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DYNAMICS OF FALLOW SUCCESSIONS AND INTRODUCTION OF ROBUSTA COFFEE IN SHIFTING CULTIVATION AREAS IN THE LOWLANDS OF PAPUA NEW GUINEA

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ABSTRACT

The traditional shifting cultivation system in the lowlands of Papua New Guinea consists of mixed food crop gardens in which yams (Dioscorea spp.), bananas, taro (Colocasia esculenta) and sugarcane predominate. The cropping cycle is usually for 18 months, followed by a fallow cycle of up to 30 years. During the cropping cycle, two speci of fruit trees, Pometia pinnata and Artocarpus altilis are also planted the leaves of the former also being used as a mulch and green manure in yam cultivation. Fallow succession follows rather systematic patterns about which farmers have a thorough understanding.

Robusta coffee, a cash-crop component, has been added to the system in some areas since the late 1950s. It is usually grown in permanent blocks, but is interplanted with Leucaena as shade. Food crops are planted in the establishment stage, bananas and Xanthosoma being retained even in mature coffee gardens. The system seems to be a potentially promising one. But very little quantitative information is available on the production and performance of the system and practicall no systematic research has been undertaken. Since the Papua New Guinea fallow gardeners are willing to accept innovations, it will be appropria and timely to undertake serious studies so that the system can be improv A few items that merit immediate research attention are indicated.

Keywords: Agroforestry, Fallow successions, Papua New Guinea, Robusta coffee, Shifting cultivation

INTRODUCTION

Systems of shifting cultivation have long been characterised as "primitive" and resource depleting. In situations where national and multi-national timber companies come into competition for forest resources with shifting cultivators, it is common to hear arguments that these primitive forms of land use should be replaced by permanent cultivation and the use of fertilisers and high yielding, introduced plant varieties. However, recent interest in agroforestry and sustainable systems of agriculture is giving support to arguments presented in the 1970s that many forms of shifting cultivation are viable systems of land use and are critically important in the context of increasing dependence on high inputs in modern agricultural systems. (4,5,7). Systems of shifting cultivation too are vulnerable to changes such as a shortening of the fallow period where a grass fallow replaces a tree fallow. It is in this context that the concepts of agroforestry and the development of viable, sustainable tropical agroforestry systems have much to offer towards the improvement of systems of shifting agriculture. The agroforestry system described here is such a traditional system of shifting agriculture, with a recently added tree crop component. A similar system involving open field cultivation of food crops, coffee and Casuarina oligodon has been described recently from the highlands of Papua New Guinea (PNG) (2).

2. GENERAL DESCRIPTION OF AREA

A general description of PNG in relation to agroforestry has recently been given by Bourke (2). Approximately one-quarter of the forested area of PNG is well developed secondary forest, created and maintained by shifting cultivation (11). The system being described here is located on the southern fall of the northwestern coastal mountains,

which run northwest and southeast and separate a narrow coastal plain to the north, from the basin of the Sepik River, the second largest in the country, to the south.

The foothills of the coastal ranges are Pliocene mudstones interbedded with siltstones and sandstones, gently dipping to the south, which have been eroded into strongly slumped, polygonally branching hill ridges. The original lowland hill forest has been replaced with secondary vegetation ranging from gardens under cultivation, village coffee plantations, fallow garden regrowth (tall cane grass to tall secondary forest) to relatively undisturbed forest. Soils are brown forest soils, shallow dark clay soils, reddish clay soils (Eutropepts) and strongly weathered red and brown clay soils (Dystropepts), the latter two being widespread over similar hill country in PNG (1).

Mean annual rainfall increases along the ranges from west to east and is less seasonable in the west. For the station nearest the site under description, mean annual rainfall has been 2,159 mm (12 years of record). May to September is notably drier than November to March. Mean daily temperatures are 26 degrees C (mean max.29.9, mean min.22.2).

