Improved production systems as an alternative to shifting cultivation

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PREFACE

Shifting cultivation, under its diverse forms of slash and burn system, is a traditional method of cultivating tropical upland soils, mostly for subsistence purposes. During the rest or fallow periods intervening between crops, the natural fertility of the soil is restored for renewed utilization in a subsequent period of crop growth. This traditional system of cultivation is in ecological balance with the environment and does not irreversibly degrade the soil resource, provided a sufficient length of fallow is allowed for soil restoration.

However, increasing population pressures necessitate more intensive use of land, particularly in the humid tropics of Asia and in the savanna and forest zones in Africa. The consequence is extended cropping periods and shortened fallows. In the extreme, short fallow periods are no longer adequate to restore the soil's productive capacity.

The subsistence farmers in the tropics - some 200 to 300 million people worldwide that live from this system of cultivation - are therefore increasingly faced with falling yields, more poverty and even less opportunity to subsist, let alone improve their living standards.

Apart from these problems of human misery, shifting cultivation, as currently practised in many areas, is wasteful of scarce land resources and frequently leads to intolerable erosion, particularly of hillsides and sloping lands.

It is for these reasons that FAO is studying and researching, in collaboration with national and international institutions, ways and means to improve this traditional farming system of the tropics. The ultimate objective is to provide feasible alternatives for improving these practices or replacing them with systems of permanent cropping.

The present set of papers is the result of an expert consultation on the subject, held in FAO in February 1983. The object of the consultation was to provide guidelines for future activities and policy decisions in this subject area.

It is clear from the proceedings reported that we are still a long way from finding all-round solutions to problems related to shifting cultivation and the up-grading of living standards for subsistence farmers practising this system. Some headway is being made and promising improvements can be recommended in certain circumstances. However, considerable work is still necessary before we can provide viable alternative cultivation systems that may help to improve the living standards of subsistence farmers.

It is fully recognized that improvement of shifting cultivation must be a joint undertaking, where governments and FAO combine efforts to find feasible solutions tailored to fit local conditions and problems.

Research and development is underway in various parts of the tropics in search of local solutions. As the results of long-term trials and observations become available, FAO intends to update its information from time to time for the benefit of governments in general and the improvement of shifting cultivation in particular.

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IMPROVED PERMANENT PRODUCTION SYSTEMS AS AN ALTERNATIVE TO SHIFTING INTERMITTENT CULTIVATION

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INTRODUCTION

The term shifting cultivation refers to farming or agricultural systems in which a short but variable cultivation phase on slash-and-burn cleared land alternates with a long, equally variable fallow period. The clearing of forest, secondary bush, woodland or grassland vegetation is accomplished with simple hand tools and it involves slashing down of herbaceous plants, stragglers and saplings. Useful trees and shrubs are selectively left standing, sometimes with light pruning. Other trees and shrubs are pruned down to stumps of varying height for fast regeneration or support of viney crops requiring staking. The dry plant debris is then burned before seeds and other planting materials are sown in holes on the flat, lightly tilled, or untilled mounds or ridges. During the short (two or three year) cultivation phase, crops are grown in mixtures of several varieties and species for subsistence and/or sales. The cultivation phase alternates with a much longer (ten to twenty year) fallow period, when the cultivated land is allowed to revert to natural vegetation or, very rarely, volunteer, protected, or planted vegetation. Marked variation in the relative lengths of cropping period as compared to fallow periods have been reported (Nye and Greenland, 1960; Braun, 1974; Ruthenberg, 1971; Spencer, 1966; Watters, 1971; and Barrau, 1971). Table 1 qives a good idea of the range of variability encountered in different locations. Usually, the period of fallow is lonq enough to enable soil fertility and productivity to be sufficiently restored to support the subsequent cropping phase. In its classical and origina! meaning, shifting cultivation not only involves movement of cultivation from one location to another but also the relocation of the cultivator’s hut alonq with the crops. Several reasons have been given for movement and timing of movement (Allan, 1966; Nye and Greenland, 1960; Ofori, 1974). The situation varies from those where the cultivator may never return to the same piece of land to others where the farmer more or less systematically returns to the same field albeit after different fallow periods.

Shifting cultivation is an extensive system of agriculture evolved and pracCised with qood results in areas of relatively low population density where the farmer has enough land at his disposal and freedom to cultivate anywhere he chnoses in a specified geo-political unit or region. A diversity of shifting cultivation systems is practised in different historical, environmental and socio- . economic situations in Africa, Central and South America, Southeast Asia and Oceania (Nye and Greeland, 1960; Barrau, 1971; Spencer, 1966; De Schlippe, 1956; Miracle, 1967; Allan, 1966; FAO, 1974; Ruthenberq, 1980, etc.; see Figure l. This is reflected in the innumerable designations given to this wide-spread practice in different parts of the world (Gourou, 1976 and Spencer, 1966; see Table 2). It was once a widespread practice in Europe (Nye and Greenland, 1960; Greenland, 1974; Iversen, 1956). In pioneer or frontier situations where ratios of fallow periods to cultivation phases are up to 10 or more, the system is stable, ecologically sound and reasonably efficient. But where it is not properly practised or when, as a result of population pressure and various reasons for intensification of production, the fallow periods become drastically reduced, the system breaks down, with erosion and loss of soil fertility and productivity as

Table 1

LENGTH OF THE CROP AND FALLOW PERIODS UNDER SHIFTING CULTIVATION OBSERVED IN DIFFERENT PARTS OF THE WORLD

No.	Place	Annual rainfall (mm)	Crop	Fallow	Periods in years Normal C	F	Excessive C	F	Typical value for R	Remarks
				Moist evergreen forest zone						
1.	Sarawak	c.3 800	Hill rice	Forest	1	>12	2	12	7	Early abandonment of land necessary to prevent invasion of *Imperata*
2.	Guatemala	3 400	Maize	Forest	1	>4			20	'Ando' type soil
3.	Liberia	2 000-4 500	Rice, manioc	Forest	1-2	8-15			11	
4.	Sierra Leone	2 300-3 300	Rice, manioc	Forest	1-5	8	1.5	5	12	Grasses (esp. *Chasmopodium* sp.) invade with excessive cultivation
5.	Assam	2 500	Rice/millet, maize, rice	Forest	2	10-12	2	<7	15	
6.	Sumatra	c.2 300	Rice, root crops	Forest	2	10-16			13	*Imperata* invades but may give place to forest
7.	Philippines	2 500	Rice, root crops, maize	Forest	2-4	8-10			25	
8.	Nigeria (a) Umuhia	c.2 300	Yams, maize, manioc	*Acioa barteri*	1-5	4-7	1.5	2.5	21	Loam derived from tertiary sands and clays; stumps of fallow carefully preserved
	(b) Alayi	c.2 300	Yams, maize, manioc	*Macrolobium* sp.	1.5	7			18	Very loose sandy soil
9.	Central Congo Zaire	1 800	Rice, maize manioc	Forest	2-3	10-15				

				Moist semi-deciduous and dry forest zone (including humid zone of derived savanna)							
10.	West Africa	1 500-2 000	Maize, manioc	Moist semi-deciduous forest	2-14	6-12			25	
11.	N. Burma	1 300-1 800	Hill rice	Grassland and pine forest			5	10	33[1/]	Kochin Hills area at c.2 000 m
12.	West Nile Uganda	1 400	*Eleusine*, sorghum, simsim, maize	Grass, mainly *Setaria* sp.	2-3	8-15	3	3	18	Refers to 'outside' fields
13.	Abeokuta, Nigeria	c.1 300		Thicket			2	4-5	30	Soil derived from tertiary sand: evidence of nitrogen deficiency
14.	Ilesha, Nigeria	c.1 300		Thicket	2	6-7			24	Soil derived from granite
15.	Central Uganda	c.1 300		Elephant grass	3	8	1	2	27	
16.	Ivory Coast	c.1 300		Elephant grass	3	3	9	6	50[1/]	
17.	N. Rhodesia	c.1 300		Thicket	6-12	6-12			50[1/]	'Chipya' forest soil
				Savanna zone							
18.	Ivory Coast	1 200		*Imperata*	2-3	6-10	2-3	4-6	24	
19.	Uganda	c.1 100		Andropogoneae	1	2.5	1	<2	28	
20.	N. Ghana	c.1 100		Andropogoneae	3-4	7-10			29	
21.	French Sudan	1 000-1 300		Short bunch grass	3	12-15			18	
22.	N. Rhodesia	c.1 000		'Miombo' woodland	2	up to 25			7	Pallid sandy soils

