys which serve as a protein bank for cattle – one of the more effective associations has been *Flemingia congesta* with *Brachiara* pasture; into an enriched secondary forest fallow with trees like *Inga marginata* or *Erythrina poeppigiana* in conjunction with cover crops, and an upper stratum of higher value timber trees; into perennial-cropped based systems, often in association with cover crops (for example, plantain, cocoa, cashew, coffee, macadamia and coconut – although some of these have market constraints); or the farmer can move back to more intensive annual crop production. One of the interesting aspects of the CIAT agroforestry programme's work is that there is no clear distinction between agroforestry and natural forest management, but a seamless continuum between the two. Farmers in the Yapacani area have begun to adopt and adapt the menu of technical options. Other significant research has involved cover crops, windbreaks and live fencing.

CIAT has also successfully developed a farming systems-based interdisciplinary approach to its work over the years; an innovative methodology of decentralised adaptive research based on Regional Research Centres (CRIs) involving farmer committees; an effective dissemination process involving a partnership between CIAT and local NGOs; and has integrated economic analysis more than in other programmes.

passed down from generation to generation, and secondly to the issue of the social status of Amerindians in the sight of colonists.

Hecht and Posey (1990), while agreeing that indigenous systems are complex and cannot be transferred as a package (partly because they are also site-specific), argue that the principles underlying them are not complex and could be selectively adopted. They also point out that there are several common features between the later Yurimungas technology approach and indigenous management like that practised by the Kayapo in Pará State – for example, the use of crop residues, relay planting, nutrient additions and short fallows – and that if research were reorientated in a combined indigenous and modernisation approach to soil management, a rich array of accessible technologies for low fertility conditions could be developed.

Box 10 presents the main management practices of the Kayapo, practised on four main soil types representing about 80% of the Amazon region. This can be considered as fairly representative of a much wider literature on indigenous systems. While the Kayapo system was more labour-intensive than typical colonist agriculture – 40 days of labour per ha compared to 25 days – the return per day was also higher, for example protein production was estimated to be 30% higher per day in the Kayapo system after five years of cultivation.

Box 10

Indigenous Management Practices of the Kayapo in Pará State, Brazil

(based on Hecht and Posey, 1990)

The keys to the Kayapo management practices include: the use of mulches, residues, dung, composting and periodic crop selective in-field burning to replace soil nutrients (the burning is facilitated by the use of fire-resistant cassava, sweet potatoes, yams, and *marantaceas*, which also control weeds). Planting patterns vary in time (sequential harvesting and replanting, mixing long and short-term crops) and space (for example, concentric ring planting). In the Kayapo system there is also a smaller clearing size: about 1 ha compared to 2–3 ha in colonist systems. Kayapo swiddens continue to produce yams and taro for 5–6 years, bananas for 12–15 years, and *cupa* for more than 30 years.

Old fields are also important for their concentrations of medicinal plants, and fruit trees encourage game in later years, important both as a source of protein and for seed distribution and germination. Native and semi-domesticated species are planted between annual crops to discourage aggressive weeds like *Imperata* spp. Mulches are very important in this system: they are provided from palm leaves, banana leaves and crop residues such as rice straw, bean vines, sweet potato vines, and chopped weeds. They protect the soil from raindrop compaction, reduce weed germination and soil temperatures, and provide a slow release of nutrients.

The system is particularly interesting in terms of chemical soil properties resulting mainly from fine tuning crop selection to soil nutrients:

- soil pH is increased and maintained by repeated burning and cooking food in fields
- the emphasis on root crops rather than grains lessens the constraint of the low nitrogen levels: rice needs 23 kg N per ton whereas cassava and sweet potatoes demand 3.5–4.5 kg N per ton
- although still low, a higher level of phosphorus is maintained over time
- use of high potassium mulches like *Maximiliana* leaves, crop residues, and addition of cooking ash
- calcium and magnesium levels are maintained over time due to soil management practices

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According to Hecht and Posey (1992) and others, agroforestry research and extension programmes should focus on the following interdependent principles:

- identification of soil quality by vegetation, and matching this to crop selection (for example, less nitrogen-demanding root crops on lower fertility soils)
- flexible use of micro-environments that suit particular crops, and multi-cropping practices to make the best use of light and nutrients
- nutrient recycling internal to the system (as far as possible)
- use of mulch
- use of fire
- variation of planting through time: mixing short- and long-cycle crops, and maintaining agroforestry plots at different stages of succession to reduce risk and maintain flexibility
- encouragement of game

But as Hecht and Posey (1990) point out, most research has been orientated towards the modernisation approach, which emphasises the use of fertilisers to overcome the nutrient deficiency. They criticise most agroforestry research for its minimal reference to local knowledge and land use practices, the loss of a systems context (including consideration of farm opportunity costs, risk, institutional, market aspects and producer rationale) and because as few as 4% of Amazonian inhabitants have access to credit and improved inputs.

However the proponents of indigenous agroforestry have often not been their own best advocates. Arguably one of the reasons why indigenous agroforestry principles have not been researched more is that they have been presented too much in anthropological and ethnobotanical terms, with inadequate socioeconomic analysis. Microeconomic research with analysis of factor use and returns is very rare, and the wider socioeconomic context (tenure, markets, institutions, etc.) has often been glossed over. There are few references to labour use in traditional agroforestry systems, and how it varies over time – it clearly falls sharply after an intensive stage at the creation of the swidden. Economic comparison with annual cropping or higher intensity agroforestry is essential for generation of more interest in indigenous agroforestry technologies. There has also been too little consideration of market constraints to wider adoption and production of traditional agroforestry products (see below).

One recent attempt at a combined approach has been documented by Schultz et al. (1994). This involved the development of a farming system in the far east of Brazilian Amazonia. Based on diversification of cocoa, it is claimed that an ecologically and economically sound system has been developed. Some modern inputs – like liming (2.2 tons/ha every 2 years) – were used, but others, like pesticides, were not. But it is difficult to assess how representative and replicable the experience has been since socioeconomic conditions were not typical and no labour inputs were recorded. Assessment was only in terms of yields per ha, and there was no discussion of the effect on soil properties.

Against the view of such as Hecht and Posey (1990), Anderson (1990) and Padoch (1987), Warner (1991) argues that indigenous swidden management cannot serve as a model for agricultural development. She argues that regeneration of the forest is crucial for the long-term productivity of swidden systems and many traditional cultivators are no longer able to fallow their fields for a sufficient length of time to maintain productivity. Also, it is argued that the technical knowledge of indigenous communities is too area-specific, or tied to cultural and religious systems, to be transferable to other societies and groups. Wilken (1989) argues along similar lines, suggesting that transfers of traditional technology require a high degree of social, economic and technical congruence between senders and receivers, but these positions perhaps make the mistake of considering the transferability question in terms of systems rather than principles.

