INDIGENOUS AGROFORESTRY IN LATIN AMERICA: A BLUEPRINT FOR SUSTAINABLE AGRICULTURE?

NRI Socio-economic Series 6

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Foreword

This series is based upon work carried out under the socio-economics research programme at NRI. Its purpose is to provide an easily accesible medium for current research findings. Whilst it is hoped that the series will be of interest to those concerned with development issues worldwide, it may be of particular relevance to people working in the developing countries.

The topics covered by the series are quite diverse, but principally relate to applied and adaptive research activity and findings. Some papers are largely descriptive, others concentrate on analytical issues, or relate to research methodologies.

The aim is to present material in as straightforward a fashion as possible so that it can reach a wide audience. We are interested in the views and opinions of readers and welcome any feedback to this series.

Alan Marter
Socio-economics Research Programme

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Glossary

Agroforestry	Agricultural systems where trees and shrubs are deliberately combined with crops and/or livestock on the same unit of land
Amerindians	Indigenous peoples of Latin America
Barbecho	Cleared forest land abandoned to bush regrowth
Caboclo	Brazilian of mixed parentage (Amerindian/European/African)
New colonists	Migrants who have settled in the frontier forests since the 1960s
Swidden	Traditional subsistence agroforestry system practised by the Amerindians which includes cutting and burning small plots of forest for crop production, followed by long-term fallowing of the land
Ribeirinhos	Brazilians of mixed race origin inhabiting the floodplains
Ribereños	Peruvian descendants of Amerindians and immigrants, usually riverside dwellers

Crops

Açai palm	*Euterpe oleracea*
Cacao	Cocoa - *Theobroma cacao*
Caimito	*Pouteria caimito*
Cassava	Manioc - *Manihot esculenta*
Cupa	*Cissus gongylodes*
Macambo	*Theobroma bicolor*
Taro	Cocoyam - *Colocasia esculenta*
Ulvilla	*Pourouma cecropiaefolia*
Umari	*Poraqueiba sericia*
Urucu	*Bixa orellana*

Summary

Large-scale rainforest destruction in Latin America has occurred partly as a result of government policy incentives to colonize and clear forest for agriculture and ranching, in order to alleviate poor economic and social conditions in other regions. Inappropriate agricultural techniques have been used which are not sustainable, and the new colonist farmers are forced to clear ever more virgin forest for agriculture in order to survive.

The objectives of this literature review are to assess the value of the traditional subsistence agroforestry (swidden) systems practised over centuries by the indigenous people of Latin America (Amerindians), and to suggest ways of incorporating these methods into a sustainable (non-destructive) and productive system for the new colonist farmers. In the past, researchers perceived these swidden methods as an exploitative and destructive form of agriculture, because they involved cutting and burning of the forest. However, clearings are small, and planting and protection of trees after the initial cultivation of annual crops aids the forest regrowth in the fallow phase.

Specific examples of swidden agroforestry systems are described, and their contribution to sustainability, biodiversity, productivity for market, soil conservation, flexibility and population density support are discussed. Overall, they are found to be less destructive and more productive than the new colonist agriculture, and should form a basis for a sustainable system.

The review then outlines the possibilities for and limits (often labour intensive, location-specific and socio-economic constraints) to the adoption of these methods by new colonist farmers. Suggestions are made for research priorities to enable their effective transfer, including thorough documentation of existing systems and their capacity, participatory field research, the marketing potential for crops and forest products and the changes in government policy required to implement these methods.

The review concludes that indigenous agroforestry systems are both ecologically and economically beneficial, but are not without some limitations. From the wealth of indigenous knowledge available and proposed new research, it should be possible to adapt these systems to produce a model or blueprint for sustainable and productive agriculture for the new colonist.

Indigenous Agroforestry in Latin America: A Blueprint for Sustainable Agriculture? will not only be of interest to policy makers and donor agencies, but also to those interested in the preservation of the rainforests.

Introduction

Improving the sustainability of the use of natural resources and the maintenance of biodiversity in Latin America is an urgent priority in order to reduce tropical rainforest destruction. Although traditional Amerindian agroforestry has been documented, there have been few attempts to assess its potential as a model or blueprint for sustainable production systems.

The objectives of this literature review are to assess:

(a) the value of traditional systems in terms of their sustainability, biodiversity, and livelihood; and
(b) the socio-economic conditions which will enable their adoption by immigrant or new colonist farmers.

Given that replicating these systems intact may well be impossible, a third aim is to:

(c) identify the characteristics of indigenous practices that could form the basis of future agroforestry research and development.

The study should therefore assist in the definition of a research agenda to improve the sustainability of natural resources management in tropical forest areas. It should also help efforts to maintain existing sustainable systems that are in danger of breaking down under economic and demographic pressures, and help speed up efforts to develop new systems for migrant settlers.

Forest destruction and environmental degradation

Smallholder settlement of the Amazon Basin forests has been driven by a combination of government policy incentives, and the prevailing socio-economic conditions which generate shortages of suitable land for cultivation in the home regions of the settlers. Forest colonization has been encouraged without, in the majority of cases, complementary programmes to promote sustainable agricultural practices. Indeed, as the examples from Brazil, Ecuador, Peru and Bolivia show, policies have encouraged the use of unsustainable practices. Although it can be argued that governments were not aware of the potential difficulties associated with the cropping systems and cattle ranching practices which they encouraged in the rainforest zone at the outset of colonization, this is no longer the case.

BRAZIL

After the construction of the Transamazon Highway, incentives set up to encourage farming were technically inappropriate (promoting monocrop rice production) and poorly administered (Fearnside, 1990). This led to low rice yields and high levels of debt. Farmers attempted to overcome this problem by increasing production through shortened fallow periods which resulted in a further decline in land productivity and the eventual abandonment of the land. The degraded land was then purchased by wealthier farmers and converted to pasture; the original settlers moved to the frontier to begin again the cycle of land clearance and degradation.

The Brazilian Government has encouraged the flow of people as a means of asserting national sovereignty over the Amazon, and of avoiding the inequities of land distribution in the migrants' home states (Mahar, 1990).

Encouragement has included massive road building schemes during the 1960s to 1980s which made large areas of the Amazon accessible for the first time, and direct incentives such as subsistence payments (Binswanger, 1991).

The number of migrants entering the state of Rondonia, for example, increased from 65 000/year to 160 000/year after the completion of the BR-364 road in 1984 . As deforestation is accepted as evidence of land improvement, land rights can be obtained for three times the area of forest cleared, up to a ceiling of 270 ha. Once title is established, the land can be sold, and this led to huge land speculation. Impoverished settlers, having few economic opportunities in their home regions, have responded to these government incentives by developing farming practices based on clearing forest, mining the land's resources, profiting from converting land to pasture and moving on (Mahar, 1990).

The final result has been forest clearance on a vast scale for unsustainable agriculture.