1/ Semi-permanent cultivation in our terminology

Source: Nye and Greenland, 1960

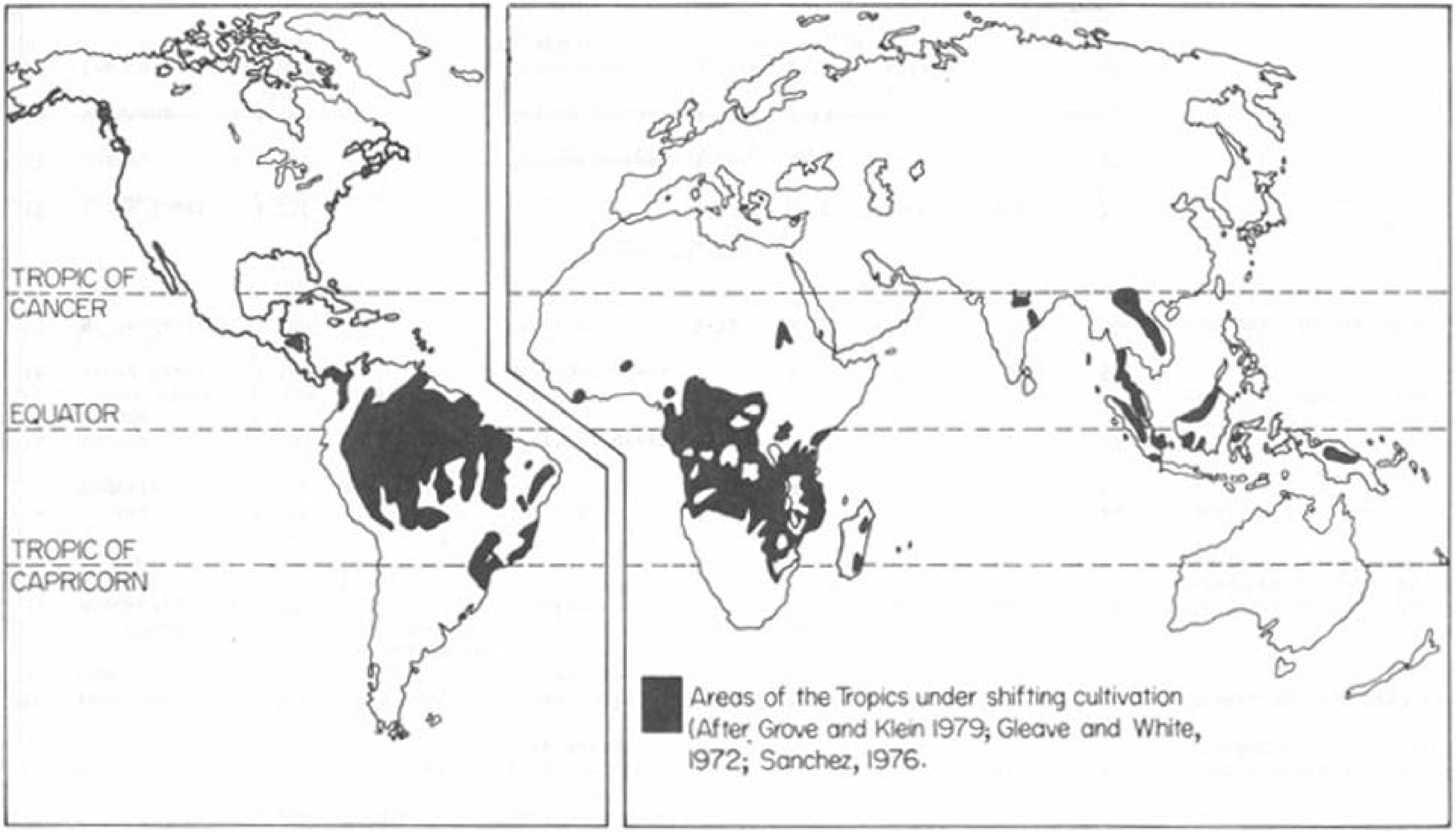


Fig. 1 Areas under shifting cultivation in the Tropics

Table 2 TERMS USED FOR SHIFTING CULTIVATION IN DIFFERENT PARTS OF THE WORLD

	Term	Country or Region
A. Asia	Ladang	Indonesia, Malaysia
	Jumar	Java
	Ray	Vietnam
	Tam-ray, rai	Thailand
	Hay	Laos
	Hanumo, caingin	Philippines
	Chena	Sri Lanka
	Karen	Japan, Korea
	Taungya	Burma
	Bewar, dhya, dippa, erka, jhum, kumri, penda, pothu, podu	India
B. America	Coamile	Mexico
	Milpa	Mexico, Central America
	Icheli	Guadalupe
	Roca	Brazil
C. Africa	Masole	Zaire
	Tavy	Malagasy Republic
	Chitimene, citimene	Zaire, Rhodesia, Tanzania
	Proka	Ghana

Source: Manshard, 1974; Gourou, 1958.

results. The various kinds of shifting cultivation in different parts of the tropical world are continuously changing as is also true of various farming systems subjected to socio-economic and other pressures of modernization. Consequently, in this paper the term shifting cultivation is used as a generic term in its broadest sense to include shifting cultivation proper and all related bush or grassland fallow systems used in various parts of the developing world.

HISTORICAL, ENVIRONMENTAL AND SOCIO-ECONOMIC SETTING FOR SHIFTING CULTIVATION

It is now generally agreed that the purposeful bringing into regular cultivation of a few (mainly 15 but up to 200) species of plants and domestication of a few (7 but up to 12) species of animals which characterize agriculture, occured at different times, either independently or by diffusion, in different parts of the earth. Agriculture, therefore, did not originate spontaneously at the same time in different parts of the world but started at different times and took several centuries of experimentation to evolve. Obviously, whether or not agriculture evolved independently or by diffusion in any given location, what is of interest is that aqriculture originated at different times among various peoples.

Shifting cultivation appears to be a stage in aqricultural development through which different peoples in various parts of the globe have passed, are still passinq, and at which few recent hunter-gatherer societies are still to arrive in certain reqions of the world. Consequently, different forms of shifting cultivation and related fallow systems are currently in existence among peoples of different historical and cultural backgrounds in different environmental situations in Africa, Southeast Asia, Central and South America and Oceania. Different crop plants with some or no animal components are involved in different soil types, topographic situations, climatic conditions, vegetation types and so on. There are, however, many similarities among shifting cultivators and smallholders practising related agricultural production systems. All farmers involved in this and related agricultural systems are now found within tropical latitudes and in the developing countries of the world. Shifting cultivation, like nomadic herding, is an extensive agricultural production system found in its truest form in areas of very low population density where man has jumped the initial hurdle of plant domestication with or without animals. Almost all the modifications of shiftinq cultivation with various degrees of intensificatinn of production are found in tropical areas of high or increasing population density. Shiftinq cultivation systems also exhibit varyinq degrees of subsistence and commercialization. The system where man relies on agricultural production to achieve his basic needs for food, some shelter and clothing with a minimum of inputs and modification of environment. Among classical shifting cultivators, a high proportion of materials required for shelter and clothing, and to some extent food, are still obtained from the wild. Tools are simple and usually consist of cutting (matchete or axes) and digging (hoes or digging sticks) implements: With the exception, nowadays, of the occasional use of chainsaws, mechanization is minimal and there are usually no draught animals, no ploughs, fertilizers, irrigation facilities or any other input typical of modern farming systems. Communities practising these kinds of intermittent farming are, like all rural people, somewhat isolated in clearings, hamlets and villages. They usually do not have much education, and a lot of their day to day actions are governed by what has been passed on culturally from generation to generation, superstition and tradition. Most farm operations depend on the natural rainfall regime and experience. The cultivator takes full account of natural events in determining how, when, and to what extent certain operations are to be carried out. Various species of plants growing during the fallow period are relied upon to restore the soil fertility lost during the cropping phase through nutrient cycling. Clearing of forest and burning are started durinq the dry period towards the end of the dry season or just prior to the beginning of the rains. Fire is used for the clearinq of forests, woodlands or other vegetation hence this kind of clearing is designated as’slash and burn’.

With increasing population densities and the influence of alien peoples, urbanization, increasing trade, industrialization, growth of markets, transportation facilities and various aspects of infrastructural development, in addition to research, education, etc., shifting cultivators are being pressed to change their production systems. Very often these changes lead to higher intensities of cultivation and a decline in the extent of reliance on natural processes, such as nutrient cyclinq in maintaining soil fertility.

Changes in objectives of production ushered in by circumstances beyond the control of the farmer may result in changes in production practices and increasing commercialization. One result of increasinq commercialization is the existence of a continuum of farming systems ranginq from totally subsistence production through varyinq degrees of subsistence/commercial production mixes to production only for sale. Among shifting cultivators a sinqle crop species may be grown in a slash and burn agriculture as a commercial crop alone in one field or in mixtures with other crops in different situations. The commercial crop may be a perennial such as oil palm, cocoa and rubber, or annual crops such as rice, sesame and qroundnut. The commercial crop may be intended for the foreign market and is subject to partial processinq, grading and fluctuating world market prices. It may also be qrown for a country’s domestic market, with or without partial processing, without grading and subject to local changes in demand and market prices, with exchanqe by barter or monetary purchase involved in disposal of produce. These changes brouqht about by increasing commercialization, population explosion and other socio-economic factors often induce farmers to introduce chanqes in order to adapt to circumstances and environmental conditions which change at a much faster and breathtaking pace than for their ancestors, who had enough time to evolve qradually through trial and error, making less disruptive chanqes in the practices that were culturally inherited as components of the traditional farming system.

As already noted, one result of intensification of production, as an outcome of increased population pressure, is the depletion of soil fertility due to loss of plant nutrients, soil erosion and soil degradation. The various characteristics of the tropical environment in which shifting cultivation is widespread, changes in shifting cultivation and other associated problems of the neglected majority of farmers who practice shifting agriculture in the tropics are discussed below.

The Tropical Environment

Shifting cultivation is the most widespread traditional farming system in the tropics. Geographically, the tropics consist of a broad belt of the earth's surface lyinq astride the equator between latitudes 23(1/2)° North and South. A brief review of the main features of the tropical environment based on Gourou (1947), Langsberg, et al. (1963), Trewartha (1968), Hare (1973), Sprague (1975), Sanchez (1976) and Walters (1977) follows.

The tropics cover five billion hectares amounting to 38 percent of the earth's surface with a population of about two billion inhabitants, equivalent to about 45 percent of the world's population. Topographically, it consists of undulating lowland of less than 900 m rising above which are isolated hills, plateaus and mountains, some exceeding 5 000 m. The distribution of potentially arable lands in the tropics in the absence of temperature limitations and in relation to moisture limiting crop growth is presented in Table 3. It is an area characterized by high isolation and uniformly high temperatures throughout the year. The mean annual temperatures range from 25-33°C with the mean temperatures durinq the coldest month usually above 18°C. Diurnal temperature variations higher than those between the coldest and hottest months of the year are common. The highest temperature variations occur in the drier higher latitudes close to desert areas near the Tropic of Cancer where dry season temperatures exceed 40°C. As usual, temperature decreases with altitude at the rate of about 3°C for every 500 m increase in elevation. This makes it possible for some temperate crops to be grown in highland areas of the tropics in Last Africa and Central and South America. It is also for the same reason that crops such as maize may take 3-5 months to mature in the lowland tropics and as much as 10-11 months in the tropical highlands.

The tropics receive more sunliqht than temperate areas with the former intercepting up to 56-59 percent of the sun's radiation as compared to 41 percent for the latter. Plants can grow in all seasons in the lowland tropics where moisture is available. Solar radiation varies from about 300- 400 g cal/cm^2 /day close to the equator to about 400-500 g cal/cm^2 /day above 10 north or south of the equator. However, cloud cover, especially during the rainy season, drastically reduces the effective solar radiation at the lower latitudes. This reduction in radiation has detrimental effects on crop yields and fertilizer response, for example in oil palm (Hartley, 1958), and is responsible for higher maize yields in savanna areas of Africa when moisture supply is adequate as compared to yields in the tropical rain forest zone. Chanqes in the length of day throughout the year vary from zero at the equator to about 2.8 hours at latitude 23(1/2)° north or south of the equator. Thus, althouqh most Cropical plants are shortday plants,

Table 3

LAND USE (MILLION HA) AND POPULATION PATTERNS IN COUNTRIES WHOLLY OR MOSTLY IN THE TROPICS 1/

Country or Region	Total land area	Presently cultivated	Pastures & meadows	Area cultivated (%)	Population (1969) (millions)	Cultivated area per capita (ha)
Tropical America						
Brazil	851	30	107	1	90.8	0.3
Mexico	197	24	79	12	48.9	0.5
Peru	128	3	27	2	13.1	0.2
Colombia	114	5	15	4	20.4	0.2
Bolivia	110	3	11	3	4.8	0.6
Venezuela	91	5	14	6	10.6	0.5
Central America	52	5	8	10	16.1	0.3
Guyanas	47	0.2	3	0.5	1.2	0.2
Paraguay	41	1	10	2	2.3	0.4
Ecuador	28	3	2	9	5.9	0.5
Caribbean	24	4	6	18	24.9	0.2
Total	1683	83	282	5	239	0.3
Tropical Asia and Pacific						
India	327	163	14	50	537	0.3
Indonesia	190	13	-	7	117	0.1
Pakistan	95	28	-	30	128	0.2
Indochina	75	6	5	8	48	0.1
Burma	68	16	-	24	27	0.6
Pacific Islands	55	2	1	4	4	0.5
Thailand	51	11	-	22	35	0.3
Malaysia	33	4	-	10	11	0.4
Philippines	30	9	1	29	37	0.2
Sri Lanka	6	2	-	30	12	0.1
Total	931	256	21	27	956	0.3
Tropical Africa						
Sudan	250	7	24	3	15	0.4
Zaire	234	7	66	3	17	0.4
Chad	124	7	45	6	3	2.3
Niger	127	11	3	9	4	2.7
Angola	125	1	29	1	5	0.2
Ethiopia	122	13	69	10	25	0.5
Mauritania	103	0.3	39	0.3	11	0.0
Tanzania	94	12	45	13	13	0.9
Nigeria	92	22	26	24	66	0.3
Mozambique	78	3	44	3	7	0.4
Zambia	75	5	34	6	4	1.2
Madagascar	59	3	34	5	7	0.4
Kenya	58	2	4	3	11	0.1
Cameroon	47	4	8	9	6	0.6
Rhodesia	38	2	5	5	5	0.4
Ivory Coast	32	9	8	27	5	1.9
Ghana	24	3	-	12	9	0.3
Uganda	23	5	5	21	8	0.6
Senegal	19	6	6	29	4	1.5
Others	237	34	85	10	29	0.8
Total	1992	166	593	8	257	0.6

Source: Sanchez, 1976

1/ Arranged by decreasing size.

