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FORESTLAND FARMING IN WESTERN AMAZONIA: STABLE AND SUSTAINABLE

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ABSTRACT

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Forest farmers are, by a long way, the number one agent in the depletion of tropical forests. Through a combination of fast-growing human numbers, generally poor soils, and declining space for migratory agriculture of traditional style, these farmers impose on forestlands a type of agriculture that is essentially unsustainable. There being no longer sufficient scope, whether in terms of space or time, for fallow systems to allow the natural forest to regenerate, the result is degradation, if not destruction, of much forest cover.

In the face of this situation, there is urgent need to develop agricultural systems that are both stable and sustainable. Recent research is showing there is a considerable number of "models" for farming strategies that make self-renewing use of forestland resources. A range of these illustrative instances is to be found in western Amazonia, where local tribes practise a variety of agro-ecosystem styles of farming. The models appear sound in concept, both ecologically and economically. They present an opportunity for development, on the part of governments and aid agencies, via trial schemes and demonstration projects. The eventual outcome could be a series of local economies, based on sustainable use of forest resources, plants and animals alike, that are naturally adapted to nutrient-poor soils of forestland zones in the humid tropics.

INTRODUCTION

Forestland farmers cause more depletion of tropical forests than all other major agents — commercial loggers, fuelwood gatherers and cattle ranchers — put together (FAO and UNEP, 1982; Myers, 1984, 1985; World Bank and World Resources Institute, 1985; see also Houghton et al., 1985; Melillo et

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al., 1985; Molofski et al., 1985). In many forest zones, slash-and-burn activities impoverish the fertility of soils and leave behind grossly impaired ecosystems. In many other forest tracts, the forest is destroyed outright, eliminating tree cover completely and permanently.

There are now some 250 million of these small-scale cultivators. Moreover their population growth rates reflect not only natural increase, but immigration on the part of the "shifted" cultivator who swells the ranks of the shifting cultivator. Overall their numbers are increasing at rates between 3% and 7% a year, which means that in many many sectors of the tropical forest biome their totals may well double by the end of the century.

The key question is, how to help these human communities to shift their farming practices from extensive, migratory and ultimately wasteful use of forestland ecosystems, to intensive, stabilized and permanently productive use?

Fortunately there is a good number of examples of forestland farming strategies that offer some answers. Several instances occur in western Amazonia, where forest tribes have devised, through a lengthy process of trial and error, a range of agro-ecosystem styles of farming, that make self-renewing use of available resources. It is these agro-ecosystem strategies that are the subject of this paper.

BACKGROUND: WESTERN AMAZONIA

Western Amazonia is the wettest large sector of Latin America's tropical forests. The perhumid climate makes it singularly unsuitable for mass settlement and conventional agriculture. Yet those parts of the region that lie in Colombia, Peru and Ecuador are being colonized by small-scale farmers at ultra-rapid rates. This western-Amazonia colonization is due to an influx of landless peasantry flooding over the Andes and sweeping down into the plains. In Peruvian Amazonia, for example, the population expanded from roughly 400 000 in 1940 to 1.3 million in 1972, and to more than 2 million in 1985, and it is projected to reach 5 million by the year 2000 (Dourojeanni, 1980).

Many of these subsistence settlers practise a form of slash-and-burn cultivation that is particularly depletive of forests (Mahar, 1979; Barbira-Scazzocchio, 1980; Goodland, 1980; Moran, 1981, 1982; Sioli, 1984; Hecht, 1982; Smith, 1982; Hemming, 1985; Schmink and Wood, 1985). There is urgent need to develop a model for settlement that makes efficient use of cleared lands, even in territories with infertile soils. Fortunately we are now gaining knowledge that enables us to develop such a model, albeit in a preliminary and exploratory form.