ECUADOR

In northeastern Ecuador settlers to the forest zone were obliged to pay for the land and its survey, and they could not gain full title until they had repaid their debt (Collins, 1986). Without a clear title they had no access to credit. They had little alternative but to maximize short-term production and profits through rapid conversion of forest to farm land and mining forest resources. Most farmers attempted to establish pasture, but this failed as measures to maintain soil fertility over the long term were ignored. They had to sell out to large ranchers and move on, thus further increasing pressure on the colonization frontier.

PERU

In southern Peru a combination of poor access to credit and difficulties with obtaining clear title to land resulted in the failure of a smallholder coffee production programme (Collins, 1986). Coffee did not yield sufficiently well without external inputs which were not affordable without credit facilities. As a result, a pattern of seasonal migration developed where the settler from the highlands began to move back and forth from upland to forest regions to maintain agricultural activities in both regions. This has put pressure on the forest frontier, and resulted in poor management in both regions and a consequent decline in agricultural production.

BOLIVIA

In the Bolivian Amazon, colonist expansion was encouraged as early as the 1960s. Land is cleared of high forest for rice production. After one or two years of cropping, in the face of declining yields and weed encroachment, the land is abandoned to bush regrowth (known locally as *barbecho*). This process is repeated until the high forest on the farmer's holding is exhausted and it becomes necessary to begin cultivating *barbecho* land. Yields fall and weed problems increase and migrants must move on into the forest frontier; the '*barbecho* crisis' ensues (Maxwell, 1980; Stearman, 1983; Thiele, 1991).

The alternatives – mechanization for production of arable crops or conversion to pasture for beef or dairy production – have failed. The land under mechanization will also, in the long run, become pasture. Those farmers with capital have become ranchers on consolidated holdings, whilst the poorer cultivators are forced to the frontier to begin the cycle over again. More recently the introduction of herbicides and integrated weed management strategies has allowed extended cropping of the land (Thiele, 1991), but its long-term sustainability is compromised by problems of declining soil fertility.

Throughout the Amazon Basin, inappropriate agriculture and poorly thought out incentives have not only contributed towards large-scale rainforest destruction, but have not worked to the advantage of the poorer migrant smallholders.

Swidden agriculture

Amerindians have practised their traditional forms of agroforestry for millennia without apparent detriment to the rainforest. These systems are generally referred to as swidden agriculture, or sometimes as slash and burn or bush fallow farming (Warner, 1991). A parcel of forest (swidden plot) is cut and the area burned to release nutrients. A mixture of short-term and annual crops, often followed by perennials, are grown until soil fertility becomes inadequate to maintain production and/or competition from successional plant species becomes too great. The farmer then prepares a new site while the old field returns to fallow. During the fallow period large quantities of nutrients are stored in the plant biomass and are released during the burning of the fallow vegetation or secondary forest when the land is cleared for the new cropping cycle.

A random generation of tree species during the fallow period may not be as common as was once thought. The indigenous inhabitants of the Amazon Basin deliberately retain economically useful species during the clearing of swidden plots. These species are protected from fire and contribute not only directly to subsistence but also shape the species content of the following succession.

Pollarding may take place to leave trunks for cultivated climbing plants and coppicing is also carried out. In many cases seeds of useful trees are planted. These include both wild and semi-domesticated plants, which contribute to a more rapid and species-rich regeneration of the forest during the fallow period.

When the annual or semi-perennial crops have ceased production during the second or third year, management of the swidden plot is reduced to occasional weeding around useful trees. However, the plot may produce valuable products for up to 25–30 years. After this time the field may be cut and burnt once more or be out-competed by high forest.

There are several common elements associated with these indigenous agroforestry systems in Latin America (Alcorn, 1990). Firstly, fallows are seen as a useful phase in the productive process and not only as a solution to declining fertility, weed and pest problems. Farmers incorporate native species into their managed fallows; species which often occur naturally in primary or secondary forest and chosen for their multiple uses.

Secondly, farmers take the best advantage of natural environmental variation. They recognize numerous ecological zones, soil types and topographical units which they use for different species according to the needs of each.

Thirdly, farmers control pests and avoid risk by enhancing diversity; a variety of native and exotic tree and crop species are introduced into the field.

This diversity also enables households to meet subsistence needs, and it encourages experimentation and change within the system as positive crop associations develop spontaneously within communities. Thus traditional farming strategies are not only flexible, responding to changing household circumstances, they are also dynamic, with new species being introduced to the system along with the possibility of increasing production for the market.

Finally, forest is only cleared in discrete parcels allowing the natural (or species-enhanced) forest to eventually regrow. Here we have the basis of a sustainable system, not a destructive one.

The literature contains many descriptions of indigenous swidden agriculture in the Amazon Basin. In the next section four case studies are used to highlight their common features.

INDIGENOUS SUBSISTENCE AGROFORESTRY

Case 1. Bora agroforestry

The Bora, Amerindians of the Amazon in eastern Peru and southern Colombia subsist from swidden agriculture, fishing, collecting and hunting (Denevan *et al.*, 1984). They use both primary and secondary forest for their swidden plots. Fallows are felled during the period of lowest rainfall and burned after drying. Useful palms and trees, as well as certain valuable timber species, e.g. Spanish cedar (*Cedrela odorata*) are spared during clearing. Coppice regrowth of certain species is also encouraged.

The main staple of the Bora is cassava (*Manihot esculenta*), and at least 22 cultivars are used locally. It is intercropped with pineapples, fruit trees and many other annual crops (Denevan *et al.*, 1984). Indeed, the crop combination of a Bora swidden varies enormously with the needs of a family and labour availability. Generally, families will have six or more fields in various stages of succession to fallow. Those fields with less diversity tend to be abandoned earlier than those in which perennial tree crops have been introduced.

Soil depletion and weed invasion does not allow the harvesting of cassava after 3–4 years. Most fields are abandoned at this stage, but those intercropped with fruit trees are still weeded to ensure that the fruit trees remain productive for longer before they succumb to the effects of secondary forest regrowth and competition for light and nutrients. The normal cropping sequence is thus from cassava or rice to pineapple and fruit trees, and finally to wild species. The wild species which eventually invade are often useful for a variety of purposes (weaving, dyes, medicines, game attractants, canoe logs and firewood). Swidden fallows also provide game. The artificially enriched (with fruiting trees) natural vegetation encourages animals to seek food in the swiddens, which in turn are hunted by the Bora. After 8–10 years from the initial clearing of the plot, weeding ceases. A further 20 years may elapse before the plot is cut and burnt again for annual crop production.

Several tree species planted in Bora fields are well adapted to growing in dense secondary forest. Umari (*Poraqueiba sericia*) and macambo (*Theobroma bicolor*) are often evident in old fallows. These species along with another 53 useful (not planted) species were observed in old fallows by Padoch and de Jong (1987). Even in older fields, up to 30 years old and more, cultivated fruit trees have been observed to survive, although the vegetation by this time includes naturally occurring useful species which were protected in the original clearing.