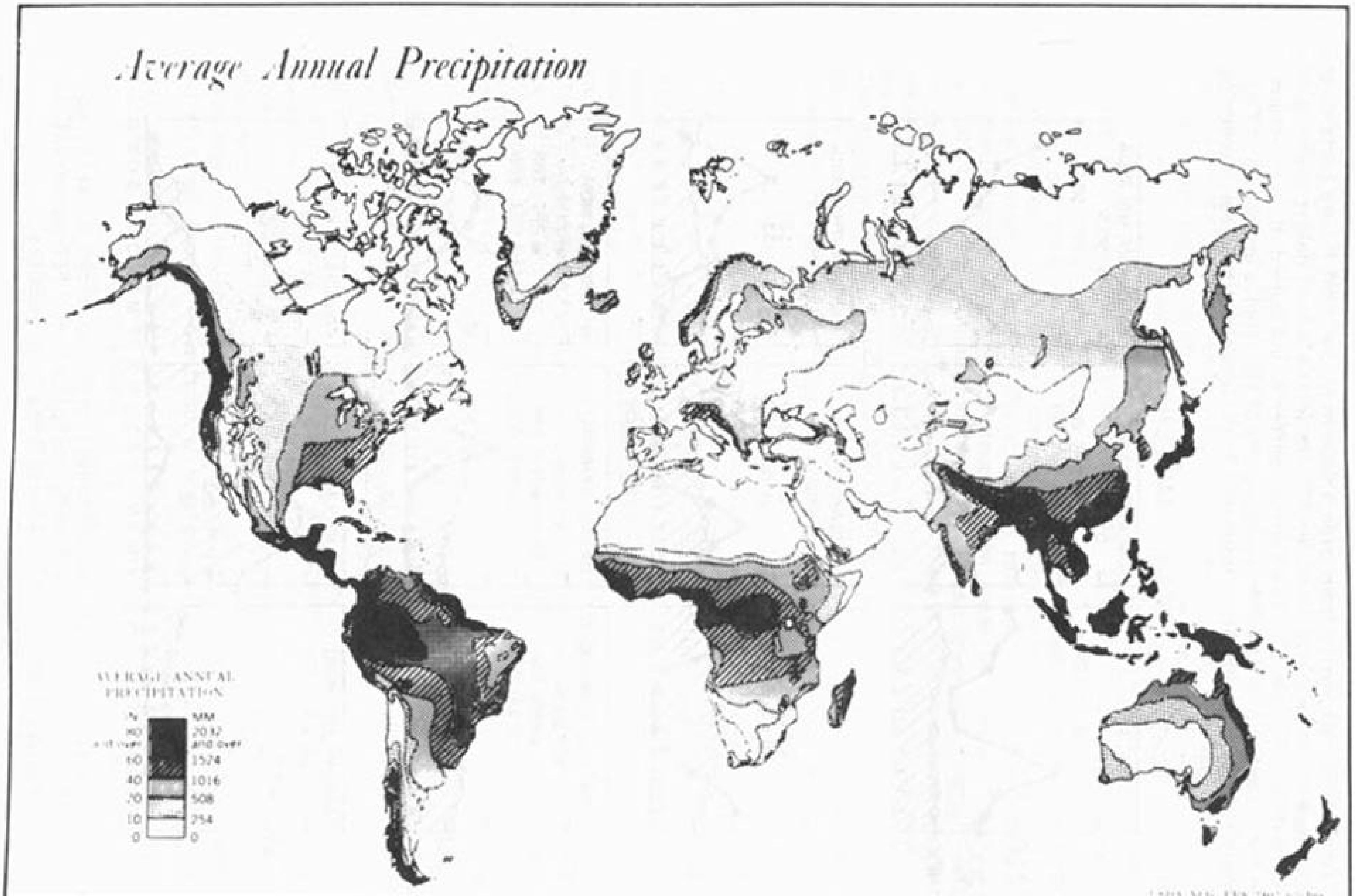


Fig. 2 Average annual precipitation
Source: Sprague, 1975

daylength variations of as low as 15 minutes may be critical in the flowering of some crop species or variaties (Njoku, 1958).

Annual rainfall varies from over 4 OOOmm in the most humid parts of the tropics close to the equator to under l00mm in the inland desert areas at the hiqher latitudes (Figure 2). The rainfall patterns and potential evapo-transpiration for a number of stations in various parts of the tropics are shown in Figure 3. Similarly, relative humidity is uniformly high throughout the year, exceeding

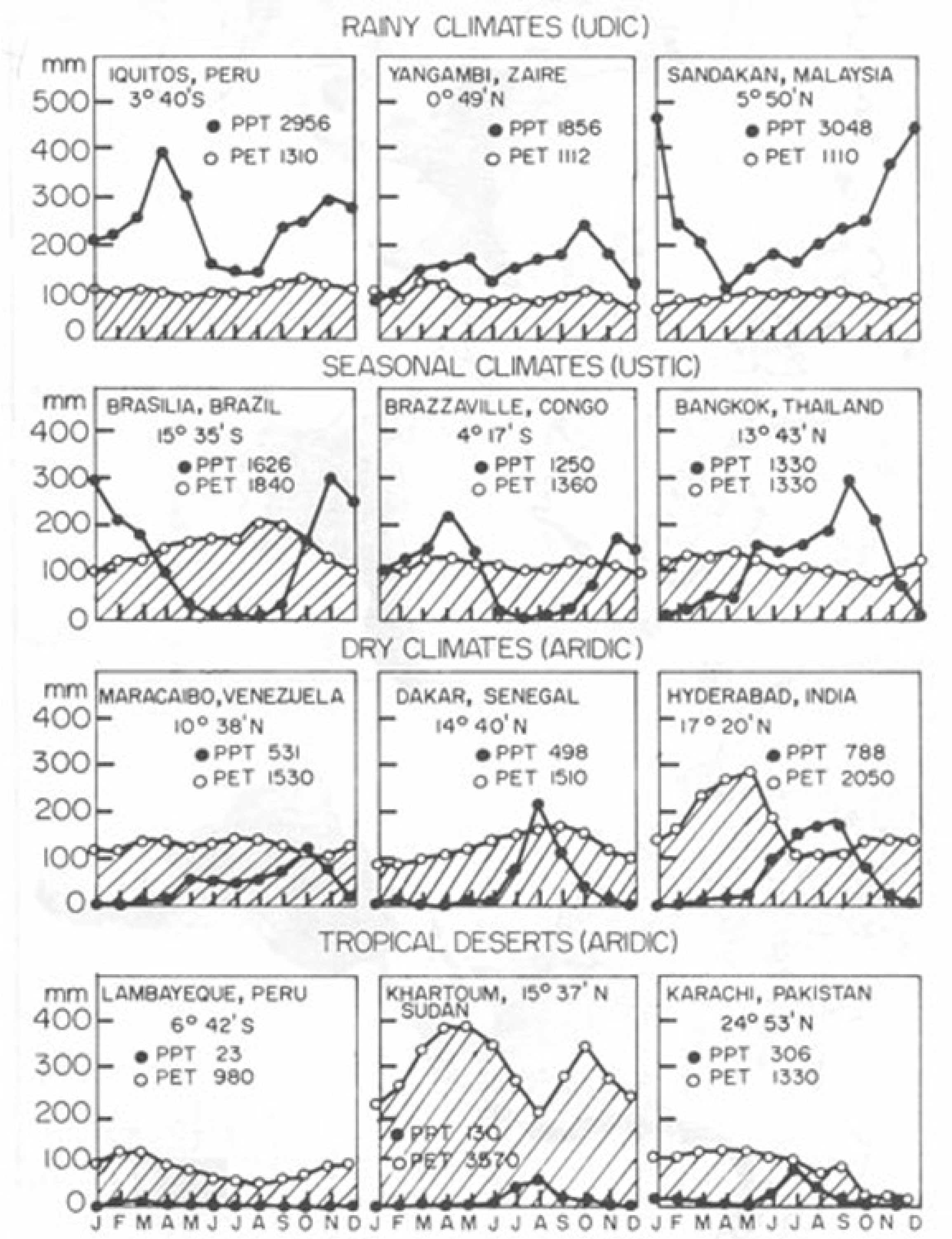


Fig. 3 Monthly rainfall evapotranspiration balances at selected tropical locations. PPT=precipitation. PET=potential evapotranspiration. Annual totals in numbers
Source: Sanchez, 1976

80 percent close to the equator, but may be as low as 30 percent during the dry season in the savanna areas above atitude 13° north or south of the equator. The rainfall may be unimodal in the high rainfall areas close to the equator and in the low rainfall areas above latitude 9° , while in areas of 1 200 - 15 000 mm between latitudes 4° and 9° from the equator, bimodal rainfall pattern is often encountered. The duration and intensity of the rainy season determines to some extent the crops that are grown and the prevailing farminq systems. The prevailing winds at different seasons, while determininq the onset, amount, duration and time of cessation of the rainy season, may also have adverse effects on crop and animal production. Very strong winds, hurricanes, typhoons and other related atmospheric disturbances have adverse effects on agricultural productivity, plant and animal life. Local winds such as the harmattan in west Africa may have both beneficial and adverse effects.

The veqetation of the tropics ranges from the tropical rainforest with evergreen vegetation of 3-4 storied structure, with the qreatest diversity of species in areas of over 1 500 mm annual rainfall, through semi-deciduous and deciduous forest of 3 storied structures in areas of 1 000 - 1 500 mm annual rainfall, tall qrass savanna woodland, Acacia/tall grass and Acacia/desert grass savannas in areas of 500 - 1000 mm; dry savanna with steppe woodland and scrubland steppe between 250 and 500 mm annual rainfall to thorn and succulent scrub and sparse to bare vegetation zone in tropical arid desert areas (Figure 4). The climatic climax vegetation has been drastically modified by human beings and many areas of forests in tropical and temperate countries have disappeared as a result of burning, farming and grazing.