Clearly colonists differ tremendously according to their areas of origin, past experience, levels of education, desire to experiment, etc., and it is impossible to generalise, as Almeida (1992) in particular emphasises, but the evidence suggests that it may be more realistic for colonists to adopt *caboclo* or *ribeirinho* (river dweller) technology than Amerindian technology. This is firstly since these groups were effectively earlier colonists from similar ethnic and geographical origins – in Brazil they were mainly from the north-east. Secondly, these technologies have already gone through a process of assimilation and adaptation. Collins (1986) has observed how in the Altamira region of Pará State, colonists more or less caught up with the *caboclos'* state of knowledge in terms of soil and crop selection after a few years, and achieved more stable incomes, partly due to government credit and marketing support. A constraint is that many of these systems are in *varzea* forest areas, and so are less relevant to the normal *terra firme* colonisation situation. This has also limited the contact between *caboclos* and colonists (Parker, 1989).

The main issue with the social status problem is that most colonists perceive Amerindians and *caboclos* as belonging to an inferior social group and therefore do not wish to adopt their technology (Dejou, 1990). Colonists typically aspire to cattle rancher status; for example, there are signs that the younger generation at Tomé-Açu is moving into cattle (Anthony Hall, London School of Economics, personal communication).

Colonist Shifting Cultivation Systems

Some colonists have their own complex 'swidden management' systems. A good example of this is the *abafado* system in the Marabá colonisation area in Pará State (see Box 11), which shows that the problem is not always lack of appropriate colonist technology, but can be more of an extension or diffusion problem. The *abafado* system has also informed and influenced the agroforestry research programme at CIAT, Bolivia, following exchange visits by researchers and farmers in the Santa Cruz and Marabá colonisation zones (Penny Davies, personal communication).

Box 11
A Colonist Swidden Management System in Pará State, Brazil
(based on author's farm interview and personal observation)

The *abafado* system introduced by migrants from Maranhão in north-east Brazil, where it was a traditional practice, involved cutting strips at the end of the rains in the year following rice production, sowing them with beans and sometimes maize, covering the strips with chopped vegetation, and allowing the beans and maize to grow up through the mulch. Leguminous trees were left to grow. This provided a good basis for enriching the fallow – in one case the farmer planted squash, and other vegetables, cupuaçu, mango, acerola and timber trees.

The interviewed farmer continued with the *abafado* system as a means of growing annual crops while developing a secondary forest system with important subsistence and cash tree products, especially fruit. This approach clearly depended on abandoning burning as a method of weed control and nutrient release.

In areas with better soils, like the ultisols and oxisols of the Andean Piedmont and Rondônia, and more established settler populations and infrastructure, longer sequences of annual crops using varying fallow lengths have proved effective and reasonably 'sustainable'. A good example is provided by Scatena et al. (1994) in a fairly old frontier near Santarém on the Trans-Amazonian highway in Pará State (Box 12). The crux of the strategy was to modify fallow lengths rather than use fertilisers or enrich fallows. The authors comment that it still has to be seen if the farming system is sustainable in the long term, but people were not moving on and there was an observable, if slow, process of on-farm capital accumulation. A second important observation was that land was not regarded as constraining – this may explain why a lower risk and relatively land extensive approach has been preferred. It also indicates that on reasonable soils, 50 ha is enough land for sustainable low input shifting agriculture.

Box 12
Variable Fallow Lengths along the Trans-Amazonian Highway
(Scatena et al., 1994)

This was a piedmont or rolling upland area of reasonable quality oxisols. Most colonists had previous farming experience, and had lived long enough in the area (14 years average on their current plots) to obtain a sound knowledge of their biological resources. Land was not regarded as a limiting factor on the 100 ha plots; it was estimated that with a 14-year fallow period on 50 ha (the other half was legally supposed to be kept forested), up to 3.5 ha could be cleared annually. Relay intercropped systems combining rice, maize and cassava were most common. Black pepper and citrus were the main perennial crops.

The farming strategy was based on short and medium-term fallows interspersed with longer fallows. A survey of 67 holdings revealed 23 distinct cropping patterns of annual crops found in 93 fields. There was a 12 to 22 year rotation, composed of up to five stages:

1 Burning and clearing the plot of trees or old bush after removing valuable wood products.
2 Rice and other crops cultivated for one to two years.
3 Plot fallowed for two years, herbaceous vegetation burnt off, and replanted with a different cropping sequence.
4 Fallowed for four years, cleared of short-fallow vegetation and replanted.
5 If productivity was high, stage 4 would be repeated again or a short-length fallow sequence used. If productivity was low, the field would be fallowed for 8–12 years before returning to the first stage.

Four distinct types of fallow vegetation were identified by farmers: more than 10-year-old *capoierao*; 4–10-year-old *capoeira*; 2–4-year-old *capoeirinha*; and less than 2-year-old vegetation. Farmers carefully weighed up relative crop revenues with demands on soil nutrients, labour and the cost of clearance, which increased with the length of fallow to restore fertility. For example, cassava was much less demanding on soil fertility than rice, and, unlike rice, did not require intensive seasonal labour inputs. Beans were typically planted in fields cropped once and then allowed to be overgrown with herbaceous vegetation before a light burn.

Fertiliser was only used on 17% of the farms, but in almost all the fields litter and organic debris were manually accumulated around the base of the plants. Farmers said this was to maintain soil moisture during dry periods rather than increase soil productivity. Only traditional technology, like the digging stick, was used.

Marketing Constraints of Agroforestry Products

The marketing of agroforestry products like fruits is seriously constrained by distance to market, perishability, inadequate processing capacity, shortage of credit, and lack of marketing cooperatives. Where markets are not too distant, agroforestry and extractivism can be reasonably successful (for example, around Iquitos in Peru, and Belém in Brazil), while the greater the distance, the less profitable they become (Padoch, 1987). With a fast-growing urban population, there is a growing market for 'colonist' annual crops, but the market for traditional forest and agroforestry products is much less certain.

Land Tenure Constraints on Agroforestry Systems

It is normally considered that title to land, or at least usufruct rights to land over the long term, is required for the successful adoption of agroforestry. Agroforestry based on successional swidden management requires access to the same piece of land for up to 30 years. But the importance of land tenure for intensification has sometimes been overstated in situations where is there is wide local recognition of *de facto* (possession) ownership. This is often the case in remote colonisation areas where there is a weak formal institutional presence.

But where land pressures are high and government is present (as the frontier matures), secure legally-defined tenure is an essential if not sufficient condition for intensification: Robison and McKean (1992) found no evidence in which the granting of secure land tenure led automatically to reforestation.

Secondary Forest Management

Secondary forest management[17] is often an integral part of swidden management, but also occurs outside a shifting cultivation context, for example where the idea is to return the area to a dense forest. Encouragement of secondary forest management is an urgent priority, since much of the land in Amazonia is gradually reverting to secondary forest following abandonment. Dubois (1990) has reviewed secondary forest management practices in Amazonia. These are based mainly on

17. Defined here as forest regrowth following an alternative land use, usually farming and/or cattle ranching.

indigenous practices and usually involve very simple management practices.