The practice of enriching fallows enhances site recovery when compared with unmanaged fallows, and discourages colonization by invasive weeds such as *Imperata* spp. (Unruh, 1988). The introduction of woody species also increases the potential leaf litter and encourages the spontaneous germination of useful fallow trees in successive swiddens.

As yet the Bora are not involved to a great degree in the wider cash economy. Their villages are too remote to enable them to market perishable commodities. Spanish cedars are, however, transplanted into swiddens and fallows, and when mature, floated down river to market. This timber can produce a substantial cash return 30 years from planting.

Case 2. Kayapo agroforestry

The Kayapo Amerindians of northern Mato Grosso and southern Para States, Brazil have a sophisticated understanding of different ecological zones and use it in farming and settlement decisions (Posey, 1983; 1985). Their territory includes grasslands, mountains and forest, and their intimate knowledge of these ecological zones and their subtle variations enables them to choose settlement sites in transitional zones. Kayapo thus reside in areas of maximum species diversity. Each zone will provide natural products and attract different game species at different times of the year. Their swidden plots are set out in the form of concentric rings; the major crops being sweet potatoes, yams and plantains. The centre of the swidden is dominated by sweet potatoes, a secondary ring begins with maize followed by cassava and sweet potatoes. The outer ring includes yams, cupa (*Cissus gongylodes*), bananas, pineapples, urucu (*Bixa orellana*) and fruit trees (Hecht and Posey, 1989).

The Kayapo recognize 22 cultivars of sweet potato, at least 22 cultivars of cassava, 21 varieties of maize, and 13 varieties of bananas and plantains. At least 46 types of fruit and nut trees are planted along with numerous annual vegetables. Fruit and nut species are not only planted in succession in the swidden but also along hunting trails, in forest gaps, various savannah sites and homestead gardens. Many miles may be travelled on hunting expeditions and trees and tubers are strategically placed to provide subsistence during these trips.

Kayapo swiddens continue to produce harvests of yams and taro (*Colocasia esculenta*) 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. Posey (1985) surveying an old swidden collected 368 plants claimed to be of medicinal significance by the Kayapo. These old swiddens also attract substantial quantities of game.

Kayapo soil fertility management depends firstly upon ash from the initial burn and from in-field burning. Burnt vegetation piles provide nutrients in selected spots and control weeds. Secondly, mulches are provided from palm leaves, banana leaves and crop residues such as rice straw, bean vines, sweet potato vines and chopped weeds. Mulches, apart from providing a slow release of nutrients, protect the soil from rain-drop compaction and reduce weed germination and soil temperatures. Thirdly, direct nutrient applications are made to some of the perennial and semi-perennial plants such as bananas, pineapple and long-lived yams. The source of these nutrients includes ashes of particular species, termite nests and Azteca ant nests. Finally, nitrogen-fixing leguminous trees may be planted in fallows.

Kayapo swiddens vary considerably, and crop combinations depend upon household labour availability, hierarchical obligations (communal fields whose surplus is distributed by the chief), personal preferences, ritual obligations (naming and death ceremonies) and internal markets (a trade in rice has developed between the Kayapo and recently arrived gold miners).

Case 3. Ka'apor agroforestry

The Ka'apor Amerindians inhabit a tract of dry land which is not subject to annual floods in the dense forest in northern Maranhao State, Brazil. Here the clearance of new swiddens is often accompanied by a change in settlement site (Balee and Gely, 1989). Once a site has been selected a communal swidden is cleared and cultivars from the old site are transported to the new. The first food crops planted are fast growing cultivars of cassava, banana and sweet potato. The inhabitants of the old site move to the new between 7 and 21 months after the first planting. At this point an area is cleared with a radius of 5 m around each house (houses are usually situated within the swidden), i.e. this part of the field is harvested first and a house garden is established (trees and herbs). Thereafter individual families clear smaller individual swiddens in the surrounding forest.

Ka'apor recognize six major vegetational zones (or types of forest or manipulated forest): (a) house gardens; (b) young swiddens up to two years from burning; (c) old swiddens 2–40 years from initial burn; (d) old fallows 40–100 years from first burning; (e) mature forest and (f) swamp forest.

The house garden is part of the original community swidden. It consists of herbs and trees, many of which are light demanding and will only grow in house gardens.

Young swiddens (between 0.5 and 1.5 ha) are characterized by cassava, sweet potato, papaya, cashew and banana cultivation. They are also an important source of firewood. When Balee and Gely (1989) examined them, out of 56 plant species found, 28 were planted by the Ka'apor. Apart from the main food crops, they found plants used for rope making, medicines, fish poisons, adornments and game attractants.

Older swiddens (over four years) returning to secondary forest have numerous palms, vines, mango and citrus trees, and other fruits, and are rich in game. Old swiddens may return to cultivation after a period of 15 years, although established fruit trees from the previous cycle will be protected from the burn.

Old fallows (40–100 years) display signs of earlier disturbance, with enhanced densities of fruit trees and palms.

Each vegetational zone is subjected to different degrees of management and planting. This diversification spreads the risk of crop failure, while producing habitats suitable for game which also contributes to household nutrition.

Case 4. Amuesha agroforestry

The Amuesha inhabit the tropical rainforests of the Palcazu valley of east/central Peru and live from subsistence agriculture, supplemented by fishing, gathering and occasional hunting (Salick, 1989). They farm small pockets of fertile soil found on the slopes of the valley (Salick and Lundberg, 1990), as much of the fertile alluvial soils of the valley floor have been taken by European immigrants.

The Amuesha practise swidden agroforestry, but contact with Europeans and the rest of Peru after the construction of a sealed road has led to some modifications and participation in the wider economy. They classify and choose land according to the soil's ability to support different forms of vegetation, and fallow times reflect differential fertility status. Following a burn (often unsuccessful in this high rainfall region) they grow:

- beans and groundnuts on seasonally flooded beaches
- maize, cassava, plantain and fruit trees on dry lowlands
- rice and cassava on upland fields
- taro on less fertile uplands
- a variety of useful plants in homestead gardens.

All fields are intercropped with a great diversity of minor crops. In the dry lowlands, cassava is planted and harvested for up to three years. Plantains are also introduced and often underplanted with fruit and fuelwood species. Plantains are harvested until the fallow species begin to dominate. For a number of years, weeds are kept from growing round the useful trees which are protected during subsequent burns so that they provide a useful harvest. Lowland fallows are short (3–5 years) reflecting the fertile nature of these sites.

In the less fertile uplands, rotations comprise one or two crops of rice or cassava for two seasons followed by a longer, ten year fallow. Taro is grown on particularly unfavourable sites and is a risk–avoiding crop, or a reserve for hard times. Homestead gardens produce a diverse range of fruits, flowers, sugar, medicines, stimulants, poisons, herbs, firewood, dyes and experimental plants, as well as a few staples.