NATURE AND SCOPE OF THE MODEL

In essence the model depends on the exploitation of all resources that can be harvested in a sustainable fashion (Goodland et al., 1978; Eden, 1980;

Denevan, 1981; Duke, 1981; Smith, 1981; Plotkin and Schultes, 1982; Bunker, 1984; Posey et al., 1984). As such, the model incorporates three principal elements: (1) agriculture and aquaculture; (2) cropping of wild and semi-domesticated species for food, notably plants but also mammals, fish, reptiles, and the like; and (3) harvesting of a range of other forest products for further purposes, such as building materials and medicine. These three activities are not practised in isolation from each other; rather they are pursued in concert, with mutually supportive benefit. Nor is the lifestyle confined to patches of cleared homesteads. Rather it combines an intensive use of croplands with an extensive use of surrounding forest. In other words, the strategy seeks to make self-sustaining use of such parts of the forest as are cleared, while drawing widely on renewable resources of the natural forest.

Overall the approach makes for ecologically sound and efficiently productive agro-ecosystems. They prove profitable; they are labour intensive; they emphasize multiple use in an integrative fashion; and their success rests entirely on locally available materials. Hence they contrast markedly with conventional agriculture in Amazonia, which leads to erosion and compaction of soils, to leaching of nutrients, to outbreaks of episodic pests and diseases, to rapid decline in crop yields and degradation of soils, and to clearing of evermore forest. Hence it also contrasts with those variations of semi-modernized agriculture that depend upon substantial inputs of synthetic fertilizers, among other artificial additives (Sanchez et al., 1982). To reiterate a central point, it is the "native" agro-ecosystems, developed with no external inputs, that are the focus of this paper.

MULTI-TIERED AND MULTI-USE AGROECOSYSTEM

The basis of the system is the growing of crops for food, in conjunction with the growing of trees for fruits, fertilizer and fuel (Basso, 1973; Smole, 1976; Bergman, 1980; Hiraoka and Yamamoto, 1980; Weil et al., 1980; Frechione, 1981; Posey, 1982; Denevan et al., 1984; Prance and Kallunki, 1984). To these ends, the system mobilizes a wide variety of multi-tiered and multi-use crops. In a fully-developed system, it can feature as many as 100 species in a single hectare. This all adds up to a polycultural system of agriculture that, by virtue of its diversity, goes some way to mimicking the ecological complexity and stability of the natural forest.

A host of crops is available, even though few feature in established cropping systems. In the topmost layer are palms, which provide food and a variety of other products, together with leguminous trees used for fertilizer as well as fuel and building wood. At middle levels are cacao and coffee bushes, together with leguminous vines and beans for food and nitrogen. Also at this level are cash crops such as lemongrass, cassia, ipecac and zingiberaceous spices. At the lower levels are short-stemmed cereals such as rice, plus root and tuber crops such as taro, yams and sweet potato, and also vegetables and weed-type crops for green manure. Interspersed among these

diverse crops are insect-repellant plants, among other biocontrols, and cucurbits that serve to counter weeds by allelopathy.

This combination represents but a small selection of promising plants available, whether for food or income. After all, western Amazonia is the putative home of one of the dozen leading food plants of the world, tapioca, and also of pineapple and cacao. Many more plants must surely be awaiting our attention, with much scope for new crops, whether for subsistence or commercial purposes. To cite but a single instance: the Cubeo Indians of eastern Colombia grow a variety of capsicum pepper, with red pods that serve as an exceptional seasoning spice.

Indeed it is the folkloric experience of local tribes that points the way for many forest plants to be developed as potential crops. The Siona and Seocya Indians of eastern Ecuador utilize an extraordinary total of 224 species, spanning 166 genera and 69 families, most of them for foods, with others for materials for tools, construction purposes and crafts, also medicines (Vickers and Plowman, 1984). The Chacobo Indians of northern Bolivia grow 40 species of food crops in their garden farms, ranging from rice and corn to papayas, water melons and cashews (Boom, 1985); and they utilize a remarkable 80% of the surrounding forest's trees, shrubs, vines and herbs, for foods, clothing, housing and medicines. With respect to medicines in particular, the Chacobo draw on an array of arboreal decoctions that serve to relieve ailments such as stomach aches, fever, diarrhoea, chest pains and skin infections; while they use a herb of the pepperplant family that appears to cure toothache when leaves are placed against gums of the mouth.