On the basis of the above temperature, rainfall and vegetation regimes, the main climatic zones in the tropics according to Landsberg, _et al. (1963), Troll (1966) and Sprague (1975) include (i) humid tropics or rainy climates, (ii) sub-humid or wet-dry tropics with seasonal climates, (iii) semi-arid or dry climates and (iv) arid and desert areas. The mountainous areas of the tropical highlands constitute a special category of climatic/vegetation zone. The distribution and some of the characteristics of these zones are presented in Tables 4 and 5, and the prevalent farming systems associated with them are presented in Figure 5. The humid tropical climates cover about 25 percent of the land surface, followed by sub-humid tropics covering 16 percent, tropical semi-desert and desert 11 percent and tropical highland areas of over 900 m covering 23 percent of the earth’s surface.

The soils of the tropics vary considerably in their physical, chemical and mineralogical characteristics which are related to their geological history and the geomorphological characteristics of their parent materials and the intensity of the different soil forming factors and processes. The soil forming factors, according to Jenny (1941) consist of climate, organisms, topography, parent material and time. The major soils of the tropics consist of Oxisols (22.5 percent), Aridisols (18.4 percent), Alfisols (16.2 percent), Ultisols (11.2 percent) and other minor soil groups of sometimes local significance in agricultural production (Sanchez, 1976). For the distribution of these soil groups and their aerial coveraqe in different continents, see Table 6 and Fiqure 6. Characteristics of the different soil groups in the tropics, based on Juo (1980), include:

Alfisols: soils formed in well-drained upland areas, of coarse to medium surface texture with a clayey B horizon of more than 50 percent exchangeable base saturation.

Ultisols: similar to Alfisols, but are highly acid leached soils with exchanoeable bases of less than 50 percent. They are found in the humid tropical and sub-tropical areas.

Oxisols: stronqly weathered soils that exhibit very little variation with

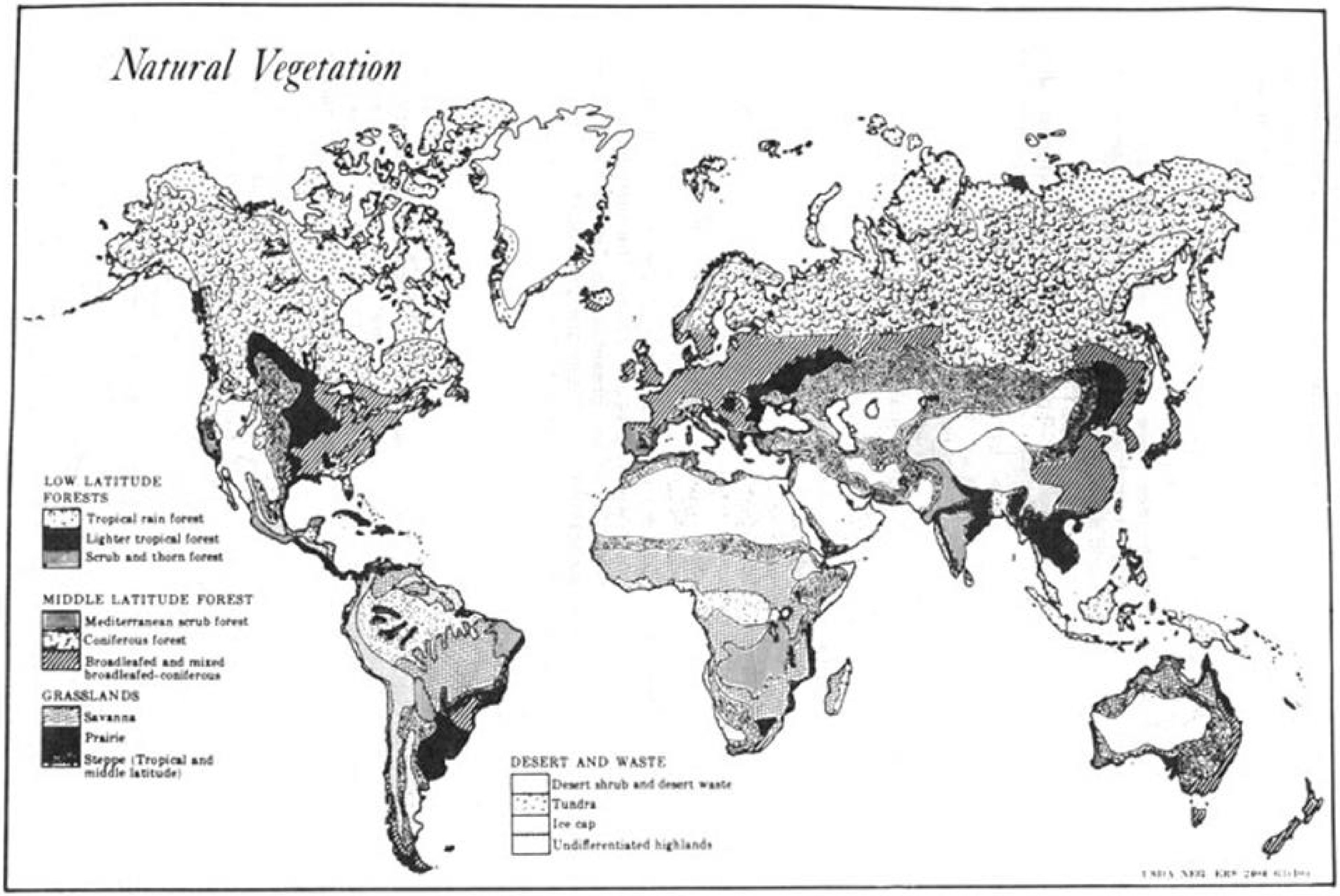


Fig. 4 Natural vegetation zones
Source: Sprague, 1975

Table 4

ENVIRONMENTAL CHARACTERISTICS OF THE TROPICS IN RELATION TO RAINFALL, VEGETATION AND APPROPRIATE GEOGRAPHICAL LOCATION OF VARIOUS CLIMATES 1/

Climate	Rainfall	Vegetation	Geographical Location
Humid tropics (rainy climate)	1 500 - 4 000+ mm Bimodal Unimodal Humid months 8.5-12	Tropical rain forest (broad-leafed evergreen forest) 30% 2/	Amazon basin, Congo basin, Indonesia, Malaysia, Philippines (part), Atlantic Coast of Central America and Pacific Coast, Colombia, Coastal West Africa, Pacific Islands
	24%	Mountain forest 23% 2/	Highlands over 900 m in Mexico, Guatemala, Costa Rica, Colombia, Ecuador, Peru, Bolivia, Kenya, Ethiopia
Sub-humid tropics (seasonal climate) (wet-dry tropics)	500 - 1 500 mm Unimodal Bimodal Humid months 4.5 - 8.5 49%	Semi-deciduous and deciduous forest + tall grass/low tree and Acacia/tall grass savanna (humid savanna) 52% 2/	Cerrado and Mato Grasso of Brazil, Llano of Colombia and Venezuela, Pacific Coast of Central America and Mexico, Veracruz, Yucatan Peninsula and Cuba. Most of Africa between Sahara and Kalahari except Congo Basin and Guinea coast, most of India and Northern Australia
Semi-arid tropics (dry climates)	250 - 500 mm Unimodal Humid months 2-4.5 16%	Dry steppe, woodland, scrubland steppe (dry savanna) 16% 2/	Sahel of Africa, Kalahari, large portion of Australia, parts of Central India, North-eastern Brazil, Northern Venezuela, Northern Mexico, Chad, Somalia, Tanzania
Arid, desert	0 - 250 mm Unimodal Humid months 0-2 11%	Thorn and succulent scrub (sparse or bare vegetation) 12% 2/	Sahara, Somalia, Australian desert, Southeast Africa, narrow coastal strip of Peru and Chile

1/ Sources: Sanchez, 1976; Sprague, 1975; and Landsberg *et al*, 1963.

2/ Percentage area of the earth. Note: mountainous areas are not presented as a component of tropical rain forest vegetation, and areas of distribution of various rainfall regimes do not directly correspond with the vegetation types, due to overlap in range of values in different classifications.

Table 5 DISTRIBUTION OF MAJOR CLIMATIC REGIONS IN THE TROPICS, BASED ON THE LANDSBERG-TROLL CLASSIFICATION (MILLION HA)

Climate	Humid months	Predominant vegetation	Tropical America	Tropical Africa	Tropical Asia	Total	Percent
Rainy	9.5 - 12	Rainforest and forest	646	197	348	1 191	24
Seasonal	4.5 - 9.5	Savanna or deciduous forest	802	1 144	484	2 430	49
Dry	2 - 4.5	Thorny shrubs and trees	84	486	201	771	16
Desert	0 - 2	Desert and semi-desert scrub	25	304	229	558	11
Total			1 557	2 131	1 262	4 950	100

Table 6 DISTRIBUTION OF SOILS IN THE TROPICS BY CLIMATIC REGIONS (MILLION HA)

Soil Groups (Soil Taxonomy equivalents)	Rainy (9.5-12)[1/]	Seasonal (4.5-9.5)	Dry and Desert (0-4.5)	Total	Percent of Tropics
1. Highly weathered, leached soils (Oxisols, Ultisols, Alfisols)	920	1 540	51	2 511	51
2. Dry sands and shallow soils (Psamments and lithic groups)	80	272	482	834	17
3. Light-coloured, base-rich soils (Aridisols and aridic groups)	0	103	582	685	14
4. Alluvial soils (Aquepts, Fluvents, and others)	146	192	28	366	8
5. Dark-coloured, base-rich soils (Vertisols, Mollisols)	24	174	93	291	6
6. Moderately weathered and leached soils (Andepts, Tropepts, and others)	5	122	70	207	4
Total Area	1 175	2 403	1 316	4 896	100
Percent of Tropics	24	49	27	100	