A good example of the potential for secondary forest management in a colonisation area comes from Rondônia State. In this area, shifting cultivation fallows are often dominated by *Schizolobium amazonicum*, a large and very fast-growing leguminous tree valued for its timber. Many colonists have adopted the following production sequence (Dubois, 1990):

1 Annual crops
2 Four to seven years of fallow
3 Selective cutting of fallow, maintaining naturally regenerating trees of *S. amazonicum*
4 A controlled burn
5 Development of a cocoa or coffee understorey

This results in a less complex forest structure, so the forest becomes more accessible. An important aspect of the system is the development of an understorey perennial crop. A farmer-developed system in Costa Rica in which *Cordia alliadora* is introduced into fallow areas and developed into an emergent stand with coffee or pasture as an understorey, has been widely extended in Central America by CATIE. Dubois (1990) identifies several species providing food, timber and nutrients that could be introduced in these sequences. Also secondary forests attract game, especially if enriched with fruit trees.

A similar association has been developed on a large scale in the Coca Agroforestry Project, with coffee, cocoa or pasture as the understorey (see Box 1). Peck and Bishop (1992) describe an extensive 'collective forest estate' that can be individually managed. This was based mainly on a combination of coffee, *Cordia alliadora* and commercial timber species planted on cleared areas. In a radius of 100 km, some 4,000 farmers have commercial volumes of 200 m^3 per ha on 15–20 year rotations – two to six times higher than primary forest – with a potential annual cut of 157,000 m^3. The Amazonian Lowland Forest Management Unit has been established and the project is moving towards the development of a forest industry.

After five years of 250 or more on-farm demonstrations, farmers had learnt to recognise valuable timber tree species in the seedling stage, to selectively protect them when clearing fields of weeds, and to transplant them to improve spacing; learnt tree planting techniques permitting the reintroduction of trees on degraded pastures; and understood how to enrich fallows using *Inga* and *Desmodium* (Peck and Bishop, 1992). Existing cooperatives were facilitating the development of farm-forest management plans in a critical buffer zone. But there was a problem with land titling legislation which only recognised plantation forestry (Ramirez et al., 1992).

An important naturally occurring secondary forest management system is that based on babaçu palm (*Orbinia martiana*) (see Box 13). Babaçu is a secondary forest species with natural stands in an area of about 200,000 km^2 in north-eastern Brazil, and grows back aggressively after slash and burn. The book by Anderson et al. (1991) is a comprehensive inter-disciplinary study which indicates the potential for management of secondary forest species in agroforestry systems. The study shows how babaçu has been successfully integrated into a variety of low to intermediate intensity crop and pasture systems by both indigenous groups and colonists. However low market values and lack of access to colonists due to land privatisation has made these systems susceptible to replacement.

Box 13
Babaçu Palm in North-eastern Brazil
(based on Anderson et al., 1991)

Up to 85% of babaçu is in Maranhão State. Babaçu has a wide range of subsistence and cash products and forms an important silvipastoral system in planted pastures, with typical densities of 50–120 adult palms per hectare providing shade for cattle and organic matter for the soil. In swidden management and at moderate densities, babaçu does not reduce the productivity of short-cycle crops. It provides many subsistence products during the fallow period and its biomass represents a vital source of fuel and nutrients, causing it to be dubbed the 'subsidy from nature'.

However, loss of access to secondary babaçu forest due to privatisation has resulted in tremendous hardship for the high proportion of landless people in this area of Brazil. In this case the priority is for tenure and policy reform which favours access to babaçu, rather than technology development.

Natural Forest Management (NFM)

For pioneer colonist farmers, it is during the early colonisation stage that support for appropriate technology development is most crucial, while there is still considerable forest cover on the plot. But there is as yet little incentive for intensification. However one approach with the potential to increase returns to capital and labour, and retain the forest cover, is natural forest management (NFM). In comparison with other land uses, there has been surprisingly little emphasis to date on NFM as an alternative for colonist farmers. Anderson (1990) points out that the potential for NFM is highest in traditional communities (including *caboclos*) due to their technical understanding, experience and common property management institutions, which appear ideally suited for it.

However, it is important to distinguish between non-timber forest product (NTFP)-based and timber-based natural forest management. Several studies have shown the complexity of NTFP-based forest management – for example, Anderson's (1990) study of *caboclo* management of *varzea* forests in the Amazon estuary, and Padoch's (1987) study of NTFP extraction in the Iquitos region of Peru show the high levels of indigenous technical knowledge and marketing complexity involved. Also most economically viable systems have been in the 'oligarchic' (dominated by fewer and more valuable species) *varzea* forest type. Extractivism (of NTFPs) has been regarded as one of the most promising avenues for forest conservation, particularly in the context of the Brazilian and Bolivian extractive reserves. However, most analysts agree that this is not a realistic option for colonist farmers, for several reasons: due to the land-extensiveness, management complexity, lack of economic viability, physical isolation, and range of marketing problems reviewed by Richards (1993a). But some colonist communities have shown longer-term attitudes to these resources. For example, frontier colonists in the Marabá colonisation zone have shown a keen interest in enrichment of secondary forest areas with such species as cupuaçu, acerola, açai palms (*Euterpe olerala*), etc. (personal observation).

Anderson's (1990) assertion that a rural population's knowledge-base of forest resources and their management is critical for NFM to be effective may be valid for NTFP extraction, but appears to be less so for timber-based NFM.

The main problems for timber-based NFM in Latin America are not cultural, technical or ecological, but economic, political (or policy-related) and institutional or organisational. Systems in Amazonia like the strip shelterbelt clearing system in Palcazu Valley in Peru appear to ensure sufficient regeneration, and small farmers in several projects have not found the technical aspects of NFM difficult to pick up (Richards, 1993b). Although successful, timber-based NFM has been rare among both Amerindian[18] and non-indigenous groups, there are emerging experiences: one example is in the Broadleaved Forestry Development Programme of Northern Honduras (Richards, 1993b), where timber

18. This is partly because of a fundamental incompatibility between indigenous or common property resource institutions, which depend on reciprocity (the 'gift economy'), and market economy institutions orientated to individual wealth accumulation (Richards, 1997).

certification has recently been obtained by the pit-sawying cooperatives. Most of the beneficiaries of this programme settled in the area after 1970.

Legal and tree tenure problems, combined with the political influence of the timber industry, have made it difficult to develop community-based NFM in several countries. For example, the Central Intercomunal de las Comunidades del Oriente de Lomerio (CICOL) in Santa Cruz Department, Bolivia, has pioneered a community-based forest management and processing project with the Chiquitano Indians since the early 1980s, but has always been involved in a struggle to gain control over forest extraction from industrial concessionaires – even in the indigenous territories. Until recently, legislation has stipulated that only concessionaires are allowed to commercialise timber at the national and international level. Although CICOL filed a forest concession for 21 indigenous communities in 1984, it was not granted the legal right to commercialise timber. Sales of timber outside the immediate local area have been illegal, and this has prevented CICOL from obtaining certification. However, the new Forest Law giving landowning groups more rights over trees on their land, has now opened the way to progress. The problems for community-based NFM resulting from the division of land and tree tenure have been reviewed by Richards (1997).