Amuesha agriculture is therefore characterized by diversity of cropping systems, which relate to particular soils, environments and managed fallows. A household may have an example of each type of production depending upon whether family members engage in wage labour, in which case there is less time available for cultivation. As the Amuesha have become involved in the cash economy, they have been able to maintain their subsistence base.

Many other indigenous subsistence agroforestry systems have been documented in the literature, for example, the Chacobo of Bolivia (Boom, 1989), the Yanomami of northern Brazil and Venezuela (Clay, 1988; Harris, 1971; Smole, 1989), Campa subsistence in Gran Pajonal, eastern Peru (Denevan, 1971) and the Chacra system of the Napo Quichas of Peru (Peck, 1990).

MARKET-ORIENTATED AGROFORESTRY

In this section case studies are analysed where indigenous systems have been adapted over the centuries to market and other modern conditions, but where, in the process, the core features of the sustainable agroforestry systems have been retained.

Case 5. Huastec agroforestry

The Huastec Maya farm the communally owned and densely populated foothills of the Sierra Madre Oriental mountains of Mexico (Alcorn, 1989a). Their agroforestry management strategy is a highly productive indigenous practice, given that landholdings vary in size from 1 ha to 15 ha with population densities of around 100/km^2. They have a mixed economy, producing agricultural goods for subsistence and the market, and are wage labourers outside the community. Thus the high person/land ratio can be sustained.

They plant maize on fallows cleared from secondary regrowth of three to seven years of age. During the burn, selected useful species are protected and firewood trees are pollarded to provide support for climbing beans and a continuous supply of firewood. Most fields produce only one crop of maize and then return to fallow, although older fallows will have sufficient fertility for two crops. Maize is intercropped with beans, sesame, squash, yam bean, sweet potatoes and cassava. Weeding is carried out only once, when care is taken to leave any useful seedlings that have emerged.

After harvesting maize, part of the plot is selected as a forest garden (*te'lom*), whilst the greater part of the original clearing is left to regenerate naturally. The garden is made up of native species that were protected during the initial burn as well as transplanted native species, coffee, garden crops and fruit trees. A garden, from 0.25 to 3.0 ha or more, can be in continuous production for at least 80 years. As new ones are created, however, other older ones are cycled back into swidden (maize) production. Crucially, if a farm plot is not fallowed after one or two years, its soil becomes so degraded that gardens cannot be re-established there.

Gardens are created and managed flexibly, depending upon the time spent working off-farm. Management consists of sporadic and selective weeding. Seedlings arise naturally to accompany those species protected when the plot was cleared. Farmers selectively remove individuals that are not required, usually those that are competing with a useful tree or those that are unproductive or diseased. Around the edges of the gardens where there is sufficient light, cacti, bananas and cassava are grown. The typical garden may contain up to 300 species, 90% of which produce useful products (construction materials, poles, furniture, firewood, food, medicine and livestock feed).

Coffee and sugarcane are the most important commercial products although fruits such as avocado, mango, orange and others may be marketed in small quantities (as much as half of total fruit production may go unharvested). Hand-sawn cedar is sold along with potted parlour palms as house plants. This system does not produce sufficient to maintain a household, so external employment must be sought. However, on little or no capital investment, it does provide for subsistence, a few marketable goods, and maintains livestock, which provides an important source of income, especially for women (Alcorn, 1989b). The system also acts as an insurance against illness or unemployment as gardens will continue to produce with little or no input from the farmer.

Forest gardens on steep slopes have great value in preventing environmental damage. Trees bring up nutrients from the deeper layers and hold them so they are not leached, and soil is not lost by erosion. The system has survived for thousands of years and has been able to absorb changes and the introduction of commercially valuable crops, without compromising its subsistence or conservation function.

The following case studies highlight how many indigenous agroforestry systems have been adapted towards the market economy by mixed race descendants of the Amerindians.

Case 6. Ribereño agroforestry

The *Ribereños*, inhabiting Tamshiyacu, 30 km southwest of Iquitos in eastern Peru are descendants of both immigrants who settled during the rubber boom of the last century, and Amerindians of the region. Their agriculture, in this lowland forested region, displays similar patterns to that of indigenous people of the surrounding area, such as the Bora (see Case 1), but has been adapted to produce goods for the market (Padoch and de Jong, 1987).

Their swidden agroforestry cycle begins with the clearing of fields from primary or secondary forest, although valuable species preserved during earlier cropping cycles are spared. Cassava and plantains are grown both for subsistence and sale. Other crops are interplanted with cassava, the most important of which is pineapple. In the second year perennial plants such as umari are introduced as cassava is harvested, and pineapples become the predominant crop. By the fourth year, pineapple yields decline and are replaced by early maturing fruit trees. These include short-lived species such as cashew, uvilla (*Pourouma cecropiaefolia*), and caimito (*Pouteria caimito*). A full list is given in Padoch *et al.* (1985). These fruits have a ready market in Iquitos, but their yields decline or harvesting becomes problematic after five or six years. In the fourth or fifth year lucrative umari begins to yield in quantity (a 1 ha field of umari will yield 80 000 fruits in one year), continuing for 20 years or more. Umari and Brazil nuts are the only products of the swidden in the later stages of the cycle.

Orchards are weeded for up to 25 years, and the secondary forest is not allowed to regenerate, with the exception of a few economically useful species which are protected when they spontaneously establish. If fields are well maintained, they may continue in fruit production for up to 50 years. As soon as production begins to fall significantly, the umari and other trees present are cut, dried and converted to charcoal for sale (Brazil nut trees are often spared); the plot then being left fallow for five to ten years. The plot is invaded with secondary regrowth which is cleared and the swidden cycle recommences.

Most families have a series of swidden fields in various stages of production. This reduces the risks associated with market production, allows the allocation of family labour to be spread over the season and ensures a cash flow throughout the year.

The *ribereños* of Tamshiyacu have adapted traditional swidden techniques into a system which ensures subsistence and produces considerable surpluses for sale, by increasing the economically useful production of forest fallows. The commercial success of this system (incomes up to US$ 5000) is determined by the proximity of a market and its limitations (gluts of umari occur when it loses its value) (Padoch *et al.*, 1985).

Case 7. Santa Rosa agroforestry

Inhabitants of the old plantation village of Santa Rosa on the Ucayali river 150 km upstream from Iquitos, Peru are also of mixed origin. Villagers inhabit dry land and practise their swidden agriculture at these sites, but also cultivate the floodplains, in contrast to other local farmers (Padoch and de Jong, 1991).

After farm sites are cleared and burnt, staple annuals and semi-perennials for subsistence use are introduced, as poor communications deny the villagers access to markets. Cropping and maintenance cease after two or three years. Fruit trees are introduced during the first year of cropping, and early fruiting species produce by the second year. By the fifth or sixth year, the plot has become an orchard. A great variety of fruit and timber trees develop in the fallow.