Source: Sanchez, 1976

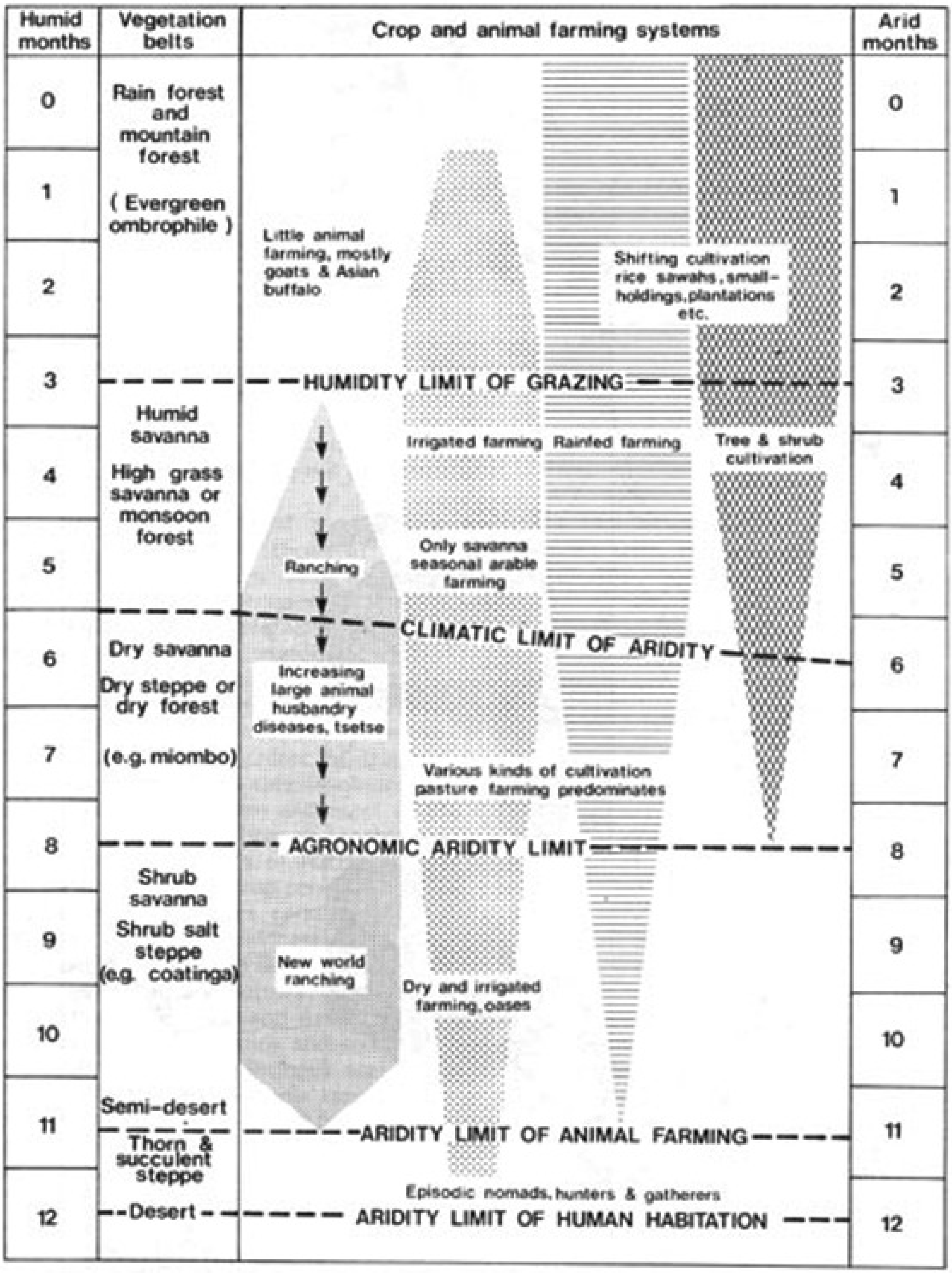


Fig. 5 Humid and arid months, vegetation belts and farming systems in the tropics (adapted from Unlig, 1965, and Andreae, 1980) Okigbo, 1981

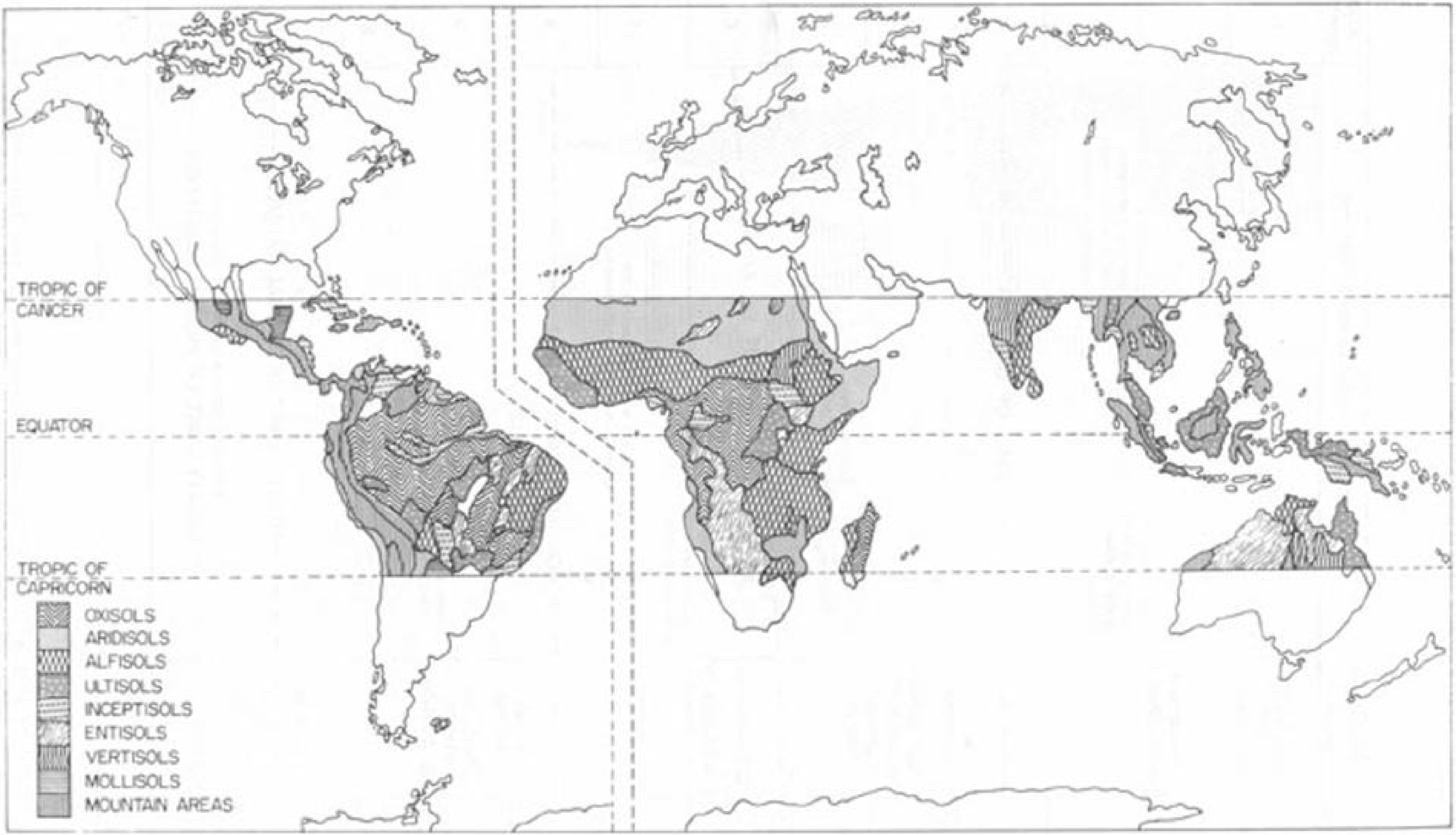


Fig. 6 Soils of the Tropics
(After Aubert and Tavernier, 1972, in Sanchez, 1976, p. 72)

depth. Some of the strongly weathered red, deep, porous Oxisols contain large amounts of clay-sized iron and aluminium oxides.

Vertisols: dark clay soils conCaininq large amounts of swellinq clay minerals (smectite). They crack widely when dry and are sticky and difficult to work when wet.

Mollisols: prairie soils formed of colluvial materials with a dark surface horizon and base saturation greater than 50 percent dominated by exchangeable calcium.

Entisols: soils exhibitinq very little or no horizon development in the profile; mostly derived from alluvial and colluvial materials.

Inceptisols: young soils with incipient or limited profile development. They are mostly formed from colluvial and alluvial materials with those soils developed from volcanic ash constituting a special group of Inceptisols of the Andept sub-order.

Aridisols: soils of arid and desert areas some of which are saline.

Histosols: soils very rich in organic matter such as peat and muck, sometimes of major horticultural importance.

The Oxisols and Ultisols abound in the humid tropics while Alfisols are found mainly in the sub-humid and semi-arid regions.

In general, soils of the tropics are more highly weathered and of low inherent fertility than those of temperate regions with the exception of the younger volcanic soils, alluvial flood plain and valley bottom (hydromorphic) soils. A sound knowledge of the characteristics and potential of these soils in addition to the problems that arise in their management under increasing cultivation intensity matched with alternative effective solutions to these problems is a prerequisite to their effective management for sustained production in permanent agricultural systems. It is now well known that the luxuriant tropical forest is more of a mirage than a direct manifestation of the fertility of the soil underneath. Most of the nutrients in the system are tied up in the vegetation and when this is cleared and burned by the shifting cultivator, the nutrient cycle is broken and most of the fertility is carried away in harvests of crops grown or lost through leaching, erosion and various processes which result in decreasinq amounts of nutrients available to the crops subsequently grown. Arable food or cash crop production on highly weathered and leached Ultisols and Oxisols of the tropics require constant use of costly inputs of lime, multi-element fertilizers and pesticides, each with its own problems especially when improperly used (Fore and Okigbo, 1974; Greenland and Okiqbo, 1980). Large-scale high input agriculture has been possible and economical in the fine textured oxic Alfisols, Oxisols and Andepts of the East African highlands, the Caribbean and South Pacific Islands and southern Brazil (Juo, 1980). Less success has been achieved with such high input agricultural systems in the kaolinitic Lateritic and highly compacted Alfisols and Ultisols of the savanna and forest/savanna transition zones of West Africa. A more detailed treatment of the climate, soils, their manaqement problems and potentials for various farming systems are covered in Webster and Wilson (1966), Sanchez (1976), Williams and Joseph (1970) and Jones and Wild (1975). It is very important not only to understand the soils of any area in the tropics but also the underlying factors in their use and management in traditional farminq systems as a basis for the development through research of scientific, ecologically and economically sound practices for their management for sustained yields under different farming systems.

It should be borne in mind that the climatic, physical and other environmental resources of the tropics often apparently appear to have higher agricultural potentials than those of the temperate zone. But it is also well known that the agricultural and related economic development efforts in the tropics are bedevilled by a host of pests, diseases and environmental stresses which must be surmounted before the tropics' potential for agricultural production can be realized. The development of alternatives to shifting cultivation should consider these constraints carefully since solution of the attendant problems is proving to be more difficult than in the temperate reqions of the world (Lee, 1957; Kamarck, 1976).