All land use systems in the region are a variation of a forest fallow system of shifting cultivation. To the east, fallow regrowth has been reduced to tall cane grass and scattered low tree species as a result of higher populations, lower total rainfall and greater seasonality, whereas to the west, gardens are cleared from well developed secondary forest. The system falls into two fairly discrete parts: mixed food crop gardens, which are cleared from forest each year, cultivated for a maximum of 18 months, and then fallowed for up

to 30 years; and permanent blocks of Robusta coffee, from which almost all cash income is produced. Some land has been cleared of all forest and sown in pasture grasses for cattle, but in almost all cases attempts at cattle farming have failed. Pigs are the traditional livestock. Most pigs are now Papua New Guinea-European crossbreeds. Sows are allowed to roam in the forest and in fallow garden areas where they mate with feral boars.

3. STRUCTURE OF THE SYSTEM

Land is cleared of fallow vegetation using axes and machetes and the debris burned, at the end of the dry period. Planting then takes place at the beginning of the wet period. The cultivated plots, known as "gardens" consist of mixed crop stands in which yams (*Dioscorea spp*), bananas (*Musa spp*), taro (*Colocasia esculenta*), and sugarcane (*Saccharum officianale*) predominate, but in which at least 27 other species are also cultivated (Table 1). During the cultivation period seedlings of two tree species, *Pometia pinnata* and breadfruit (*Artocarpus altilis*), are planted and they form "orchards" along the upper margins of ridges used most often for gardening. Sago palms (*Metroxlyn sp.*), coconuts (*Cocos nucifera*) and *Gnetum gnenom* are the other tree species which are grown from seed.

TABLE 1 ABOUT HERE

Between 1942 and 1945 Japanese and Allied armies fought across this area with consequent severe disruptions to village life. After the war many people experimented with radical changes to traditional life. One experiment involved the cultivation of hill rice for sale as a

cash crop. But the venture failed because of poor processing and marketing facilities. In the late 1950s the government introduced Robusta coffee as a cash crop, recommending that each family plant 500 trees in bush gardens, shaded with Leucaena.

Coffee has been widely adopted, but the average size of coffee gardens is small, consisting of 150 and 250 trees. It is, however, almost the only source of monetary income in the area, apart from government or mission salaried and wage employement. Coffee gardens and food gardens are located on discrete sites. However when forest is cleared for coffee, food crops are commonly planted during the Leucaena establishment stage, and when the garden is fully established bananas and Xanthosoma are often found amongst the coffee trees. At present coffee gardens are stable with little replanting or expansion. It is probable however that some people will shortly expand coffee planting onto 20 ha "communal" gardens.

Food gardens fall into three categories. The first garden planted following forest clearing is the most important and contains a restricted number of species. Yams planted in these gardens provide tubers used in ceremonies and exchanges and the gardens have many ritual restrictions. After the first harvest, yams are replanted almost immediately in the holes left by the first crop. Thereafter fewer restrictions would apply and more introduced species planted. A third yam crop is sometimes planted following the second harvest, but this is a less common practice, because it involves a greater effort in weeding. After the last planting has been harvested the garden is allowed to return to fallow. But even in the fallow period the land continues to produce food crops such as bananas, Xanthosoma and sugarcane which can compete with the invading tall cane grasses for some years.

FIGURE 1 ABOUT HERE

The general arrangement of the system is shown in Figure 1. Garden Site A is the newly cleared garden, B the replanted garden and C the less common third planting. After the garden site is allowed back into fallow it is rapidly invaded by weeds and short grasses dominated by Imperata. Within a year the short grasses will be shaded out by the tall cane grasses dominated by Saccharum robustum. This is an important succession providing cool, damp, dark conditions for tree seedlings, particularly during the drier part of the year. After about 12 years tree successions begin to shade out the cane grasses and 25 years after clearing, a 10-15 m tree succession becomes established. The pattern of species succession in fallow regrowth is given in Figures 2 and 3. New gardens are cleared in from 15 to 25 year-old fallows, with land nearer the village being cultivated more often than land farther away. Fallow successions are categorised by type, not by time: fallows ready for re-cultivation are known as "ripe" fallows. Farmers avoid letting fallows go beyond the "mature" stage, because of the dangers involved in felling tall forest.