However, the major source of cash comes from rice and plantains which are cultivated on the river plains and the seasonally inundated mudflats fertilized by annual deposits of silt.

Case 8. *Ribereño* floodplain agroforestry

The *ribereños* of San Jorge, 45 km southwest of Iquitos in Peru, have a very diverse economy. They farm, fish, gather forest products, hunt and work for wages. Traditionally they cultivated the floodplains of the Amazon and its tributaries which are seasonally fertilized by the rich silts deposited in the short annual floods (Hiroaka, 1989); swidden agroforestry is practised on rarely flooded parts of the lowlands.

Swidden management begins with the clearance of high or secondary forest. Cassava is intercropped with plantains, maize, beans, a number of minor crops and fruit trees. Weed and pest control are carried out up until the third year of cultivation by which time yields of annual crops begin to decline and weeding becomes increasingly time consuming. The field is left to the fallow natural succession, although the bases of fruit trees are occasionally weeded. The orchard swidden continues to produce for at least ten years, and provides an ideal hunting ground for small game; this is important in the flood season when fish become dispersed and catches small.

A family clears and plants a new swidden plot every one or two years, ensuring a constant supply of the staples, cassava (9.5 t/ha in the first year; 5.2 t/ha in the second) and plantain. The swiddens are generally used for subsistence, but increasingly staple foods and crops are marketed.

The annually flooded areas produce rice (the principal cash crop), maize, beans, cucumber, tomato and vegetables. However, the returns are small, averaging US$ 50/ha, but the increasing desire to purchase consumer goods provides strong motivation for the *ribereños* for further commercial agricultural development.

The average swidden area managed by each household is 2.2 ha, and the average seasonally flooded holding is about 1.5 ha. It is estimated by Denevan (1976) that the floodplains of the large rivers of the Amazon Basin supported a population density of as many as 28/km^2 at the time of the European contact; six times the present population in the Peruvian Amazon (Hiroaka, 1989).

Case 9. Açai palm forest systems

The riverside dwellers (*ribeirinhos*) of the Amazon estuary in Brazil inhabit the floodplain and use the forest cover in a variety of ways. They have, to a great extent, maintained native species to assure sustained production of the açai palm (*Euterpe oleracea*). In contrast to the extensive upland areas of the Amazon, the floodplains do not display a high biotic diversity and are dominated by the açai palm (Anderson, 1990; Anderson and Jardim, 1989; May, 1990). This plant is an important source of palm heart and its fruit is processed into a beverage that has a ready market throughout Para state, although this market has been recently disrupted by a cholera epidemic. The inhabitants of the estuary, while collecting fruit and hearts from wild palms, introduce açai seeds or seedlings into their shifting cultivation plots promoting high density stands which utilize the fallow period.

Their agriculture is characterized by three types of land use. House gardens are made near the dwelling and are used for the production of a wide variety of native and exotic shrubs and domesticated animals. Swidden plots used for the production of staple crops such as rice, beans and maize are found some distance from the dwelling to minimize disturbance by domestic animals.

Between these and the natural forests (used for hunting, gathering of fruit, latex, palm heart, wood, fertilizer, honey, fibres and medicines) there exist partially managed forests where desirable trees are favoured, such as the açai palm, rubber, fruit trees and firewood species. These forests are thinned involving the removal of vines and understorey vegetation which improves access. Mango, cacao (*Theobroma cacao*), coconut and other trees may be introduced as seeds or seedlings.

Although gross outputs from swidden plots are much higher than those of the managed forest, swidden cultivation cannot be practised continuously on a given site and requires substantial inputs of labour. The managed forest system, however, can produce marketable goods with few inputs, and can be carried out indefinitely over extensive areas. Anderson (1990) considers such forest management as a tolerant strategy that maintains a forest cover (although reduced in number of species), successfully integrates extraction and forest management, reduces dependence on swidden agriculture, produces a marketable surplus and contributes to household income. The system is both ecologically sustainable and economically profitable. As in other Amazonian agricultural systems the use of managed fallows increases the useful species occurring in the swidden cycle.

Case 10. Caboclo agroforestry

The term *caboclo* refers to a Brazilian of Indian-European-African parentage (Moran, 1974; Parker, 1989). *Caboclos* have been generally ignored by development planners, having been considered of low social status. However, they make their livelihood from marketing extractive forest products whilst maintaining subsistence agriculture to survive the boom or bust nature of the market.

The *caboclo* have adapted to the Amazon environment over three centuries and have an intimate knowledge of the natural resources of the region in terms of its agricultural potential and as a source of naturally occurring products for extraction. Although they inhabit areas accessible by rivers and good for fishing, they practise swidden agriculture on the dry lands. Because of their cultural links with both the indigenous populations of the region and the new colonists, the *caboclo* provide a very good example of the ways that indigenous subsistence and new marketing livelihoods can be combined in a sustainable way.

In the final case study, we look at a group of people who have copied the indigenous systems in order to survive, but have kept their own discreet culture.

Case 11. Japanese agroforestry systems

Japanese farmers have been cultivating remote forest regions of Tome Acu in Para State, Brazil since the 1920s. Over time their agricultural systems have developed from subsistence based farming to commercial agriculture, fully integrated into the national and world economies (Subler and Uhl, 1990). These systems are new, although there are some similarities between their methods and those of the indigenous populations of the region. They replace forest vegetation with a mixture of both native and exotic species of economic value, producing a variety of high value cash crops through a mixture of annual and perennial plants. The systems are intensive, relying on large inputs of labour, capital and materials in the form of inorganic and organic fertilizers.

The colony of Tome Acu is situated 115 km south of Belem, an important port and capital city of the State of Para. The first settlement occurred during the 1920s. The original attempt to establish cacao plantations failed and the immigrants resorted to subsistence agriculture. More recently they have diversified into perennial cash crops and currently produce black pepper, cacao, passion fruit, rubber, African oil palm, citrus and 55 other perennial and annual crops. All of this production takes place on the dry land, on 280 farms of between 100–150 ha each, although only 20 ha is in cultivation on each farm at any one time.

The system is a multilayered mixture of perennials and annuals in succession. A typical example would be the planting of rubber seedlings following forest clearance. This area is then intercropped with rice and maize. After harvesting the grain, the rubber is interplanted with cotton. After the cotton harvest black pepper and papaya are planted in rows between the rubber followed by a crop of pumpkins. After two years the papaya has completed its productive phase while the black pepper begins production. The pepper continues production for 3–4 years by which time the rubber begins to produce latex.

Japanese farmers do not cultivate large areas at one time; 1–4 ha is usual, although any one farmer will have several plots at different stages of succession. This is a risk avoiding strategy, having a number of perennial crops in different stages of production, allows flexibility if market conditions alter, and a change to annual crops or abandonment to secondary forest.