THE NEED FOR A FARMING SYSTEMS RESEARCH ORIENTATION IN DEVELOPING ALTERNATIVES TO SHIFTING CULTIVATION AND RELATED FALLOW SYSTEMS

In many developinq tropical countries progress in agricultural production has been limited to perennials or tree crops such as oil palm, rubber, coffee, cocoa, coconut, bananas and tea, qrown in large-scale plantations in ecological zones where they are suitably adapted. Much less success has been achieved in these crops in smallholder agricultural production systems. Even more disappointing are the arable crops irrespective of whether they are grown on larqe-scale farms or by smallholders except for such crops as sugarcane, irrigated cotton and some of the 'Green Revolution' crops such as paddy rice in Southeast Asia and maize in isolated areas in the tropics. Consequently, all arable food crops and cash crops such as groundnuts, sesame, sunflower, etc. are still produced by over 90 percent of the smallholders in the tropics who practice shifting cultivation and related intermittent bush, woodland, or grassland fallows. In several developing tropical countries, agricultural research has been in progress for over half a century. Yet the problem of developing farming systems which are viable alternatives to shiftinq cultivation has remained as intractable as ever. The realization of the often emphasized high crop production potentials of the tropical environment continues to elude the millions. of farmers in the tropics. As a result, many developing countries are increasingly relying on food imports and sometimes food aid from developed countries to satisfy their increasinq demand for food due to rapid population growth, high urbanization rates and a demand for convenience foods by well-to-do segments of the population. Okigbo (1981) listed several reasons for this situation.

First, very high priority was given to research on cash crops such as cocoa, rubber and coffee with virtual neglect of food crops. Second, relatively better extension, marketinq, infrastructural development and other services were developed to encouraqe production of cash crops in support of industries of the developed countries of Europe and North America sometimes to the disadvantage of food crops. Third, agricultural production is location specific and direct horizontal transfer to the tropics of results and practices developed in temperate countries is often unsuccessful. Even if such results could be adapted, lack of manpower capability in science and technology rendered adaptive research impossible until recently. Fourth, agriculture's location specificity has in no way dampened interest in reliance on agricultural production strategies, techniques and practices developed in temperate countries as a basis for projects aimed at increasing agricultural production in the tropics. Fifth, the priority given to cash crops in research, extension and infrastructural support resulted in higher returns for farmers who grew cash crops, who therefore lost interest in food crops especially when demand was rather low. Finally, scientists in agricultural research were often too isolated from the farmers whose farming systems and welfare they were workinq to improve. Consequently, few relevanC Cechnologies were developed to solve the farmer's food crop and animal production problems in the tropics. Even then, the potentially promising new technologies developed could not be readily adopted by farmers due to:

i. fragmentary results when elements required for production were not all specified and available;

ii. technology sometimes not adapted to the farmer's environment

iii. innovations sometimes unrelated to the farmer's needs and not socially and culturally acceptable; and

iv. innovations not economically viable (Wharton, 1968).

Several examples can be cited in different parts of the world. For example, in Nigeria some of the early new high yieldinq and rust resistant maize varieties distributed to farmers in the 1960's were not adopted because they were yellow and were too chaffy for boilinq and eating off the cob. Faulkner and Mackie (1933) reported that an improved cotton variety was not acceptable to Nigerian farmers because it could not be grown intercropped with other crops as was the prevailinq practice with the local cotton variety. These problems did not arise with plantation crops which were tackled in individual commodity research institutes where several scientists were engaged in different aspects of the production, handling and utilization of one crop and the characteristics desired in the economic product were determined in the developed countries and could be tested in the laboratory or field. In food crops, the situation is different. Not only are there numerous food crops, but one has to study soil management, crop management, crop improvement, cropping sequences, crop protection, etc., of more than one crop in any one research station. In most cases, only well-known crops such as maize were of major interest at research stations but no small-scale farmer can risk growing maize alone on a small farm of two hectares or less. Thus, research on food crops was Iimited to spacings, variety trials, fertilizer trials, etc., conducted by only one or two agronomists at any one time. Limitations in staffing and other resources often resulted in only one agronomist working on all aspects of a range of food crops. Under such conditions there is very little chance of success in the limited time during which attention has been so far directed to food crops. Progress in tropical food crops improvement and production is limited to paddy rice. This is because rice is a crop with well-defined environmental requirements and has been produced for centuries in Asia and researched as a crop grown in pure culture as are plantation crops.

Even where progress has been made in attaining increased agricultural production as in some of the developing countries of Asia, the new technologies as indicated above have not been adopted by small farmers since their limited land resources, adverse environmental conditions, limited capital and other constraints have been overlooked. As a result of this and based on experiences in Asia, Harwood (1979) observed that:

> Agricultural development programmes inevitably tend to concentrate their efforts on those few factors that seem most crucial to crop production and easiest to improve. The resulting advances - the development of high yielding varieties of key grain crops, the proliferation of irrigation systems, and the widespread introduction of fertilizer and other inputs - have helped g1reatty to keep national food production in the developing countries more or less in step with rapidly rising demand. So far, however, these production increases have come largely from the most favoured farming areas where the constraints on production are relatively light. However, the continuing need for more food production and the growinq concern for wellbeing of the small farmers who have been largely untouched by the new technologies are drawing attention to the special problems of small farmers in the tropical and subtropical countries.
>
> When resources are limited, the key to farm productivity and thus to

well-being of farm families is the interaction of varied but complementary farm enterprises. Analyses of these interactions, however, have traditionalty focused on larger farms and emphasized labour productivity and return on investment as critical variables. The small farmer in the tropics seldom enjoys the option of varying his capital.

Also, traditional development programmes have often been aimed at a single commodity. Not surprisingly, they have been most successful in situations where farmers depend predominantly on a single food grain, and where there is a profitable market for their production.

The small farmer often finds such programmes irrelevant or unacceptable because they do not encompass the varied mix of crops and livestock that is his daily concern, and because they put him at the mercy of market forces he cannot control and probably does not understand.

This brings us to a distinction between farm development as proposed (here) and its common use in today's development programmes. Farm development is usually considered synonymous with commercialization. The most frequently stated objective of today s programmes is increased farm income. Other indicators of development progress are amounts of cash inputs used and the farmer participation in credit programmes. The underlying assumption is that greater cash flow across the farm boundaries (increased commercialization) is a true indicator of increased farm productivity and improved farm family wellbeing.

Our slowness or outright inability to commercialize large segments of the world's farmers and the questionable effects of such commercialization on family wellbeing in other cases lead us to a more general concept of development for small farms. Farm development as used here signifies a progression to more efficient and more productive use of limited farm resources. It nearly always implies an increase in labour productivity and an increase in quality or quantity of the food and fiber output of a farm unit. In the early growth stage, in particular, it probably will not involve commercialization.

The problem of finding suitable efficient alternatives for sustained production to replace shifting cultivation encompasses the improvement of small farm production systems. It also entails ensuring that all kinds of farming systems practised in the tropics are economically and ecologically sound and constitute planned, scientific and rational use of resources. This new approach calls for a farming systems research approach - which is a recent development and is discussed in some detail below.

Farming Systems Concept

Systems thinking, theories and applications have grown since Wlorld War II and have found early applications in the military, business and industry. Applications of systems theory and methodologies to agricultural problems have increased during the last two decades, as shown in discussions of different authors including Duckham and Masefield (1970), Dent and Anderson (1971), Ruthenberg (1971) and Spedding (197.5), IRRI (1976) and CGIAR/TAC (1978). The brief treatment here is based on CGIAR/TAC (1978) and Okigbo (1981).

A systems approach to agricultural production recognizes agriculture as a complex bio-economic activity in which several factors (resources and inputs) are manipulated in varying numbers, amounts, sequences and timing by the farmer to satisfy a range of objectives in a given environmental setting. A farm, farming or whole farm system is

> "not simply a collection of crops and animals to which one can apply this input or that to expect immediate results but rather a complicated interwoven mesh of soils, plants, animals, implements, workers, and other inputs and environmental influences with the strands held and manipulated by a person called a farmer who given his preferences and aspirations attempts to produce outputs from inputs and technology available to him both natural and socio-economic that result in his farming system" (CGIAR/TAC, 1978).

The farm is a unit of production and in West Africa, for example, a farm may consist of a family enterprise made up of one or more field systems farmed by one or more individuals with only some or all members of the family participating fully or partly in farm work (Figure 7). The main effort in farming

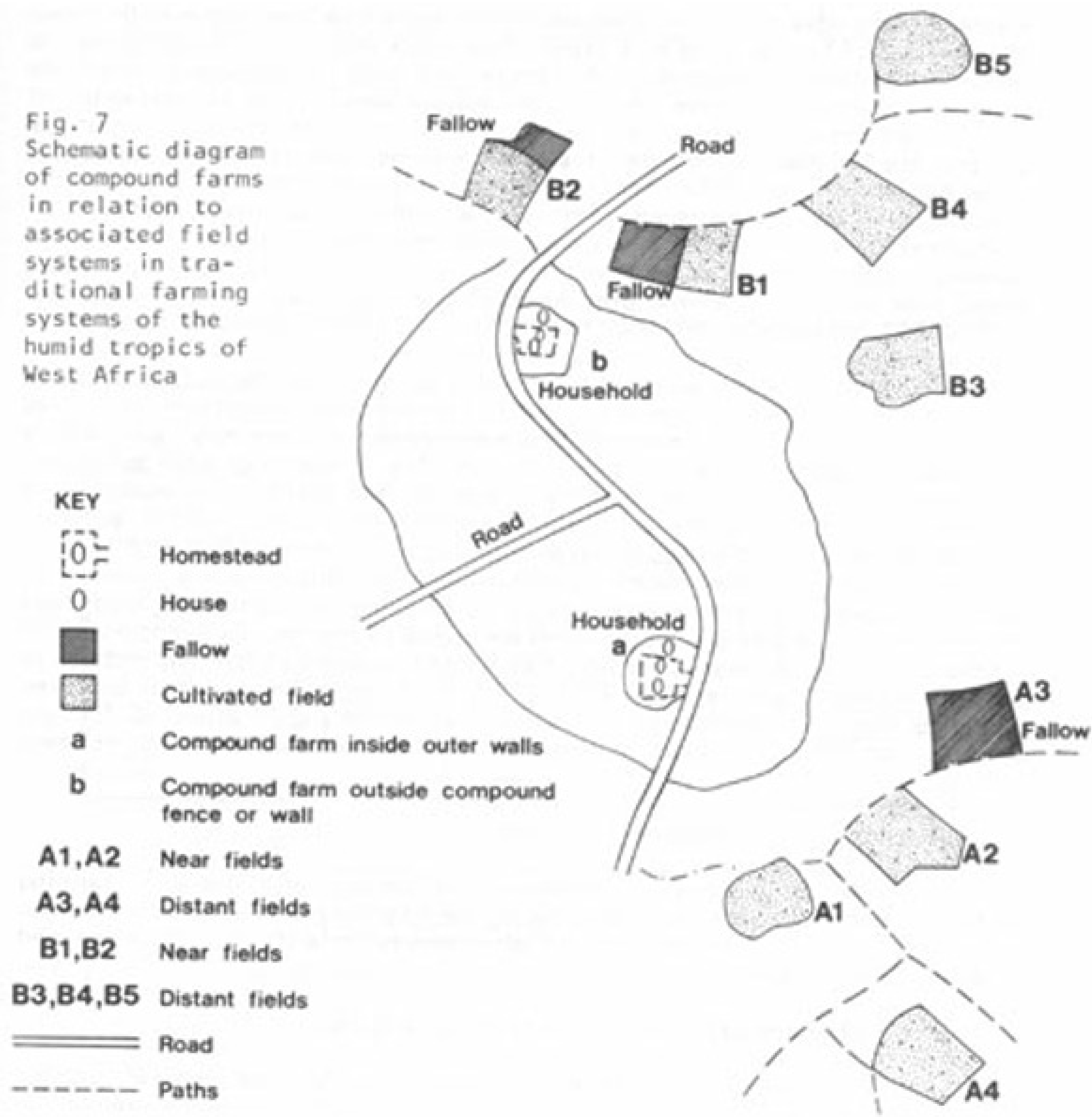


Fig. 7 Schematic diagram of compound farms in relation to associated field systems in traditional farming systems of the humid tropics of West Africa

is the management of the environment and crops to ensure that favourable conditions for high levels of photosynthesis can be attained by the plant while minimizing all factors (weeds, pests, diseases, etc.) that could rob the farmer of the yield of economic products. The crop plant may be grown for human or livestock consumption and/or sales.