FIGURES 2 AND 3 ABOUT HERE

Yam gardens are established along the upper slopes of ridges. Many coffee gardens are also found in these locations, as a result of the extension advice to farmers to plant the introduced crop on their "best land".

A particularly interesting aspect of the system is the use of Pometia pinnata leaves during yam planting. The Pometia is a large handsome tree, related to the litchi, with similar fruit. The fruits are borne on the ends of the branches between November and February. Harvesting is accomplished by climbing and lopping off fruit bearing branches. Later, during yam planting, the then dry leaves are collected by women, carried to the gardens in large bundles and applied into the ground with the "seed" yams. Gardeners believe that the leaves "give the tubers room to grow", but the leaves, rich in nitrogen, provide a good mulch in addition to their nutrient value. The regular cutting back of the trees appears to have an effect similar to pruning and stimulates fruiting. Figure 4 illustrates the method used to carry Pometia leaves, and Figure 5 shows bundles of leaves in a new garden.

FIGURES 4 AND 5 ABOUT HERE

4. SYSTEM FUNCTIONING

Almost all inputs into the systems come from within the village community. Land is occupied under laws which guarantee rights to customary owners and access to land is controlled by the leaders of extended families. Inheritance of land rights is normally from father to son, but daughters, particularly widows have no difficulty in

obtaining land for food crops. Many food gardens are cultivated on a usufructory basis and land which is not being cultivated is open to all village residents for collecting fuelwood and building materials or hunting. Land for coffee is more restricted, and some families have coffee gardens at a distance from the village. However most people build substantial "garden" house in which they stay while they work in gardens or coffee blocks away from the main village.

Most families clear land for gardens in co-operation with up to 15 other families. Once the heavy tasks of clearing and burning are completed, each family becomes responsible for its own individual block. Coffee blocks are established in a similar way. A very small amount of paid labour is employed in coffee gardens, usually small bands of youths or unmarried girls, raising money for such social activities as a sports club or a youth club. During the introduction of coffee, government nurseries were established, but now people raise coffee seedlings themselves from established trees.

Productivity measurement in mixed gardens of this nature is very difficult. Yields of individual species are highly variable within and between sites. Harvesting of some species occurs within a restricted time, while others are harvested continuously over the life of the garden. Yield estimates of the most important crop, Dioscorea, ranges from 10 to 20 t ha^{-1} for D. esculenta and 16 t ha^{-1} for D. alata. When rice was grown yields ranged from 0.45 to 2.8 t ha^{-1} and coffee yields are around 250 g per tree of dried parchment, or about 115 to 120 t ha^{-1}. The average price of dry parchment at the "farm gate" for 1982 was 0.55 kina per kg (1 kina=1.2 US$), thus coffee provided the average family with a cash income of around US$60 in 1982.

Production of the yam staple is markedly seasonal, but other crops such as sugarcane, taro and bananas are less seasonal. Coffee production occurs mainly between May and September (Figure 1). Variability from year to year is low and is dependent on rainfall as well as social demands. Production is increased to meet the requirements of large ceremonies, with planning occurring some years ahead to build up planting materials and to select sites which are known to produce good yam harvests.

All coffee production is for sale for cash and marketing is done through a regional cooperative society, which is involved solely in coffee marketing. Small amounts of food are sold in a bi-weekly periodic market on a nearby government station, where the main buyers are government employees.

An important feature of the system is that ground cover is maintained almost permanently, except for a short period between clearing and the development of the crops. Even during clearing and planting, the surface is disturbed as little as possible. Large trees are not felled, but are pollarded and the bases burned to prevent regrowth. Smaller trees, in particular some of the Ficus genera, do regrow and help speed the recovery of a tree cover. Branches from the taller trees are cut up and stacked for fuelwood and only the leaves are burned.