With regard to the economic difficulties, a review of prospects for NFM in Latin America concluded that the 'generally low prices of wood products and high costs of harvesting and transportation combined with long rotations have been sufficient cause for dismissing the idea of good forest management' (Kirmse et al., 1993). However, 'economic viability' is slightly different for rural communities with low opportunity costs in comparison with logging companies and businesses.

Organisational, institutional and marketing problems can also complicate community-based NFM. For example, one of the few non-indigenous small farmer NFM experiences in Amazonia is the ODA-supported El Pan community project in Northern Ecuador. This has struggled to get established due to organisational and marketing problems. It is popularly considered that NFM depends on large blocks of natural forest in common ownership – this may be a reason why there has been less effort to develop it among colonist farmers. However emerging experiences in Central America show that, although desirable, it is not a precondition. The ASACODE (Agricultural Research and Rural Extension Enterprise) experience in eastern Costa Rica shows that community management of non-contiguous individual blocks is possible (Lopez Vasquez, 1993).

It would appear that NFM has most potential for colonists where social cohesion is highest, as in some communities at the early frontier stage. There are now several embryonic attempts to develop NFM among colonists, for example an NGO called CIPCA (Small Farmer Research and

Promotion Centre) is working towards it in the Choré area of the Santa Cruz colonisation zone in Bolivia, and there are various emerging experiences in Brazil, for example under the Agro-Ecological Programme of the Transamazonica in the Altamira colonisation zone,[19] as well as by LASAT/CAT in the Marabá colonisation area. The latter initiative grew out of farmer–researcher exchanges between Santa Cruz and Marabá in 1992, 1993 and 1994, indicating again the importance of regional links and dialogue in appropriate technology development (Penny Davies, personal communication). However these approaches are bound to require long-term donor support. A case in point is the well-known Pilot Forestry Plan among the forest ejidos of Quintana Roo, Mexico, which has been supported by GTZ from 1983 to date (Richards et al., 1996).

Cattle Pasture

In view of the powerful economic and risk-aversion logic for colonists to invest in cattle (discussed in Chapter 2), cattle have an important role in the development of stable farming systems. According to Uhl et al. (1990), there is an estimated 10 million ha of pasture in the Brazilian Amazon, which is typically productive for four to eight years and is then abandoned. There are therefore millions of hectares of abandoned pasture. It is important to distinguish between non-regenerating and regenerating sites for trees: it is estimated that only 10% of Amazonian pasture is non-regenerating – these are areas that have been subject to heavy use involving chemical or mechanical weed control, annual burning and prolonged (12–20 year) use.

Uhl et al. (1990) found vigorous forest regeneration with above-ground biomass accumulation of about 10 tons per ha on pastures submitted to 'light' use (about 20% of the total pasture area), and of five tons per ha on pastures submitted to 'moderate' use (about 70% of the area). Ferraz (1995) also reports on the successful rehabilitation of degraded pasture in Itacoatiara in western Amazonia to Brazil nut (*Bertholletia excelsa*) plantations – although the pasture was only four years old. Serrão (1995) points to the need for more research and development on the adaptation of forage grasses to acidic, low fertility soils; on the ecology of pasture weeds; on biotic and abiotic mechanisms for natural regeneration; and on pasture–crop and pasture–tree systems that are more efficient, ecologically and economically, than purely herbaceous systems. But Hecht (1992) sees this sort of technological response as misguided because it assumes that inappropriate land management reflects a

19. This includes development of the Uruará Municipal forest.

technical problem – whereas it is driven by economic incentives like cheap land.

Summary Discussion of Land Use Alternatives

More Promising Land Use Alternatives

This review indicates that one of the areas of highest potential is the use of green manures or other cover crops (with minimum tillage technology). In a recent evaluation of four World Neighbours' projects in Honduras up to 40 years after their inception, Bunch (undated) reported that land values had increased 8–16 times and outmigration had almost stopped. While this was not only due to technological factors, it is a significant finding in the context of Chapter 2. Bunch (undated) goes on to argue that such technologies 'could be especially important for land-rich but resource-poor farmers . . . along the agricultural frontiers of Latin America, for whom weeding is a major limiting factor'.

At the same time, in spite of widespread adoption in Central America, there is little concrete evidence as yet that this has led to quantitative changes in incomes, farmer stability and deforestation (David Kaimowitz, CIFOR, personal communication). Caution is also needed to ensure against an over-narrow range of genetic material. A recent fungus in Paraguay wiped out two of the four velvet bean varieties used there (Bunch, undated). Robison and McKean (1992) also question whether shallow-rooted cover crops can substitute deeper-rooted fallow species which achieve greater lateral interception of nutrients, and whether homogenous litter can have the same effect as more varied woody litter.

The case studies presented show that with suitable species and practices, extensive agroforestry can reproduce most of the benefits of bush fallow, but there has been surprisingly little emphasis in research programmes on tackling the crux of the shifting cultivation problem – how to increase the number of years in production and/or reduce the fallow period through fallow enrichment. This has been partly due to the dominance of researcher-driven agendas rather than the use of a needs assessment approach, and a failure to appreciate the microeconomics of farmer decision-making (Fearnside, 1992).

There have also been few attempts by agroforestry researchers to work with traditional agroforestry systems (Robison and McKean, 1992) – perhaps because it is thought that the 'cultural' constraints make the systems inaccessible to colonists. This attitude runs the risk of 'throwing the baby out with the bathwater'. Several analysts like Hecht and Posey (1990) argue that there are vital indigenous soil management principles that can be adapted by colonists. But the latter also face more tangible constraints in frontier areas to adoption of agroforestry practices – like insecure tenure, the risk of encroachment, lack of extension and institutional support, and insecure markets. There is still a need to document successful traditional agroforestry systems, especially as practised by *caboclos* on *terra firme* land, but the documentation needs more emphasis than hitherto on microeconomic analysis, especially of the returns to labour, other opportunity costs, and on institutional and market constraints.

Secondary forest management, in association with agroforestry, clearly has a high potential for restoration of abandoned farming or pasture areas. The priority here is for economic incentives, more detailed studies of successful secondary forest management practices, and more on-farm research and demonstration (as in the RECA and Coca projects).

Timber-based natural forest management has high untapped potential for colonist farmers under appropriate social, institutional and biological conditions, and has received too little attention in the past. A number of embryonic experiences need careful monitoring. Donors should not underestimate the need for continuity of external support to successfully establish these production systems, and the powerful economic interests which would like to see them fail. Such support is justified on the grounds of the externality benefits of forest management which accrue mainly to the global community.