A complex farming system in West Africa or elsewhere usually consists of one or more subsystems each of which differs in the physical, biological, socio-economic, technological and management elements involved in the production process. The most simple component of the farming systems may consist of just the production of a single commodity such as maize. This usually involves some tillage, planting, fertilizer application, hand weeding or weed control with herbicides, harvesting, drying and storage. The maize variety may be local or an improved variety, both of which may vary in susceptibility to pests and diseases, and production may involve the use of machinery in various operations and the different ways they are managed in different cropping patterns are all part of the cropping system. The management of the crop will depend, of course, on the soil characteristics, the prevailing rainfall regime, the purpose for which the maize is being grown, etc. In other situations, more than one crop may be grown in sequences of two or more pure stands during one year or in intercropping and relay intercropping sequences. All these and their management constitute cropping systems. Similarly, the farming system may consist of production of just one species of livestock such as poultry. In this case, the breeding of the poultry, the method of hatching the eggs, disease control, feed formulation, watering, housing, egg collection, slaughtering and processing and the ways the production system is managed constitute an animal production system. In traditional farming systems, there are usually complex situations in which the farming system is made up of several component systems consisting of arable crops, tree crops, and animal production systems pari parsu with several non-agricultural activities all managed by one farmer or farm family (Figures 8-19). These various enterprises exhibit varying degrees of competition and compatibility. Fach of these component subsystems is location specific in the details of their management which depends on overall environmental conditions, objectives to be satisfied, the constraints faced by the farmer and the technologies available and within his or her ability to use. The elements of each subsystem that interact with each other will vary in quantity and quality. Consequently, to be effective, research in farming systems should be based on a holistic approach to agricultural production which takes into account the need for scientists of various disciplines to cooperate in simultaneously tackling different elements of each subsystem. A good starting point in research would be the study and understanding of existing systems which we intend to change. As Spedding (1975) emphasized, it is necessary to study, classify and understand farming systems in order to operate them, repair them, improve or otherwise modify them and even model or construct new ones. It is the multidisciplinary nature of farming systems that calls for interdisciplinary interaction in research aimed at their improvement.

Farming Systems Research Orientation

A review of objectives, principles, methodology and status of farming systems research provides a suitable background for formulation and preparation of project(s) on the development of alternatives to shifting cultivation and related fallow systems.

Briefly, the aim of farming systems research is to:

i. conduct studies facilitating an understanding of farmers' physical, biological and socio-economic environments in a given ecological region or

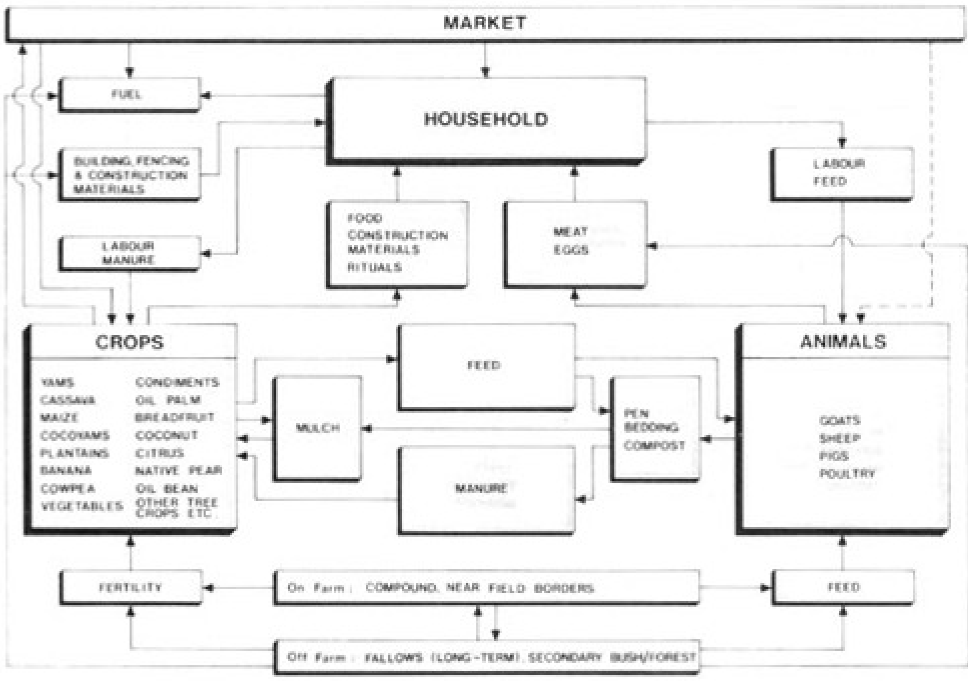


Fig. 8 Compound farming, intensive cultivation and bush fallowing in tropical rain forest region, Imo State, South Eastern Nigeria (based on Lagemann, 1977, adapted from McDowell and Hildebrand, 1980)

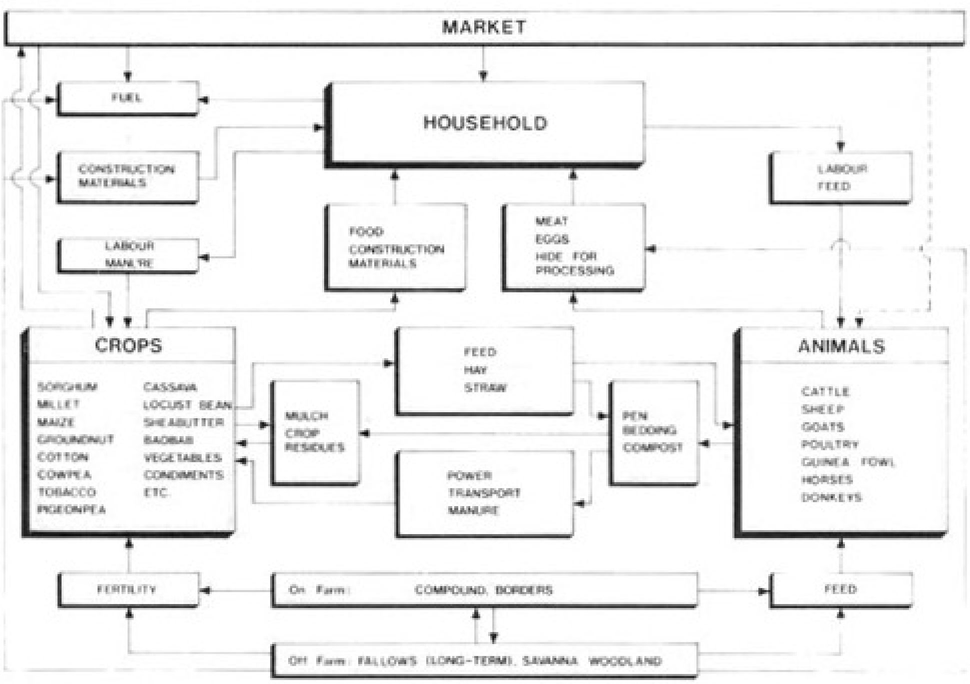


Fig. 9 Compound farming with rudimentary sedentary agriculture and bush fallowing in the Northern Guinea Savanna of Northern Nigeria (adapted from McDowell and Hildebrand, 1980)

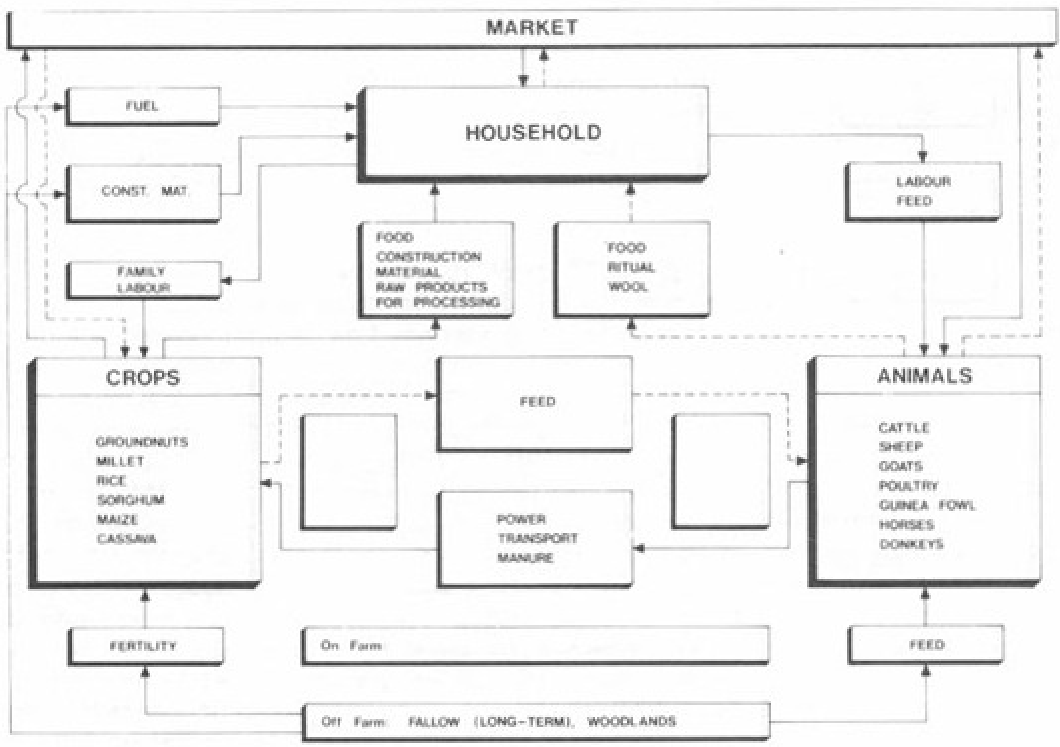


Fig. 10 Rudimentary sedentary agriculture in West Africa (The Gambia), shifting agriculture, moderate integration of crops and livestock (animals herded or tethered)
Source: McDowell and Hildebrand, 1980