The proportion as well as the spatial arrangement of cleared land in relation to land in regrowth/secondary forest is such that broad scale erosion does not occur. Poles are laid along the contour, supported by pegs, to reduce surface run-off and yams are plante

in individual holes upslope from the barrier. Other crops are spaced amongst the yams, also across the slope. However, much backward rotational slumping occurs in the area and many gardens are deliberately sited on slumps to take advantage of the recent soils found there. Thus small slumps within gardens are not uncommon. On the other hand, some gardens are sited on slopes over 30 degrees and little soil movement occurs.

Men and women share the labour of food and cash crop production relatively equally. Men carry out the heavier tasks of clearing while women sweep and arrange slash material for burning. Customarily women may not cultivate the soil with digging sticks or spades in the first yam garden, so men plant most of the yam crop, taro, sugarcane and bananas. Women plant restricted varieties of yams in piles of ash above the ground surface, and greens. Women do most of the weeding, while men attend to the other aspects of crop management such as tying up vines and covering exposed tubers with soil. The first yam crop is harvested by men and after that restrictions on women to harvest the crop are somewhat relaxed. Both sexes pick, process and sell coffee. Children also help with garden work. The major bottleneck in coffee production is the processing of the cherry to parchment.

5. SYSTEM DYNAMICS

The food production system is a very old one. Recent changes, in particular the introduction of malaria control programmes and modern medicines, have contributed to a decline in infant mortality, and that, coupled with a relaxation of customary restrictions on sexual activities, have resulted in an increase in population. Emigration has helped reduce the rate of increase in resident populations, but in areas with greater seasonality and population pressure, the system is

degrading from forest fallows to cane grass fallows. The introduction of steel tools and implements has reduced the amount of labour required and allowed larger trees to be cleared.

The coffee production system is only 30 years old. It involves a tree cover and maintains sustained production without outside inputs such as fertilisers. However, most blocks are under-exploited, probably because of lack of incentives for higher production and the high labour costs of processing. Investigations are underway into the possibilities of producing either wet cherry, or dried cherry to encourage greater production. Meanwhile most people produce at a level which just satisfies their day-to-day cash requirements for imported food stuffs, local taxes and school fees.

6. EVALUATION

The system provides almost all the food and immediate cash requirements of the household and involves practically no external inputs. However, it is vulnerable to any changes which bring about a shortening of the fallow period to the point where a grass fallow replaces a tree fallow. Robusta coffee, a new tree crop in the locality, has been very quickly and successfully adapted to the system. But there is, at present, a serious gap in the knowledge on the requirements of the individual crops, relationships between the fallow vegetation communities, and soil conditions so that sound advice cannot be given on methods of avoiding degradation of the tree cover in areas where the fallow period is being shortened, and on other aspects of management of the system. The PNG shifting cultivators have a deep knowledge of the fallow succession characteristics, and they are willing to accept innovations if enough incentives and motivations are provided.

This strength of the farmer is a major aspect which should be built upon in any attempt to improve the system.

Similar systems exist in many parts of lowland and mid-altitude PNG, and results and experience of one system could, within limits, be extrapolated to others. Critical site factors influencing the stability of the system are rainfall and, to some extent, altitude, which determine the rate of growth of successional tree species and thus the vulnerability of the systems to degradation.

It is essential that research is undertaken urgently with a view to providing appropriate guidance to improve the system and enable the farmers to attain optimal productivity on a sustained basis. Some studies that have been carried out in the mid-altitude localities of the country (9, 3) are of significance in this context. Similarly, in the immediate area of the system described here, land evaluation studies have been undertaken by CSIRO of Australia (6, 8). Some other studies on a country-wide basis are also underway (10). Areas on which research needs to be intensified on a priority basis include:

- pattern and dynamics of grass and tree succession following cultivation;

- conditions which each succession provides for the development of the following succession;

- relationship between the succession communities and soil fertility;

- effect of intervention in natural succession (through shortening of fallow cycles, introduction of new species, and so on) on the sustainability of the system;

- agronomic requirements of individual crops for optimal production in the system.

REFERENCES

1. Bleeker, P. (1983) Soils of Papua New Guinea. CSIRO and the Australian National University (ANU) Press, Canberra.

2. Bourke, R.M. (1985) Food, coffee and casuarina: a agroforestry system from the Papua New Guinea highlands. Agroforestry System Description No. 6, Agroforestry Systems (in press).