However, there are also risks, which are accentuated where colonists do not have a long-term view of land occupation, due to the temptation to mine the forests as a means of raising capital quickly and moving on to new land. This is, of course, no different to the situation facing commercial loggers in the Amazon. When new forest land is cheap, the opportunity cost of retaining the forest for a second cutting cycle is too high. Also weak control of illegal extraction lowers forest product prices. This indicates that isolated project approaches are unlikely to be effective; they must take place within a supportive policy and institutional framework, as the Mexican Pilot Forestry Plan experience clearly shows (Richards, 1993b).

Less Promising Land Use Alternatives

There are a number of factors explaining the disappointing uptake of intensive agroforestry technologies by colonists: they require careful management, involve higher labour inputs, tend to meet resistance by colonists (because it is perceived that trees compete with crops), and similar effects are often possible from simpler interventions (for example, mulching with organic matter from other sources than trees). Relatively few examples of successful agroforestry systems have been documented and much more economic analysis is needed to make comparisons with annual cropping alternatives (Robison and McKean, 1992). Both the latter source and Fearnside (1992) think the emphasis on intensive agroforestry has been a reflection of weak farmer participation in defining research priorities.

The case study examples (RECA, El Ceibo and Tomé-Açu) also indicate the overriding importance of institutional factors in successful perennial crop establishment and processing. The risks and difficulties of perennial crop development include the need for external nutrients (and thus credit), susceptibility to disease and pest build-up, product perishability and transport cost, ease of market saturation, and price fluctuations. Effective perennial crop development requires considerable capital, research and infrastructure, and thus represents a high cost and risk approach to stabilisation. In addition, successful market-orientated perennial crop production attracts the commercial farm sector, exerting increased pressures to sell up.

A more intensive approach by colonists to pasture management is only likely to occur in older frontier areas as land prices increase. Investment in pasture rehabilitation and more intensive livestock use in older frontier areas has been discussed. This sort of technology development can help reduce the area deforested by wealthier colonists or ranchers, but is unlikely to help stabilise pioneer colonists – unless the underlying economic and institutional incentives radically change so that they survive to the closing frontier stage. However, given the powerful economic logic for colonists to invest in cattle, more should be done to encourage silvipastoral systems earlier in the process. This would require both appropriate technology development and financial incentives. Disappointingly little work has been done on small-farmer silvipastoral systems, the work on forage alleys at CIAT, Bolivia (see Box 9) being an exception.

4
Policy Discussion and Conclusions

Reducing the Push and Pull Factors to the Frontier

In the past, the macro-level policy discussion has revolved around measures to slow down the rate of migration to the frontier by influencing the push and pull factors. The push factors can be reduced by improving social and economic conditions in the colonists' areas of origin, and influencing macroeconomic policies which push the colonists to the frontier, for example structural adjustment causing urban unemployment. On the pull side, the need has been to reduce the incentives which attract land speculators and other second-wave agents of deforestation. Road construction has notoriously caused major negative environmental impacts – although there is a vital distinction between new roads and improvement of roads in already colonised areas.

It could be argued that the best approach to the colonisation problem would be to do nothing which might attract more colonists – or even, more extremely, to withdraw resources from colonisation areas. This would make conditions for all at the frontier less attractive, eliminate the speculative element and cause a gradual reverse migration. Arguably scarce development resources would be better directed at urban poverty problems, which would further reduce the push factors (Cleary, 1992).

However, in most colonisation areas there is already a strong 'internal' market economy dynamic driving environmentally damaging processes at the frontier, and therefore withdrawing support would not have as much impact as imagined on the deforestation process. Secondly, from the national (rather than international) point of view, this could be a higher cost option, since urban poverty is more expensive to service than rural poverty. There have also been important economic gains from colonisation, for example in food production, as Almeida (1992) and others have pointed out.

The New Challenge: Reducing Intra-Regional Migration

Recent evidence has shifted the focus from push and pull factors to the Amazon frontier, to pull and push factors within the Amazon frontier. Almeida and Campari (1995) present data to show that, whereas in the

1970s and 1980s most small farmer 'deforesters' came from outside the Amazon region, now most of them are from within. Based on an extensive economic analysis of the causes of deforestation in the Amazon, these researchers also found that farmers whose main source of income was agriculture tended to curb their deforestation when land prices rose and their incomes fell, whereas landholders for whom farming was not the primary concern deforested more under the same conditions.

During the 1980s, as land prices rose in old frontiers, speculative motives tended to surpass agricultural motives to deforest, resulting in increasingly non-productive land holdings with a high proportion of fallow to cropped area, and a decreasing proportion of farming to total income. Colonists became less agriculturally active and sensitive to efforts to stimulate farming. In order to regain this sensitivity, policies are needed to encourage colonists back into farming - most obviously by penalising the environmentally more aggressive alternatives. Almeida and Campari (1995) conclude that intra-regional migration can only be stemmed by reversing local economic costs and benefits of speculation and 'itinerancy', and by measures to stimulate farming in the old frontiers. Specifically they recommend 'innovative local-level economic policies', such as:

- promoting productive agriculture by appropriate research, extension, marketing, credit and zoning support (unit costs of such efforts are lower in older frontier areas, while better market access, higher land values and tenure security mean that there are more opportunities for success in comparison with newer frontiers)
- taxing agricultural incomes from farms above a certain size in order to penalise the tendency of 'successful' farmers to deforest
- punishing speculation by taxing capital gains from land transactions
- penalising deforestation directly by taxing stumpage and levying fines

In a similar vein, it has been suggested by IMAZON (Man and the Environment Institute of the Amazon), an influential NGO based in Belém, that Municipalities need to develop a land use monitoring capacity in order to levy differential land use taxes (Almeida and Uhl, 1995).

Given that such policies would have to be developed and enforced at the local level, it is recognised that a considerable increase in local institutional capacity would be needed. Almeida and Campari (1995) argue that the World Bank and other donors should promote the local institutional capacity to implement economic policies, which would be in tune with the rapidly accelerating process of political and fiscal decentralisation in such countries as Brazil, Bolivia and Colombia.

Almeida and Campari (1995) also argue for policies that will increase the opportunity cost of moving to a new frontier, and thus call for a general poverty reduction programme in the old frontiers. Efforts to encourage colonists to remain on their existing plots should target risk factors through social infrastructure development, and counter the processes leading to land concentration and social differentiation. Priorities here include recognition and protection of pioneer (and indigenous) as opposed to second-wave colonist land claims, support for labour unions and NGOs supporting colonists, support for more democratic municipal elections, progressive taxation, elimination of publicly subsidised credit to larger farmers, the granting of smallholder forest concessions and less policy support for industrial forest concessions. Such measures should significantly reduce land speculation pressures and thus the presence of the principal agents of deforestation (David Kaimowitz, personal communication).

Another, as yet undiscussed, means of encouraging colonists, or other actors, to maintain forest is through recognition of national and global 'externality' values through some kind of incentive or subsidy payment. While major political and administrative constraints remain to such a development, it is clear that if the 'consumers' want the 'producers' of environmental services to follow their priorities, they are ultimately going to have to find a way of paying them. This principle, at least at the national level, has been recognised in the new Forest Law in Costa Rica, although there is also a strong element of economic self-interest due to eco-tourism's pre-eminent position in the Costa Rican economy (Richards et al., 1996).