Some of these tribes are already adept at cash-cropping of forest products. The Gavioes Indians of western Brazil are so capable of production, transporting and marketing of forest goods, that in some areas with dense stands of Brazil nut trees, the produce generates more revenue than an equivalent area of pasture devoted to catle ranching (Ramos, 1980; Bunker, 1981).

Fruits and beverages

In particular, there is an abundance of forest plants that can be incorporated into smallholder agriculture, notably fruit trees (National Academy of Sciences, 1975). Thriving on nutrient-poor soils of eastern Peru is an endemic tree, *Parahncronia peruviania*, that produces an exceptionally sweet fruit (despite its local name of "rotten orange") and is almost entirely unknown outside its local habitats (Gentry, 1984). Native to the uplands of the western rim of Amazonia in Colombia and Ecuador is a fast-growing shrub, *Solanum quitoense*, of the potato family, that produces prolific quantities of an acid-sweet fruit, the naranjilla, looking like a small orange tomato and featuring abundant juice of uniquely refreshing flavour (Heiser, 1972). So promising is the naranjilla that it has recently been developed into a commercial crop in several countries of humid Latin America — a portent of what could lie ahead for other forest fruits. Something similar applies to nut-producing

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plants: the almendro tree of Peruvian Amazonia produces an almond-like nut that is eaten widely, though undeveloped as a commercial crop (Gentry and Dodson, 1984).

A number of distinctive beverages are also available (Weil et al., 1980). Native to western Amazonia is a shrubby vine, *Paullinio cupana*, that furnishes a popular stimulating drink known as guarana. A close relative is *P. yoco*, a woody climber that grows in the borderlands between Colombia and Ecuador, with a bark that yields a caffeine-high drink without the irritating side-effects of more common stimulants such as coffee.

Edible Oils

Still other trees produce unusual amounts of that crucial yet scarce component of Third World diets, edible oils. For instance, the cacay tree, *Caryodendron rinocense*, is an abundant source of a high-quality oil used widely for cooking (and as is the case with certain edible oils, for industrial applications, e.g. soaps and cosmetics) (Weil et al., 1980). A quick-growing tree that is native to dense forest, the cacay is ideal for multi-storeyed agroforestry systems — unlike many crop plants that prefer lots of light. According to research experiments in Colombia, the cacay may soon be promoted as a commercial crop.

Of course the best sources of edible oils are palms. The Buriti palm, *Mauritia flexuosa*, produces an oil with as much vitamin A as spinach and carrots, and as much vitamin C as citrus fruits (Braun, 1968). Also an abundant source of edible oil is the seje palm, *Jessenia bataua*, with a fatty-acid content equal to that of olive oil; the fruit also possesses an amino-acid complement to surpass soybean and even to rival meat as a source of protein, while the fruit's juice offers nutritional value comparable to human milk (National Academy of Sciences, 1975). Several other species of *Jessenia* supply high-quality edible oils among other products for local people, and bear investigation as commercial crops for widespread use.

Perhaps the most promising source of edible oil is the Babassu palm, *Orbignya martiana* (though its oil may ultimately serve best as a fuel, and as an industrial feedstock for detergents and fatty acids) (Balick, 1984; Pick, 1985). A single palm readily produces one tonne of fruit per year, one-twentieth of which is oil (half the kernel). This translates into a yield of 40 kg oil, equivalent to one quarter of a barrel — together with 40 kg protein and 350 kg carbohydrate. After the kernel is extracted, the nut's hard shell makes an excellent fuel that can be burned directly or converted to charcoal.

The Babassu is being developed, albeit slowly, as a commercial crop for smallholders. During the course of the 1983—84 harvest, forestland dwellers sold kernels totalling about 300 000 t, yielding 120 000 t of oil and 90 000 t of mealcake, with peak prices of $1200 per tonne of oil and $100 per tonne of cake. An average household gained an income of about $170 (Pick, 1985).