3. Clarke, W.C. (1971) Place and People: an Ecology of a New Guinea Community, University of California and ANU Press, Berkeley.

4. Clarke, W.C. (1976) The maintenance of agriculture and human habitats within the tropical forest system. Human Ecology 4, 247-25

5. Clarke, W.C. (1977) The structure of permanence. In T.P. Bayliss-Smith and R.G. Feacham (eds), Subsistence and Survival: Rural Ecology in the Pacific, 363-384, Academic Press, San Francisco.

6. CSIRO (1972) Lands of the Aitape-Ambunti Area. Land Research Series No. 30, Canberra.

7. Grandstaff, T. (1978) The development of swidden agriculture (shifting cultivation). Development and Change, 9 (4), 547-579.

8. Heyligers, P.C. (1968) Quantification of vegetation structure on vertical air photographs. In C.A. Stewart (ed), Land Evaluation, 251-262, Macmillan, London.

9. Manner, H.I. (1977) Biomass: its determination and implications in tropical agro-ecosystems: an example from montane New Guinea In T.P. Bayliss-Smith and R.G. Feachem (eds), Subsistence and Survival: Rural Ecology in the Pacific, 215-242, Academic Press San Francisco.

10. McAlpine, J.R. and G. Keig (1982) Supporting traditional farming systems in Papua New Guinea. Research Report 1981-82, CSIRO Division of Land Use Research, 8-11.

11. Paijmans, K. (ed) (1976) New Guinea Vegetation. CSIRO and ANU Press, Canberra.

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Figure 2: The pattern of regrowth of fallow garden sites: (a) area of low grasses (mainly Imperata) per ha; (b) area of cane grasses (mainly Saccharum) per ha; (c) total basal area of tree species per ha; (d) number of stems of tree species per ha. The horizontal axis in each figure represents the number of years since clearing.

Figure 3: Cross-sectional transects through fallows of different ages: (a) 1 year after clearing and planting - the righthand slope has been weeded and replanted for a third time, the left has been allowed to go back into fallow; (b) a 5 year old fallow - tall cane grass and fast growing softwood tree species dominate, but some food crops still remain; (c) 10 year old fallow - on the lower, moister slope tree species have shaded out the cane grass, which remain dominant on the upper slope; (d) 25 year old fallow - all cane grass has now been shaded out and the first tree species are being succeeded by slower growing trees. The large Pommetia has been planted during some previous cultivation. This side is ready for re-cultivation.

Figure 4: Large bundles of dry Pommetia leaves are collected together and carried to the new yam gardens by woman, to be used by their husbands in planting the yam crop. Bundles commonly weight over 40 kg.

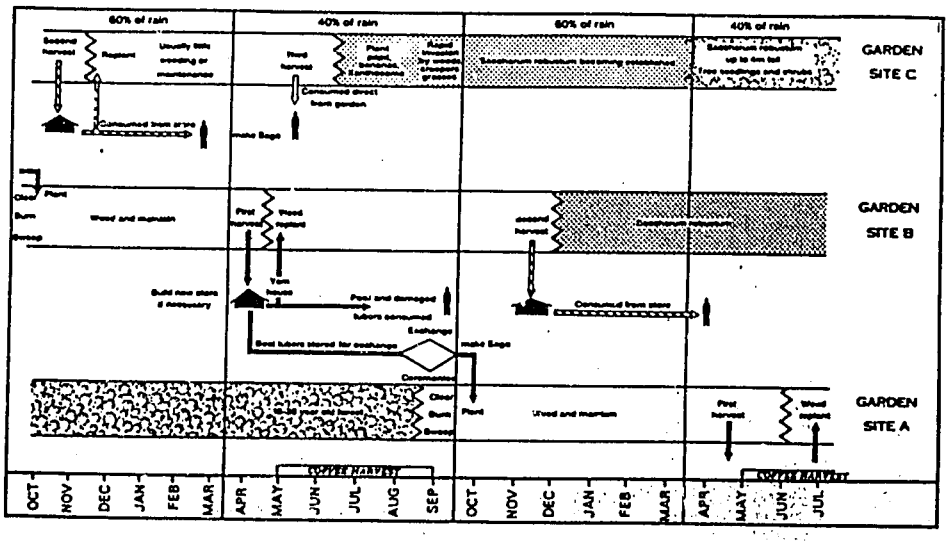
Figure 5: A newly cleared yam garden during planting. Seed tubers have been laid out near holes prepared for them and bundles of Pommetia are ready for use. The trees which previously covered the site have been pollarded and killed by burning, but are not felled. The surface of the garden has been swept of ash and debris but otherwise is undisturbed.