The Role of Appropriate Technology Development

This review finds that incentives linked to policies and institutional factors are more important than appropriate technology or soil quality in frontier stabilisation. While land is cheap, colonists compensate for falling production by bringing new land into production if they can. This also explains the minimal use of modern technology in the Amazon. Thus technological improvement *per se* is likely to have only a minimal positive impact on colonist stability. Hecht and Cockburn (1990: 127) observe that 'no study anywhere in the Amazon has been able to show that colonists on poor soils have a higher likelihood of failure than those on excellent ones. Certainly agricultural technology could make a difference in the precarious conditions in which the colonists found themselves, but agricultural ability was not the determining factor'. Some even argue that the most popular policy response to colonist instability, raising productivity or incomes on existing plots, could be mistaken as statistical analysis shows there is no correlation between incomes and stability, and may even indicate a higher rate of land turnover with higher incomes. A less extreme position is that other policy measures are more important.

Any attempt to stabilise the colonist frontier, whether focusing on technological interventions or otherwise, must take full account of its dynamic nature. In particular, appropriate technology development aims at a moving target in terms of factor scarcities and microeconomic incentives. At least initially, increasing returns to labour and capital are more important than land, which most technological approaches in the past have tended to focus on. Even during the emerging market economy stage, increasing the return to family labour is likely to be as important as the return to land.

Technology development faces various dilemmas and trade-offs in objectives, although ideally technologies (as well as policies and institutions) should aim at both poverty amelioration and growth objectives simultaneously. For example, resource-poor farmers are the most likely to move, but are also the most difficult to stabilise through technology development. During the earlier part of the colonisation process, it is difficult to interest rational colonists in land use intensification. Natural forest management can be an important option in the early frontier stage in situations where social cohesion is high, but is likely to require prolonged outside support.

However, if alternative land-intensifying approaches are left until later, when economic incentives are more supportive, many, if not most, of the target group may have already been pushed off the land, and the soil's capacity to respond become drastically reduced. This would appear to contradict the above-stated advantages of focusing on the older frontier. Perhaps the most important point is the need to target support by channelling it through labour unions, grass-roots NGOs, etc., and that any technological, institutional or infrastructure support must be complemented by policies which discriminate against second-wave colonists and unsustainable land uses.

Additional constraints to technology development *per se* include the general difficulty of extending 'unembodied' technology or principles, as opposed to 'embodied' technology such as fertilisers, varieties, etc., and the relatively large distances between farmers resulting in a high cost of participatory technology development (David Kaimowitz, personal communication).

More fundamentally, policy and institutionally-based approaches are likely to be more cost-effective at influencing land use practices than technologically-based approaches because land use practices are a response to prevailing farm-level incentives, rather than the relative availability of different sorts of technology. Technology should be considered only within the context of appropriate policy and institutional support, and it may be that its greater importance is as a tool for small farmer mobilisation (as in the *Campesino a Campesino* Movement in Central America).

Appropriate Institutional Support

Policy-makers and donors should recognise the role of appropriate decentralised institutional support in the early stages of colonisation, and especially the role of this in reducing risk. Support to grassroots and support institutions like church-based NGOs and emerging rural labour unions should be of the highest priority, in view of the need for agricultural support services to respond to colonist priorities – rather than national economic priorities. Community organisation and education are also needed to develop greater social cohesion, secure external support, improve marketing margins and resist opposing land claims.

Continuity in institutional support is also essential – Almeida's (1992) research shows there is a significant time lag in colonist response to new institutional opportunities. She argues that inconsistency and lack of continuity in settlement programmes have been a major cause of colonist failure in the Brazilian Amazon. It takes time for ingrained 'itinerancy' attitudes to change to a desire to settle and to respond to new economic and institutional opportunities, for agronomic experimentation and for capital accumulation from consistent economic incentives, like access to markets, stable prices and credit.

The complexity of the factors discussed in this study mean that an appropriate configuration of institutions is needed in each main colonisation area, in order to increase the likelihood that policy, technology and institutional interventions complement rather than contradict each other. Technology development out of synchronisation with policy and institutional influences is as likely to exacerbate the problems as ameliorate them.

An inter-institutional (public/private sector) and inter-disciplinary research and development framework is essential, and because of the great heterogeneity of conditions and problems on the Amazon frontier (recalling the opening quotation), must be locally or regionally developed, as was the case with PESACRE. Allied to the institutional basis is the key issue of participatory methodology. It appears that only on the basis of a new institutional and methodological axis is a set of appropriate policy and technological options likely to emerge which can 'create a legal and economic environment consistent with a new technology and a new social fact: that of retaining farmers on their land' (Almeida, 1992: 280).

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Appendix 1

Review of Colonisation Case Studies

Early Frontier Zone Dynamics

Type/Location	Government/Institutional Factors	Main Economic/ Social Processes	Colonist Response and Outcomes
Government directed integrated colonisation projects (PICs) along the Transamazon highway; e.g. Altamira, Marabá, Itaituba in Pará State. (Moran: 1981, 1989)	Selection of colonists meant lower levels of initiative in government settlement; tenure and production incentives provided, especially for rice; broken promises on infrastructure; poor support services; lack of information flow and institutional flexibility to respond to unplanned problems.	Loss of colonists' social institutions; rapid differentiation with clients becoming wage labour of broker colonists; difficulty of access to markets; credit for rice but not cassava, which had high value on local market.	Initial clearance and reproduction of technology from colonist origins; rice monoculture and poor support services resulted in shorter fallows/falling yields and indebtedness; 60% farmers left after 5 years; loss of confidence in government; more success in Altamira where soils better, big financial inducements (e.g. salary for 6 months), 30% colonists were cabodos.
Directed (official and private) colonisation in eastern Pará and Matto Grosso. (Almeida: 1992)	Government slow to provide secure title to early colonists; facilitated influx of outside capitalists by creating conditions for market economy: land titles, formal credit, etc.	Family-based agricultural production responds to financial and human resources; merchant colonists supply credit in form of food, inputs for advance purchase of harvest – this non-monetorisation maintains subsistence economy; outside capitalists move in when institutional and market conditions right: private property, wage market, roads, etc.	Dependence on family labour (the farm's working capital) greater with less financial and human capital resources; small, young or old families unable to develop more commercial or permanent crops, and driven by perception of insecure tenure, condemned to subsistence-abandonment cycle. Credit forces family to direct more labour to cash crops until too little left for subsistence production causing abandonment.
Directed colonisation in NE Ecuador, Lago Agrio zone in 1970s – study focusing on early colonisation period. (Hiraoka and Yanamoto: 1980)	10,000 settlers recruited and transported to region in early 1970s; many spontaneous settlers also attracted by road building due to oil extraction; but high cost of plot included obligatory membership of coop., surveying, mapping, registration; credit tied to land title.	Land tenure/credit problem (unable to obtain credit and title until land paid off) made it difficult to accumulate capital rapidly with traditional farming system; speculation by wealthy absentee landlords.	Most small-farmer colonists at first practised slash-mulch polyculture involving permanent cover of soil and mixed annual and perennial crops; but economic/institional problems forced many to migrate or work as landless labourers; sold to colonist survivors, who moved into ranching, and wealthy absentee landowners.
Government support services in spontaneous colonisation area of Napo Province in north-east Ecuador in 1970s. (Peck: 1990; Remirez et al.: 1992; Peck and Bishop: 1992)			