So much for some general comments on native plants of Amazonia that

lend themselves to intensive cultivation in homesteads, as well as to collection in the wild. It is exceptionally significant that when the U.S. National Academy of Sciences (1975) reviewed some 400 plant species, mostly of the tropics, that are of promising economic value while grossly under-utilized, well over 100 proved to be Amazonian plants; and of 36 species chosen for urgent development, 12 were Amazonian.

Animals

A number of animals contribute likewise (Wetterberg et al., 1976; Ross, 1978; Dourojeanni, 1980; Smith, 1982). In floodplain areas, for instance, smallholders can raise the capybara (Gonzalez, 1977; Vasey, 1979). The largest living rodent, often attaining the size of a pig, the capybara regularly reaches 50 kg and occasionally 75 kg. In its natural habitat, it puts on weight at a rate of more than 50 g a day, while under captivity and with better feeding, it proves to be 3.5 times more efficient in meat production than cattle, generating an average of 63 kg of meat per ha on ranches — while the net cash return is almost three times higher, $11 versus $4. The capybara produces between 1.2 and 1.8 litters per year, with four—six, and occasionally eight, progeny, per litter. The animal can be harvested at a rate of about 40% of stocks per year, by contrast with only 10% or so for cattle.

In a similar fashion, there could be prospect of a first-rate domesticate in the form of the paca (Smith, 1976 and 1982). This rodent's meat tastes rather like pork, but it is richer in protein and lower in fat; it sells locally at prices higher than for good-quality beef. A female paca typically produces only one or two young, even though she bears four to six nipples, which suggests scope, through domestication, for an increase in litter sizes. There could be an eventual prospect that, in terms of unit—area productivity, the paca could match cattle as a source of nutritious meat in the humid tropics, especially insofar as traditional livestock tends to fare poorly in forest zones because of disease problems.

Even reptiles can be domesticated. Seven species of river turtles, for instance, could generate large amounts of high-grade meat through careful management (Mittermeier, 1978). Turtles feed readily on many sorts of aquatic plants; they withstand food shortages at the end of the dry season without harm; because of their low metabolic rates, they do not need as much food as warm-blooded creatures; and they are adapted to less living space than higher vertebrates. Theoretical calculations suggest that a 1-ha lake of turtles could produce well over 2 tonnes of meat a year, by contrast with 50 kg of beef per ha of average cattle pasture in Amazonia. Domestication of turtles is not so unusual as it may sound: forest-dwelling Indians used to corral breeding groups of turtles for year-round cropping (Smith, 1974).

Even the green iguana could be raised in captivity on smallholdings. Experiments of the Smithsonian Tropical Research Institute (Rubinoff, 1985) show that as many as 60 animals can be raised in a 10-m^2 enclosure. With a

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head—body length of 45 cm, an adult can convert vegetation to protein with an efficiency comparable to that of cattle. The iguana has long been prized for its meat when cooked in heavily spiced stew, while the eggs, boiled in salt water, are likewise considered a delicacy.

In addition to these leading candidates for semi-domestication, there could be a prospect of raising agoutis and manatees, among other wild herbivores. Whatever the species, all can be raised on sectors of homesteads interspersed among crop patches, through integrative management systems (Goodland and Bookman, 1977; Goodland, 1980). For those farmers who wish to persist with cattle, a more rational form of husbandry may lie with stall-fed glucose and other types of carbohydrate feed, derived from pretreated foliage taken from standing trees (Tosi and Voertman, 1975).

So much for terrestrial components of agro-ecosystems. In addition there is the aquaculture dimension. Amazonia contains the most diverse freshwater fish fauna in the world (Goulding, 1980; Smith, 1981; Chernela, 1982). Were the fish resource to be even superficially exploited in a systematic fashion, it could generate far more animal protein for the region than the 40 000 km^2 of cattle ranches presently established. As an example of the curious attributes to be found among Amazonian fish, with potential for agro-ecosystems, air-breathing fishes could lend themselves to artificial ponds. According to the Smithsonian Tropical Research Institute (Rubinoff, 1985), many natural ponds in Amazonia shrink during the drier parts of the year, whereupon crowded conditions in the pools leave fish short of oxygen. Air-breathing species can cope with this oxygen deficiency; and in such fish, a mass of blood vessels on the creature's forehead works much like a human lung, pumping atmospheric oxygen directly into the bloodstream. Should these fish prove to be suitable for semi-domestication in artificial ponds, they could provide a much-needed native source of protein.