These diverse systems make efficient use of light, water, nutrient resources and reduce the risk of pest attack. However, they do require a sophisticated management approach, and the complexity of the system limits the area that a farm household can cultivate. They are also dependent upon large inputs (400–1500 kg/ha/year) of inorganic fertilizers as well as inputs of organic manures from intensive pig and poultry production which has expanded during the last decade (Barrow, 1990).

It is not clear how this cropping system affects fertility in the long term although many plots have been in continuous production for over 15 years. Labour inputs are high despite mechanization; one person is required for every 3–4 ha under cultivation, and capital requirements are equivalent to US$ 1000/ha for each year of cultivation of black pepper.

Much of the success of these farming systems must be attributed to the proximity of the colony to Belem and therefore access to national and international markets. Farmers also have the benefit of a marketing co-operative which provides access to inputs and credit, technical expertise, processing and the development of markets.

Benefits of swidden agriculture

The core beneficial elements of both the indigenous and market-orientated systems can be set out under the following headings: sustainability, productivity, biodiversity, soil conservation, flexibility, population density and use of native species.

SUSTAINABILITY

These case studies show that agroforestry systems used by the indigenous people are both productive and potentially sustainable; forest is only cleared in discreet parcels and can easily regrow. Production is sustained by use of species-enhanced long-term fallows and biomass recycling. The systems even contribute to biodiversity and soil conservation. In their flexible use of locally adapted, as well as exotic species, they can respond to new conditions and in doing so can support high population densities. It is now clear that Amerindians make good use of the natural resources available to them, both in terms of production for subsistence, and sustainability. They have a sophisticated understanding of their environment, its micro-variations, and its potential for crops (Clay, 1988; Hecht, 1989).

PRODUCTIVITY

Hecht (1990) has compared three types of land use system in the eastern Amazon. Short cycle new colonist slash and burn systems and pasture/ranches were contrasted with the Kayapo indigenous system (see Case 2). Kayapo yields (edible harvest) over a period of five years were roughly 200% higher than new colonist systems and 175 times that of livestock production systems. New colonist agriculture rarely continues beyond five years as the soil is exhausted of nutrients for annual cropping. Therefore a comparison between Kayapo and new colonist agriculture over a ten year period is not possible. However, Kayapo and livestock comparisons reveal that animal production is a mere 700 kg of beef compared with 84 t of crops from the indigenous system. Not only is the indigenous system more productive than modern forms of agriculture but it is also less environmentally damaging and more sustainable.

BIODIVERSITY

Balee (1989) and others have argued that Amerindians have manipulated natural resources so much, by the interchange of useful plant species between ethnic groups, that they have transformed much of Amazonia, and thereby increased biological diversity throughout the region. Balee estimates that 12% of non-flooding forest is of cultural origin and that useful species such as the Brazil nut are much more abundant than they would have been without the intervention of indigenous cultures. Long-fallow swidden cultivation recreates the diversity, complexity and use of biomass for nutrients that existed in natural forest (Warner, 1991). Swidden cultivators actively recreate the forest in their fields, selectively protecting useful species, so as to preserve long-term stability and production. Thus the local biology is disturbed as little as possible and its periodic re-establishment ensures useful future production of plant materials and game. Diversity exists in varieties, crops and the number and type of swiddens cultivated, which reduces risk, maximizes options and guarantees household subsistence.

SOIL CONSERVATION

Not only do indigenous societies possess technical knowledge concerning the suitability of soil types for cropping but it is argued that their soil management is superior to new colonist and large-scale livestock production (Hecht, 1989; Unruh, 1988; 1990). There is less destruction of the nutrient cycling root mat in the swidden cycle, as coppicing and the selective protection of valuable species is practised. Therefore, the root mat quickly re-establishes itself during the fallow cycle. Useful standing trees in new swiddens protect the soil from the effects of excessive insolation and precipitation and also protect naturally occurring seeds from the initial burn, thereby encouraging a faster regeneration.

FLEXIBILITY

Traditional swidden systems are not static; new varieties of plants are incorporated as they become available. For example, valuable timber tree species have been introduced to forest fallows by the Bora of Peru (Denevan *et al.*, 1984). Maize, plantains and rice are relatively recent introductions (Warner, 1991), although cassava remains the staple in the Amazon region. These new introductions have expanded the diversity of the system and may have improved food security and resulted in higher productivity (Alcorn, 1990).

POPULATION DENSITY

Although swidden cultivation is generally practised in areas of low population density (with the exception of the Huastec of Mexico), this is not necessarily a reflection of the carrying capacity of the land. The indigenous populations were decimated by Old World diseases from the 15th century onwards, and scattered populations were brought together by Christian missionaries.

Adapted indigenous systems in the Peruvian Amazon appear to be able to provide for household subsistence and sale to market from areas of 1.5–2.5 ha (Hiroaka, 1989); with a 10 year fallow a maximum of 25 ha is sufficient for one family. Few of the studies of indigenous swidden cultivation have measured, calculated or estimated the area required for household subsistence under this form of management. It appears that these systems require less land than colonist agriculture (50 ha in Bolivia, 50–100 ha in Brazil) mainly because fallows are enhanced and managed with useful species over as much as 30 years, which reduces dependence on annual crops for subsistence and sale.

USE OF NATIVE SPECIES

The encouragement and planting of native and semi-domesticated species amongst annual and semi-perennial crops discourages the establishment of noxious weeds and grasses (e.g. *Imperata* spp.), whilst improving the colonization of early successional species. Crops domesticated by indigenous groups use locally available nutrients more effectively than imported cultivars (Clay, 1988). Managed fallows have a litter-fall higher in nutrients than unmanaged fallows (Unruh, 1988). Fallow management also increases the chances of distribution of seed by frugivores which may result in the presence of more economically useful plants. Not only is soil less likely to degrade under these practices but swidden fallows produce a forest with more useful species present than undisturbed forest. Many of these useful fruit producing species in turn attract game which are harvested by indigenous communities.

Recent agroforestry research

There have been few attempts in the tropical moist forests of Latin America to promote agroforestry techniques based on the wealth of indigenous technical knowledge. Recent research has generally attempted to solve the problem of declining soil fertility and degradation by other means, but has had limited technical success. Projects are beset with infrastructural and economic difficulties, as shown in the examples below.

ANNUAL CROPPING RESEARCH, YURIMAGUAS, PERU

Research at Yurimaguas in the Peruvian Amazon is based upon the premise that poor soil fertility is the major constraint to agricultural output and this problem can be overcome by correct applications of chemical fertilizers (Nicholaides *et al.*, 1985). A continuous cropping system was developed to replace slash and burn agriculture in which yields of annual crops could only be maintained at an adequate level for two years, before fallowing became necessary. The theory underlying this approach was that if continuous production is possible on Amazonian soils, agricultural production systems can be stabilized through the use of modern inputs. The need to migrate once the soil is exhausted no longer becomes necessary.