Later Frontier Zone Dynamics

Government/Institutional Factors	Main Economic/ Social Processes	Colonist Response and Outcomes	Observations and Main Findings
Government gradually reduces presence: withdrawal of education and health personnel caused problems.	Land concentration and social differentiation process deepened: survivors mainly broker farmers who came with some capital and entrepreneurial orientation.	Broker colonists bought land of clients, invested in cattle, trucks and diversified into urban development.	Emphasis on institutional factors and government role: failure to provide appropriate support to client colonists and over-rapid induction into cash-crop economy, when needed time to experiment. Moran emphasises luck (weather, soils, disease), initial capital, previous farming/credit experience.
Impact of growing local institutions increased over time as influence of colonists' regions of origin weakened: main impacts in access to technical assistance and land title.	High indebtedness and land concentration. Monetorisation of economy.	Statistical analysis showed best capital growth was achieved by colonists who moved most times before coming to frontier and in early frontier stage, ie capital accumulation through land transactions proved successful. Thus itinerancy proved an effective strategy.	Emphasises initial human and capital resources, family structure, and reproduction of economic and social problems from colonists' areas of origin; transition over time from 'origin' influences to 'destination' influences – of which new institutional opportunities proved most significant in statistical analysis. Itinerancy seemed to be part of a continuing vicious cycle in early colonisation stage but proved to be a successful strategy for later stabilisation. Policies and institutional take time to have desired effect.
			Emphasis on institutional constraints placed by government on colonists; authors comment that all the colonists aspire to be ranchers.
Very effective farming systems agroforestry research and extension programme, building on local skills and earlier research; also vital tenure, credit, market support.	Successful establishment of 70,000 ha coffee planted 1978-89.	Reasonable stability of colonists; showed keen interest in new and modified technology, including use of trees; recently responded to development of farm-forest management plans in secondary forest areas.	Strong institutional support provided, especially research and extension responding to colonist interests; also importance of higher and more stable income on cleared lands through coffee; some indigenous colonists – this helped in organisational and fallow management aspects.

Early Frontier Zone Dynamics (Continued)

Type/Location	Government/Institutional Factors	Main Economic/ Social Processes	Colonist Response and Outcomes
Spontaneous and NGO supported colonisation in eastern Bolivia. (Maxwell: 1979; Thiele: 1990: Painter and Partridge: 1989)	10-50 hectare plots initially assigned to colonists, later increased but few colonists given land title; government gave only peripheral support to colonists – seen as preparing land for ranchers; but in San Julian area, a church multinational NGO provided 3 month orientation and farmer training programme.	Marketing problems for main crops, in excess supply; many colonists saw settlement as a means of raising capital for small highland holdings, which were retained.	Colonists ran into 'barbecho' (fallow) weed crisis after clearing forest; falling fertility, increasing weeds and labour costs: 40% abandonment rate, even higher in first settlement period; lack of revenue made it difficult to generate sufficient revenue to diversify; lower abandonment (20%) in NGO supported colonisation area.
Spontaneous early frontier development in Marabá Colonisation zone, eastern Pará State. (LASAT/CAT: 1995; and discussions, personal observations)	Federal and state agencies, allied to regional commercial elites, opposed giving settlers land rights in second half of 1980s. Strong labour unions formed in struggle for land rights; University of Para and unions formed CAT at end of 1980s for support services/ research.	Cheap land ($5-20 per ha in remoter areas) can be tripled in value by clearing, sowing pasture. But several factors determine whether colonist can raise enough capital to move to better land, afford cattle, fencing, etc.: distance from market; area owned; hired labour work, etc.	High turnover of lots in early years explained as rational, rapid way of accumulating capital to buy better lot, nearer markets and social infrastructure, and cattle; but can also be failure. Often insufficient capital means need to migrate or move to frontier to start again. Second time round or older colonists less keen to pursue this capital accumulation strategy, but all want to be nearer social infrastructure.
Study of old frontier region in eastern Para State; government absent. (Toniolo and Uhl: 1995)			Poorer first wave colonists go to city (50% of those selling) or to frontier.
Directed and spontaneous development in Amazonian Brazil. (Schneider: 1994, based on several sources)	Government absent at first, except roads, but then supported development, land speculation, private colonisation schemes of 1970s, early 1980s.	Cheap land encourages extensive land uses regardless of soil quality; initially little interest in land rights but increasingly expensive for first-wave colonists with limited education and influence to defend them.	High turnover rates in spite of increasing yields and incomes (incomes in Amazonia higher than national average) – evidence shows increase in turnover even where better performance/soils; also forced into short-term outlook due to high risk and interest rates.
Spontaneous colonisation in low pressure area of south-east Ecuador – Morona Santiago. (Rudel: 1995)	Tenure legislation allowed colonists to claim ownership through use.		Initially attracted by tenure, roads, land speculation. Speculators followed road constructors north – 60% left in first year. Initial clearance of land for title, but usually less than 20% area. Small landowners worked as wage labourers for larger landowners, without selling land.

Later Frontier Zone Dynamics (Continued)