HARVEST OF WILD PRODUCTS FROM THE FOREST

The established forms of meat production are often supplemented by harvesting of wild creatures from the surrounding forest — not only pacas and turtles, but also tapirs, peccaries, deer, primates, birds, armadillos, snakes and lizards. The Yekuana Indians of southern Venezuela harvest 9 species of terrestrial mammals, 9 species of monkeys, and 18 species of birds, on a regular self-renewing basis (Linares, 1976; Frechione, 1981). A number of other human communities consume an average of 25 g of wild meat per day, occasionally 10 times as much (Smith, 1976; Wetterberg et al., 1976). In the Peruvian sector of Amazonia, rural people obtain well over four-fifths of their animal protein from hunting and fishing (Dourojeanni, 1980). In one extensive area, they consume an average of over 50 g a day of wild animal meat, plus 135 g of fish, by contrast with 22 g of domestic fowl and 12 g of pig meat. In Peruvian Amazonia as a whole, the 1977 output of wild animal meat is estimated to have surpassed 13 000 tonnes — and this official figure

could under-estimate the actual total by half, in which case the commercial value would at least equal that of commercial logging.

In addition to animals, of course, local people harvest many wild plants as sources of food from the forest, notably fruits. This constitues a further contribution to the harvest available from forest tracts surrounding human settlements. All in all, the strategy depends upon the farmer making intensive use of his homestead in conjunction with extensive use of the forest environs: without selective exploitation of the forest and its extreme diversity of products, a homestead can scarcely remain a sustaining lifestyle. The essence of the overall strategy is that it adds up to a stabilized (i.e. non-shifting) and self-renewing mode of agriculture, in the proper broad sense of the term.

Forest ecosystems can contribute in still further ways. For instance, a good number of products are available for harvest as non-food cash crops. The capacity of the forest to generate commercial goods is often underestimated, even though, to cite one of the most experienced scientists in this field, it harbours "incalculable value as an untapped emporium of germplasm for new economic plants" (Schultes, 1980). Among major categories of potential products are fibres, waxes, oils and essential oils, latexes and other exudates, resins and gums, insecticides and medicines (Plotkin, 1982, 1983). Chicle, for instance, already ranks as a smallholder cash crop,

As for fibres, other parts of the tropical forest biome indicate the scope that surely lies ahead. In Southeast Asia, rattans and bamboos constitute a cash crop with an annual export value of more than $50 million (Dransfield, 1981). In the case of western Amazonia, fibres have scarcely been investigated at all for their commercial potential. Yet in Peruvian Amazonia, lianas constitute almost one quarter of plant species, with an average of 41 species in the sampled 0.1 ha plots (Gentry and Dodson, 1984). In the light of experience in Southeast Asia, these lianas surely represent a vast stock of raw materials for the needs of innovative industry, especially as synthetics become ever-more expensive. Were suitable candidates to be researched and developed, they could supply sizeable incomes to forest-dwelling farmers.

Much the same applies to less obvious products, such as waxes, insecticides and dyes (Plotkin and Schultes, 1982). As an example of the last-named category, the tree *Chlorophora tinctoria* supplies fuscic, a specialized dye with a range of natural colours that are coming into increasing demand in commercial markets.

MEDICINALS

As for medicinal products, tribal peoples of western Amazonia employ no fewer than 1300 plants as drugs and narcotics, many of them with biodynamic principles of relevance to modern medicine (Schultes, 1980; Plotkin, 1982). Certain of these species could, with research and develop-

ment, emerge as potential cash crops, whether cultivated or collected wild. Already ipecac and quinine generate significant revenues for a number of smallholders.