A rotation of rice / maize / soyabean (three crops per year) was introduced, which was repeated continuously. To achieve this 1 t lime, 80–100 kg N, 25 kg P and 100–160 kg K were required per hectare per year, along with pesticide inputs. These inputs produced good returns and a threefold increase in income over traditional techniques. While producing information on crop / soil dynamics for specific tropical zones, this research has completely ignored any indigenous knowledge of land use and soil management. The infrastructure required to maintain the system is not in place throughout much of the Amazon. Chemical inputs are simply not available, nor is credit without land title. The distance to market is often a limiting factor to profitable commercial agriculture.

NORTHWEST BRAZIL INTEGRATED DEVELOPMENT PROGRAMME

The Brazilian Government has attempted to promote sustainable perennial crop-based agricultural systems in Amazonia. It set up the Northwest Brazil Integrated Development Programme or *Polonoroeste* in 1981 which applied to all of the State of Rondonia and the western part of Mato Grosso. The objective was to reduce forest clearance on land of little long-term potential and promote tree crop farming.

These initiatives have failed to slow the rate of deforestation or change colonist farming systems. The implementation of macro-economic austerity measures during the early 1980s resulted in a reduction in funds available for credit and subsidized inputs. When credit was available, farmers were reluctant to invest in perennial crops as the subsidies on offer were not sufficient to offset the risks associated with the cultivation of new crops of which the new colonist had little or no experience (Mahar, 1991).

The long-term investment required for sustainable land use is unattractive where inflation is high and tenure insecure, and short-term profit seeking has become the predominant strategy (Anderson, 1990). The end result has been an abandonment of land after several years cropping or the sale of such land to cattle ranchers and a movement of colonists to the frontier.

BRITISH TROPICAL AGRICULTURAL MISSION, BOLIVIA

Until recently the British Tropical Agricultural Mission based at Santa Cruz in the Bolivian lowlands had not investigated agroforestry as a possible viable alternative to the problems of declining fertility under annual cropping systems. In the past few years alley cropping with *Leucaena leucocephala* and the introduction of macadamia, cashew, peach palm and coconuts have been investigated (Johnson, 1991; Wilkins, 1991). Difficulties have been experienced, however, with marketing of tree crop products and *Leucaena* does not perform well under acid conditions.

Experiments are also being attempted with biologically and economically improved forest fallows, again with the introduction of exotic leguminous species. So far no attempt has been made to study indigenous farm management practices to assess their potential for improving the management, fertility and output of settler agriculture.

THE COCA AGROFORESTRY PROJECT, EQUADOR

The Coca Agroforestry Project in Napo Province of Eastern Ecuador has been promoting agroforestry techniques since 1984 (Peck, 1990). Here, the indigenous swidden system of the Napo Quicha Amerindians did form the basis for some of the management practices recommended by the project. Demonstrations focused on agroforestry practices within the existing perennial crop systems (robusta coffee) and pastures of the colonists. Some technical successes have been reported on the establishment of economic tree species in pastures and coffee plantations, but their economic potential and the market potential of the new products has not been taken into account.

Blueprint for colonist agriculture?

Much of the research completed to date on indigenous agroforestry practices has been of a descriptive nature. There have been few attempts to translate the results of an improved understanding of the complexity of these systems into practical advice for new colonist farmers in Latin America.

Warner (1991) argues that indigenous swidden management cannot serve as a model for agricultural development for future farming systems in the tropics. She states that the regeneration of the forest is crucial for the long-term productivity of swidden systems and many traditional farmers are no longer able to leave their fields fallow 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 too tied to cultural and religious systems to be readily transferable to other societies and groups. Wilken (1989) also argues along similar lines, suggesting that transfers of traditional technology require a high degree of social, economic and technical agreement between senders and receivers.

These arguments, however, appear to ignore the success of both *ribereño*, *caboclo* and Japanese (see Cases 6, 8, 10 and 11) adaptations of traditional agricultural techniques in the Amazon Basin, and the success and adaptability of Huastec agroforestry in Mexico (see Case 5). The Japanese of Tome Acu, although they had little cultural similarity and had access to capital and education, based many of their agricultural practices upon the techniques of the Amerindian, as it was essential to do so to survive during the early days of their colonization.

TRANSFERABLE ELEMENTS

It is acknowledged that there are enormous cultural differences between the Amerindian and the recent colonists in Latin America. It will not be a simple task to transfer the more sustainable indigenous systems to the new colonists whose current practices are based upon the techniques used in their home states. It is admitted that many traditional Amerindian practices are too area-specific and tied to indigenous cultural practices to be wholly transferable. However, the principles of traditional practice have been adopted by the *caboclos* and *ribereños* of the Amazon Basin, in part commercialized, and can serve as a basis for the development of agroforestry practices by the new colonists. The more important elements of traditional practice suitable for replication on colonist farms are listed below.

1. The integration of trees into the agricultural system, in particular in enriching fallows to increase their productivity.

2. The flexible use of micro-environments, for which different crops are suitable, and the maximum use of light and nutrients in multi-cropping practices.

3. The use of intensive mulching practices alongside extensive fallow 'slash and burn' practices.

4. The maintenance of agroforestry plots at different stages of succession, which reduces risk and maintains flexibility in the system.

5. The use of wild game and fish.

The adoption of agroforestry does not imply an end to the production of new colonist preferred annual crops such as rice, or of the rearing of domestic animals. Annual crops are produced at the beginning of the swidden cycle, and animals are integrated into indigenous practices. Systems based on indigenous agroforestry may however, result in a reduction in the area per farm of annual crops as farmers become more dependent for subsistence and sale upon tree crops in the swidden succession. This would be a positive change resulting in less annual destruction of forest for the production of staple food crops.

LIMITING FACTORS

There are several major constraints which may prevent the successful transfer of traditional agroforestry techniques to colonists in the Amazon Basin.

1. Those currently practising swidden agriculture have low social status which is a barrier to the adoption of their techniques by settlers (Dejou, 1990). Many new colonists aspire to become 'modern' cattle ranchers despite the low productivity of ranching in the Amazon region, as they see cattle as an inflation-proof capital reserve.

2. Those who practise traditional agroforestry systems are increasingly migrating to centres of population to benefit from health and education services. Their children do not inherit their local technical knowledge. Even where such farming families reside in rural areas, their children attend boarding schools elsewhere and do not learn farming skills. There is, therefore, a danger that their knowledge may become increasingly diluted over the coming decades.

3. Recent colonization has resulted in little contact between new colonists and local traditional farmers, leading to little exchange of information and agricultural techniques (Parker, 1989). The latter inhabit, for the most part, lowland floodplain areas, whereas much of the colonization has followed the construction of roads in the dry lands.