Table 1. CULTIVATED AND NON-CULTIVATED FOOD CROPS IN THE MIXED CROF GARDENS

FAMILY	BOTANICAL NAME	
Acanthaceae	*Graptophyllum pictim*	
Amaranthaceae	*Amaranthus hybridus*	
	Amaranthus tricolor	
	Deeringia polysperma	
Anacardiaceae	*Mangifera indica* #	
Araceae	*Alocasia sp.* #	
	Cococasia esculenta	(11 cultivars)
	*Xanthosoma saggitifolia**	
Bromeliaceae	*Ananas comosus**	(2 cvs)
Bursuraceae	*Canarium sp.*	
Caricaceae	*Carica papaya**	
Convulvulaceae	*Ipomea batatas**	
Cruciferae	*Brassica chinensis**	
	Nastertium homalospermum	(2 cvs)
Cucurbitaceae	*Citrullus vulgaris**	
	Cucumis sativus	
	*Cucurbita moschata**	
	Lagenaria sp.	
	Trichosanthes anguina	
Dioscoreaceae	*Dioscorea alata*	(22 cvs)
	D. bulbifera	
	D. esculenta	(43 cvs)
Euphorbiae	*Manihot esculenta**	
Gnetaceae	*Gnetum gnemon*	(2 cvs)
Gramineae	*Saccharum edule*	(14 cvs)
	Saccharum officinale	(9 cvs)
	*Zea mays**	
Leguminosae	*Arachis hypogeae**	
	*Phaseolus vulgaris**	
	Psophocarpus tetragonolobus	(2 cvs)
Liliceae	*Allium odorum**	
Malvaceae	*Abelmoschus manihot*	
	Abelmoschus moschatus	(2 cvs)

Moraceae	*Artocarpus altilis* *Ficus copiosa*	(3 cvs)
Musaceae	*Musa spp*	(26 cvs)
Myrtaceae	*Eugenia malaccensis**	
Oxalicaceae	*Averrhoa carambola**	
Palmeae	*Areca catechu** *Cocos nucifera* *Metroxylon sagu*	(2 cvs) (2 cvs)
Piperaceae	*Piper nigrum*	
Rutaceae	*Citrus sinensis**	
Sapindaceae	*Pometia pinnata*	(2 cvs)
Solanaceae	*Capsicum frutescens** *Lycopersicum esculentum**	

* Introduced since c1900 #Cultivated outside of gardens



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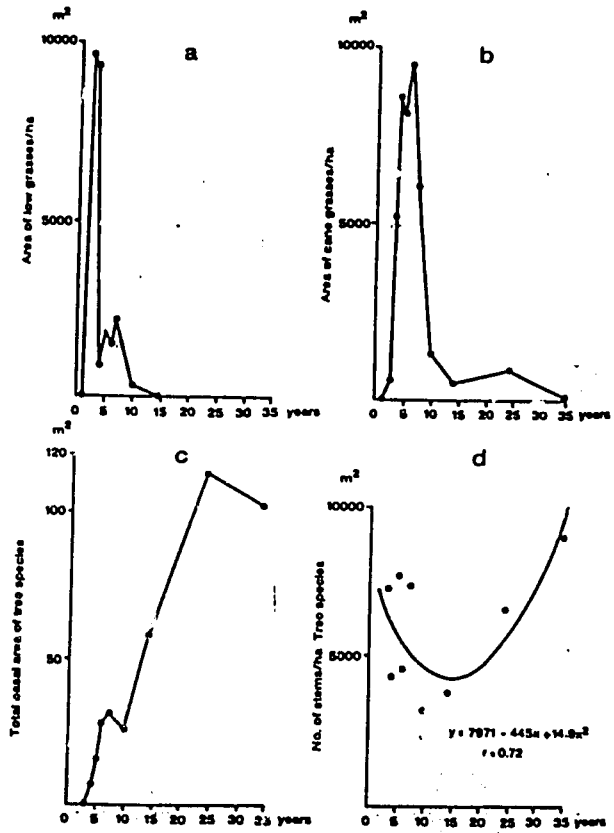