Equally promising could be plants with potential against cancer (Douros and Suffness, 1978; Plotkin, 1982; Gentry and Dodson, 1984). Among the dozens of Amazonian species found to possess anti-cancer activity, there could be, according to a statistical analysis (Duke, 1982), at least five with the capacity to generate "superstar" drugs on a par with the two from the rosy periwinkle. Something similar applies to plants for use as contraceptives and several have been documented (Duke, 1981; Plotkin and Schultes, 1982; Plotkin, 1983; Gentry and Dodson, 1984). Certain common types of fungal infection of the skin can be countered through a red resin from the bark of several species of *Virola* (trees that also offer promise for commercial timber, by virtue of their specialized hardwoods). Several tree species of *Brunfelsia* yield potent materials for use against rheumatism, arthritis and syphilis; one species, *B. grandiflora*, effective against inflammations, has been developed to the extent that it is starting to rank as a cash crop (Weil et al., 1980).

Modern medicine is further served through wild primates used for biomedical research. The most frequently used primates, after the Asian macaques, are the squirrel monkeys, *Saimiri* spp., of western Amazonia. In addition there are the night monkeys, *Actus* spp., important for malaria and eye research, and the moustached tamarin, *Saguinus mystax*, used for study of hepatitis. A single monkey is worth between $200 and $300. According to preliminary investigations (Heltne, 1982) on two small islands near Iquitos in Peru, amounting to just a few hectares, wild populations could, if managed for sustainable yield, generate a sustainable crop worth $24 250 per year.

Of course, a cropping operation of wild fauna need not be confined to primates. The same tract of forestland can produce an export harvest of birds, notably parrots, with revenues that could match those from primates. In addition, and as we have seen, the same forest patch can supply a harvest of turtles, capybaras and other animals for meat, plus caimans for luxury-trade hides.

ECONOMIC RETURNS

What could be the economic returns for a forestland settler with an agroecosystem developed along these lines, drawing produce from both his own holding and from the surrounding forest; i.e., what would be an economic return from cash crops on top of subsistence food and materials? We have little research to guide us. Again, there is pressing need to establish an economic quantification of forestland agroecosystems.

Fortunately two pieces of enquiry offer some insights, albeit preliminary and approximate. In a small locality near Iquitos in Peru, exploitation of several dozen plants — notably the fig known as oje, *Ficus antihelminthicus*, for medicinal materials, barbasco (*Lonchcarpus* spp.), palm heart, and several

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fruits (but not wild meat) — yields a household income ranging from $500 to $5000 per year, with a rough mean around $1200 (Padoch, 1984).

A somewhat broader-ranging analysis has been developed by the Ministry of Agriculture in Ecuador (Paucar and Gardner, 1981). As much as 85% of animal protein consumed by local people is obtained from wild creatures, such as peccaries, pacas and deer, some 40 mammal species in all. One km^2 of forest can yield a sustainable harvest of 240 kg of wild meat per year, worth a little under $2 per kg, or a total of almost $440. Were this harvest, haphazard as it now is, to be upgraded into a methodical operation, and were it to be extended to birds, turtles and fish, the minimum potential value could surely be increased 10 times. In addition, and since almost one-third of Ecuadorian Amazonia is made up of rivers and swamps, there is plenty of scope for cropping of caimans, at least two per ha per year, for a return of $14 550 for hides and $1820 for meat. In addition again, a harvest of 20 primates per km^2 could generate $5000 a year. This all means that 1 km^2 of forest could produce an overall annual income of well over $20 000, provided it were scientifically managed for self-perpetuating cropping — an income to be contrasted with only $150 from commercial logging, and not much more from cattle ranching, both of which activities, while being the main forms of current exploitation, do not leave forest ecosystems nearly so intact.

CONCLUSION

So much, then, for a preliminary appraisal of smallholder "agro-ecosystems" in forestlands of western Amazonia. The model appears sound in concept, both ecologically and economically. What it needs is urgent development through trial schemes and demonstration projects. This presents a fine opportunity for innovative and action-oriented research on the part of governments and aid agencies. Ultimately one can visualize a potential economy emerging, based on sustainable use of forest resources, plants and animals alike, that are naturally adapted to nutrient-poor soils of forestland zones of the humid tropics.

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