4. It appears to be technically possible to produce a wide range of useful fruits and other products from traditional agroforestry in Latin America. Marketing of these products is seriously constrained, however, by the distance to market, crop perishability, a shortage of processing capability, a shortage of credit and a lack of marketing co-operatives. Where markets are not too distant, agroforestry and extraction appear to be reasonably successful, e.g. Iquitos in Peru and Belem in Brazil, although the greater the distance from the market, the less profitable they become (Padoch, 1987). The urban areas of Amazonia are growing, and half the population of the region is estimated to be living towns (Butler, 1989). Therefore, there appears to be a market for new colonist annual crops but not a well-established market for traditional forest and agroforestry products.

5. Title to land, or at the very least usufruct rights to land over the long term are required for the successful adoption of agroforestry. Indeed, successional swidden management requires access to a particular piece of land for up to 30 years or more. Current new colonist agriculture can only succeed while there is further land at the frontier to colonize. If title could be guaranteed to settlers and no further rights allowed whilst in possession of a plot, then the colonist may be encouraged to invest over a longer period in the land. There is, therefore, a need for government policies to be put in place which help to curb land speculation, and / or grant title or clear usufruct rights in order to encourage the new colonists to adopt agroforestry practices.

For example, there is little evidence as yet that neighbouring Brazilian farmers are adopting the Japanese techniques (see Case 11) on a large scale. They do not have secure title to land (a prerequisite for obtaining credit) and cannot, therefore, invest labour and capital into a perennial crop-based system that requires several years before it begins to yield a return.

6. Little research has been completed on productivity and labour use in swidden agricultural systems. It is not clear how much land is required for household subsistence. Although high incomes from *ribereño* agroforestry in Peru have been reported (Padoch and de Jong, 1987), these are the result of the proximity to the market. There are few references to actual labour use in traditional systems of agroforestry. It is clear that in successional management systems labour requirements on a given plot decline over time. High inputs, however, are required at the creation of the swidden and during the production of annual staple crops. As tree crops begin to dominate, labour needs are much less; only occasional weeding and harvesting work is required. However, where there are dense stands of tree crops ready for harvesting, labour requirements will once again be substantial.

RESEARCH PRIORITIES

From the factors outlined above, further research is required to enable a suitable blueprint for sustainable agriculture in the tropical rainforests of Latin America to be drawn up. The main research areas are listed below.

1. There is a danger that the agricultural systems of the indigenous populations of these regions may disappear in the not too distant future as contact with outsiders increases. Although market-orientated systems derived from Amerindian techniques of swidden management are not subject to the same pressures and will probably survive, they are adaptations of traditional practices. It is therefore essential that further research is commissioned on indigenous management systems whilst this is possible.

2. Micro-economic research is needed to establish resource requirements and productivity, especially of land and labour in both Amerindian production systems, and those derived from them. Such research needs to identify the socio-economic and biological constraints to improved performance and replication.

3. Further investigations are needed to establish the market potential for the products of traditional agroforestry practices, and to assess the effects of market development; i.e. if markets were to develop would this result in large-scale clearance of forest? There is little or no evidence to suggest that any Latin American farmers would not readily respond to market opportunities.

4. More research is needed in the fields of sustainable agroforestry both formal and of a more participatory nature. The Overseas Development Administration is already addressing this problem with its 'Floodplain Forest Ecology and Management Project, Belem' and the 'Tocantins Forest Management and Rural Development Project', although the latter does not intend explicitly to utilize indigenous technical knowledge as part of its objective to encourage sustainable farming systems. The need is so great, however, that there is potential for many further such projects throughout the Amazon region and more generally in Latin America.

Conclusions

It can be argued that traditional agroforestry practices in Latin America make the best possible use of forest plant and animal resources. Not only are these management systems sustainable at current land/man ratios and possibly sustainable at much higher population densities, but they also increase the economic and social usefulness of the forest at large, by encouraging biotic diversity through successional management and providing a wide range of products for consumption and sale. Adoption of these systems would reduce the need for widespread annual cropping, large-scale forest destruction and land degradation associated with pasture creation by the new colonists.

Much of the research on traditional indigenous agriculture (both Amerindian and its derivations) has been of a descriptive nature. There have been few attempts to translate this experience into a system for sustainable agriculture for the new settlers of the Amazon Basin or elsewhere, even though many of the commentators on this subject (Anderson, 1989; Browder, 1989; Denevan *et al.*, 1984; Eden, 1990; Padoch and de Jong, 1987, 1991; Posey, 1985) have suggested that this approach has the greatest potential both economically and ecologically.

At present indigenous techniques of agroforestry do not play a significant role in the rural economies of many Latin American countries. This is largely because of the decline in numbers of traditional societies; 87 Amerindian ethnic groups have been lost this century (Posey, 1983) from the introduction of exotic diseases by outsiders.

Furthermore, in development circles, indigenous agroforestry techniques have been ignored. The focus of research and development has been concentrated on community natural resource management and extractive reserves, despite the fact that it has been estimated that there are between 1 and 2 million households in the Brazilian Amazon alone that derive their living almost exclusively from agriculture, not extractivism. The high profile that extractive practices have developed in the past few years persuaded institutions to support this activity, when it is argued by some (Anderson, 1990; Browder, 1990) that this form of forest management produces less in terms of income than extensive or intensive agroforestry.

Besides the lack of appropriate research, the main constraint to the potential adoption of indigenous agroforestry techniques by new colonist farmers lies in their very complexity. High levels of often very location-specific technical knowledge and skills are needed to implement them. Also, sufficient micro-economic information regarding labour use and production costs of agroforestry activities is not available, whether to help agricultural research institutes develop the more economically viable adaptations, or to help governments develop enabling policies.

It is certain that public or donor support, both technical and financial, will be necessary to aid the new colonist to adopt these techniques. Extension services will be essential, given the lack of agroforestry knowledge of the new colonist at the frontier. Financial support will be required for the development of rural marketing infrastructure, post-harvest technology and research to establish the socio-economic conditions necessary for the successful introduction of this type of land use.

Furthermore, there is a need for government policies to be put in place which would help to curb land speculation and encourage new colonist farmers to adopt sustainable management practices. It is also necessary for governments to improve conditions for the poorest farmers or landless in their home states, in order to stem the tide of colonization of the rainforest.

Thus few serious attempts have been made to develop and promote sustainable agricultural or agroforestry based upon traditional swidden management practices in Latin America, despite the interest in these techniques over the last decade (Anderson, 1990; Browder, 1989; Denevan *et al.*, 1984). There is, therefore, great scope for donors to contribute to research and extension, and to assist in the dissemination of existing indigenous technical knowledge, so that it can be adapted to form a blueprint or model for sustainable and productive agriculture for the new colonists. The governments of the Amazon region should also play a part in improving access to resources for the poorest farmers, and establish that they are committed to the conservation and sustainable use of natural resources.

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