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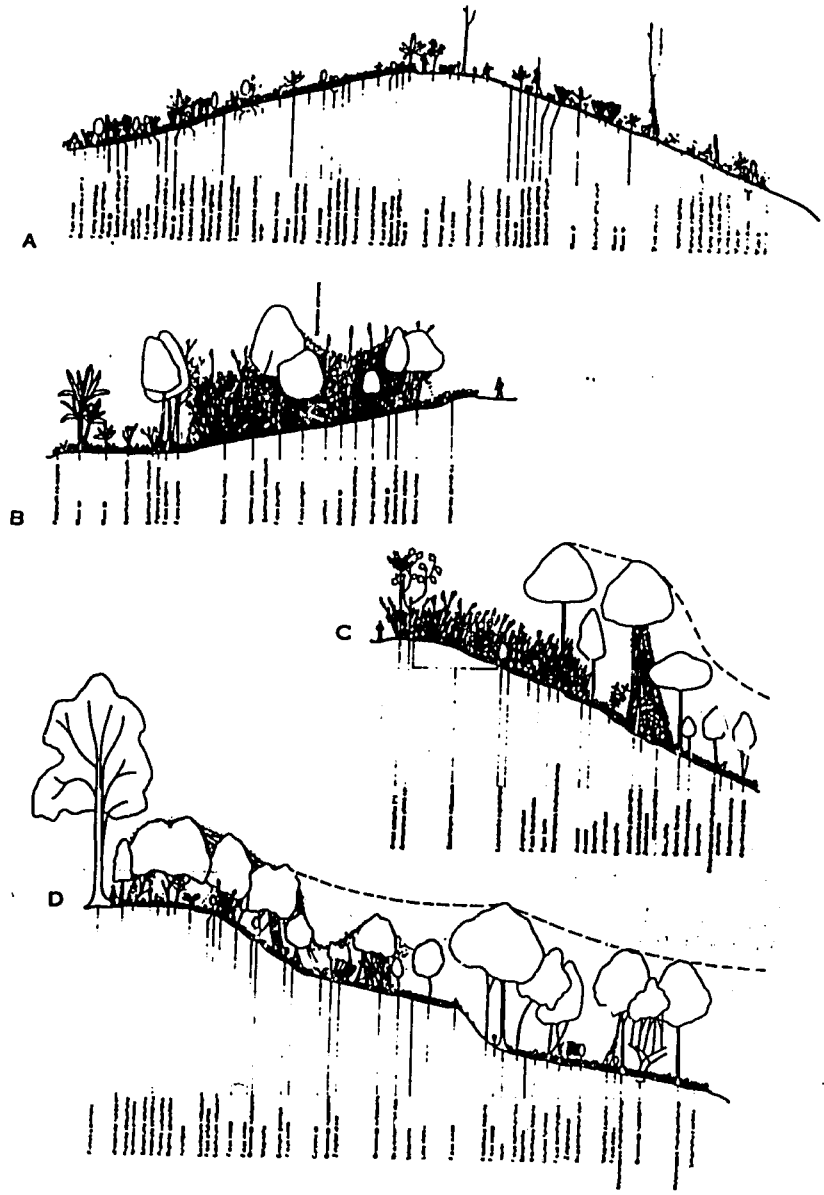

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