Government/Institutional Factors	Main Economic/ Social Processes	Colonist Response and Outcomes	Observations and Main Findings
	Labour rice price ratio critical; if unfavourable reduction in cropped area, and more dependence on off-farm work to survive.	Successful colonists either on better quality soils/more land so able to maintain slash and burn productivity. Countered weed problem with capital for hired labour or herbicides, or 'escaped' barbecho crisis by mechanisation or cattle ranching; capital availability critical.	NGO supported area regarded as a more successful colonisation project with better initial institutional support, but economic/marketing problems have made it difficult for colonists in all areas; capital accumulation vital.
State agencies now providing limited support to CAT – mainly international assistance.	Land concentration by wealthier colonists and ranchers/speculaters, especially in areas nearer market.	Colonists who have accumulated capital from land sale to buy better land usually do not wish to go through same process again; but gradual loss of pasture productivity means decapitalisation can take over if unable to buy more land or diversify income sources. Also labour productivity/soil fertility crisis due to weeds problem. Many surviving colonists in older areas had urban connections.	Rapid increase in land values from 'improving' land means powerful incentive to clear, sow grass and sell: quickest way of accumulating capital. But technological problems in old frontier areas, due to falling productivity of cattle pasture, means colonists unable to diversify from cattle/shifting cultivation and are on downward spiral: the combination of an economic and technological crisis.
NGOs/religious groups providing training and support services in absence of government; but major constraints are still community organisation, infrastructure (e.g. storage) and credit.	Increase in price of land from \$10-50 per ha in 1970s to average \$150 in 1990s; land concentration and social differentiation.	Over two-thirds sold land 1981-93; survivors shifted to more labour and capita- intensive agriculture, perennial crops, including raised beds and vegetable farming; best farmers were urban businessmen; shift away from slash and burn to commercial agriculture.	Increase in land values and proximity of markets in old frontier provided economic incentives to intensify land use, but this also required capital, acquired technical knowledge; growth but not equity if left to market forces.
Second-wave colonists buy up land of first-wave, but then often abandoned due to higher opportunity costs; lands reinvaded but Government arrives to defend land rights of influential and more educated second-wave colonists.	Increasing price of land in old frontier regions encourages land investment, e.g. pasture restoration in eastern Para.	Second-wave capitalist colonists/ranchers buy out pioneers; advantage of cheaper formal credit due to land title, vs. expensive credit of pioneers; more attractive to latter to sell than attempt sustainable land use management; also high cost of defending land rights.	Land values, changing property rights and government role, and socio-economic differences between colonists are more important than soils and income potential of land.
Since mid-1970s no new roads built by government in region; in-migration slowed down.	Land values have not changed much; some social differentiation, but not land concentration. More successful colonists moved into commerce, rather than expanding agricultural area.	Low turnover of families in spite of gradually falling land productivity; *mestizo* colonists have formed colonisation cooperatives – built infrastructure, raised revenue from external sources and negotiated with government agencies; respect of land claims over uncleared areas has meant limited deforestation.	Land not sold off by client to broker colonists as in other case studies: due to inactive state presence in the area (lack of new roads, development projects), absence of high value natural resources, land values have remained stable. Informal (CPR) controls have emerged in the absence of speculator-type colonists and outsiders, following a relatively long, stable period with little in in-migration.

Appendix 2

Statistical Evidence of Deforestation in the Amazon Region

1. Brazilian Amazonia

Estimates of deforestation in the Brazilian Amazon vary by source, and especially by the way the area is defined. Taking the larger area of Amazonia Legal (nine States), Mahar (1989) used various sources to estimate that about 60 million hectares or 12% of the area had been deforested by 1988. Homma et al. (1993), based on INPE (Brazilian Institute of Space Monitoring) data using LANDSAT images, put the figure at 11%.

Annual levels of deforestation in recent years according to INPE have been as follows:

Year	*Area deforested*
1987	20,000 km^2
1988/9	17,900 km^2
1989/90	13,800 km^2
1990/91	11,000 km^2

The INPE data shows a dramatic reduction at the end of the 1980s, as some of the main policy-based causes as road building, development projects, etc., receded in importance.

However, data presented by Fearnside et al. (1991) on deforestation in the six 'core' Amazon States imply a much lower overall level of deforestation – only 6% by 1990. Varzea (seasonally flooded) forest has suffered disproportionately – possibly only 15–20% of this forest type is left. The following data reflect the impact of the major development and colonisation areas in Rondônia and Pará States:

Area Deforested as % of Original Forest

State	*Forest 000 km²*	*Jan. 1978*	*Apr. 1988*	*Aug. 1990*
Acre	154	1.6	5.8	6.7
Amapa	132	0.1	0.6	1.0
Amazonas	1,561	0.1	1.1	1.3
Pará	1,218	4.6	10.6	11.7
Rondônia	224	1.9	13.2	14.8
Roraima	188	0.1	1.5	2.0
Amazonia	3,477	1.8	5.4	6.0

Source: Fearnside et al. (1991).

However a recent report by the Brazilian Government, reported in *Environment* (Vol. 39 (1) p.23), indicates that deforestation in the Brazilian Amazon may have increased in the 1990s. According to this short account (which does not name the report), the data show there was a 34% increase in 'slashing and burning deforestation' from 1991 to 1994. In the 1993–94 burning season, some 15,000 km^2 of forest were destroyed compared to 11,000 km^2 in 1990–91. However the account does not reveal if it is known how much of this was secondary forest, and how much is attributable to small farmers as opposed to other actors.

2. Countries in the Amazon Region

Deforestation of Amazon Basin forest in the main Amazon Region countries to 1985 is presented below, and reveals major national differences in terms of the total area deforested and annual deforestation rates. Brazil had the highest annual rate of deforestation, according to these estimates, but was about average for total deforestation in the Amazon region (unsurprisingly in view of the fact that it accounts for almost 60% of the total Amazon forest area).

Country	*Forest area 1985 million ha.*	*Deforestn. as % of nat. area*	*Annual deforestn. 000 ha*	*% p.a.*
Colombia	43	18.8	350	0.81
Ecuador	13	21.3	60	0.48
Brazil	363	11.7	3,200	0.88
Peru	74	7.3	300	0.40
Venezuela	43	20.2	150	0.35
Bolivia	56	2.4	60	0.10
Other*	43	0.8	9	–
Total	634	12.6	4,129	0.65

Sources: World Bank Development Report (1989), Proceedings of Meeting of Specialists on Monitoring and Inventory, Belem, Brazil, 15–19 May, 1989 (based also on information from FAO and the World Resources Institute).

* French Guyana, Guyana and Surinam

More recent estimates of annual deforestation derive from FAO (1993) and information provided by the World Conservation Monitoring Centre (WCMC). However, in the case of the WCMC data and the FAO figure for Bolivia, the estimates refer to the total forest area in each country, rather than the Amazon or tropical rainforest areas. The FAO estimates are based on deforestation over the 1981 to 1990 period.

	FAO	WCMC
Colombia	0.47%	0.7%
Ecuador	1.99%	1.8%
Brazil	0.35%	0.6%
Peru	0.28%	0.4%
Venezuela	0.75%	–
Bolivia	1.27%	1.2%

These data suggest that deforestation rates fell towards the end of the 1980s in Brazil and Colombia, but there were sharp increases in Bolivia and Ecuador.

Index

ODI Research Studies

Missing a Moving Target? Colonist Technology Development on the Amazon Frontier

Michael Richards

This study brings together recent literature and the author's regional experience to assess the problem of rapid land turnover in colonisation zones in the Amazon Region. It particularly assesses various land use alternatives, including 'slash and burn' farming, by observing field or project experience. The study indicates that institutional factors and market incentives are more powerful determinants of colonist farmer stability than land productivity, and discusses why development efforts need to pay particular attention to the dynamic nature of the frontier. Farmer response to economic and institutional incentives changes as the frontier matures, and projects/technologies have often missed their 'moving target'. Greater success has come when policy, institutional and technical strategies have been more integrated.

Michael Richards is a natural resource economist and a Research Fellow in the ODI's Forestry Programme. Following thirteen years as a field-based economist in Central America, Malawi and Sri Lanka, since 1990 he has worked on issues surrounding forest policy, economic incentives and institutional change in Latin America and West Africa, especially in the context of the forest margin and participatory forest management.

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