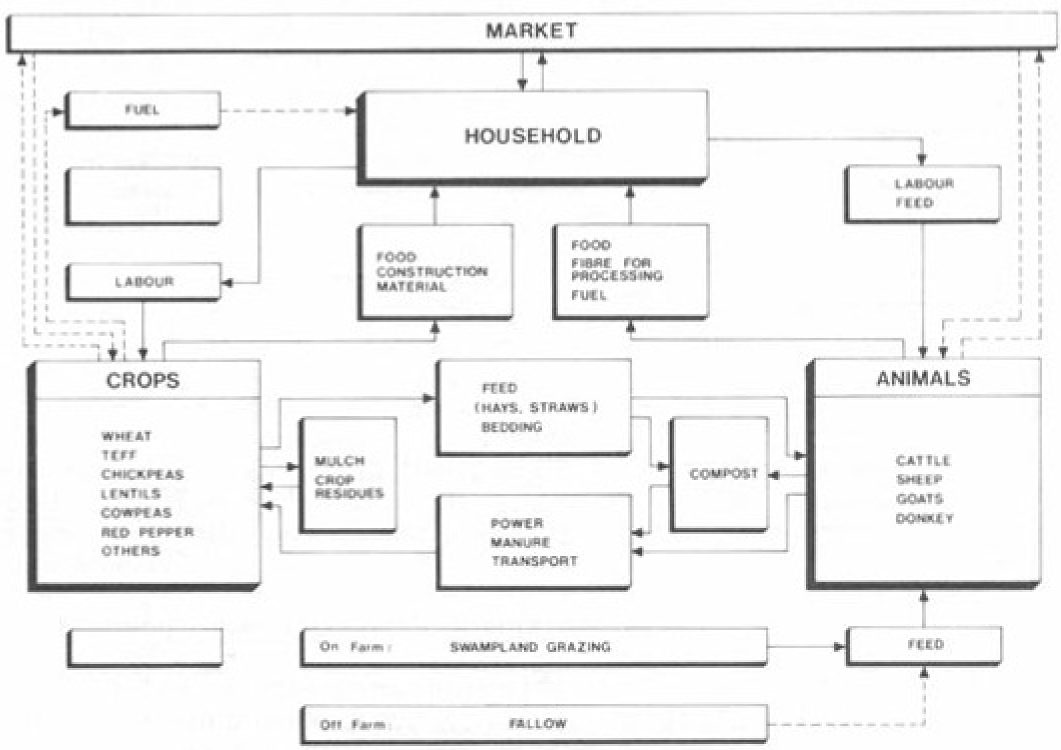


Fig. 11 Highlands of Ethiopia, permanent cropping, high-level integration of crops and livestock (animals confined or herded)
Source: McDowell and Hildebrand, 1980

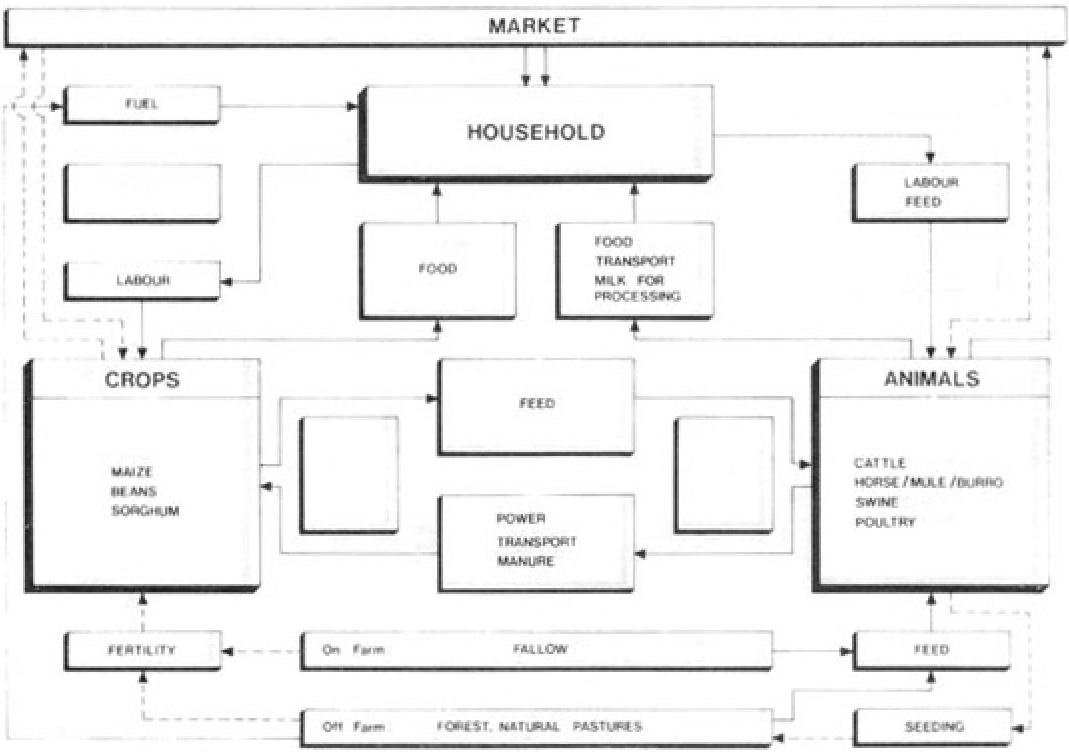


Fig. 12 Honduran system (Central America), long-term cropping, with rotation, high integration of crops and livestock (animals herded or roving)
Source: McDowell and Hildebrand, 1980

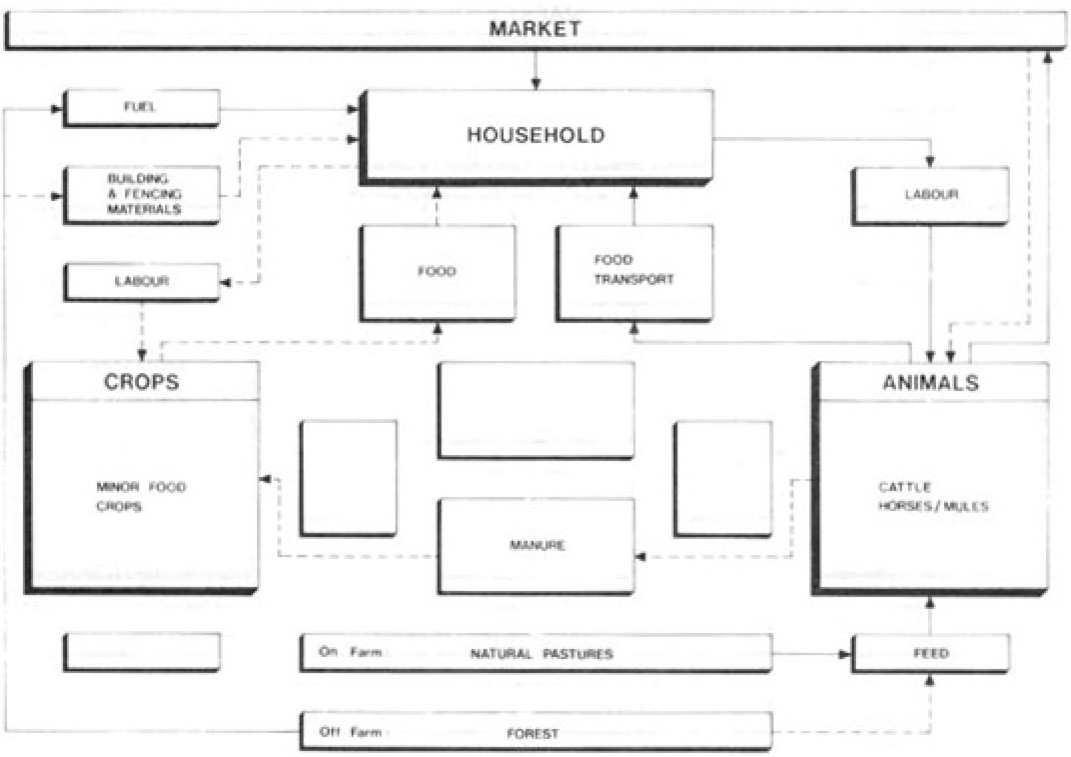


Fig. 13 Savanna system (Central and South America), extensive commercial livestock (>100 ha)
Source: McDowell and Hildebrand, 1980

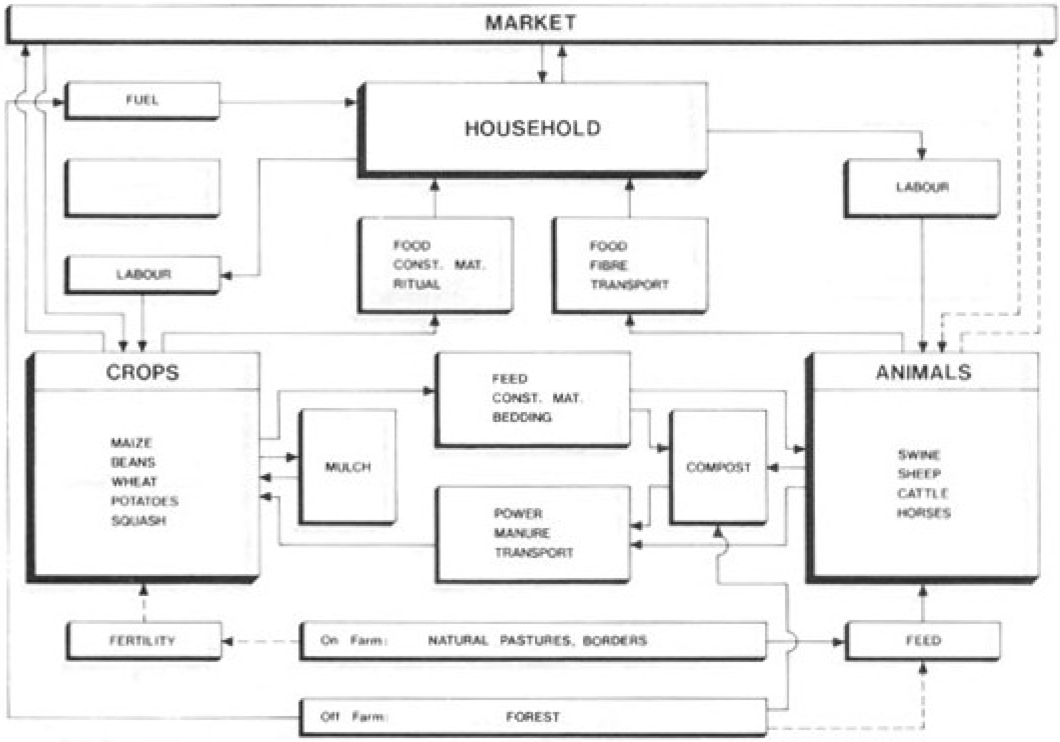


Fig. 14 Central American highlands, permanent cropping, high-level integration of crops and animals (animals herded or confined)
Source: McDowell and Hildebrand, 1980

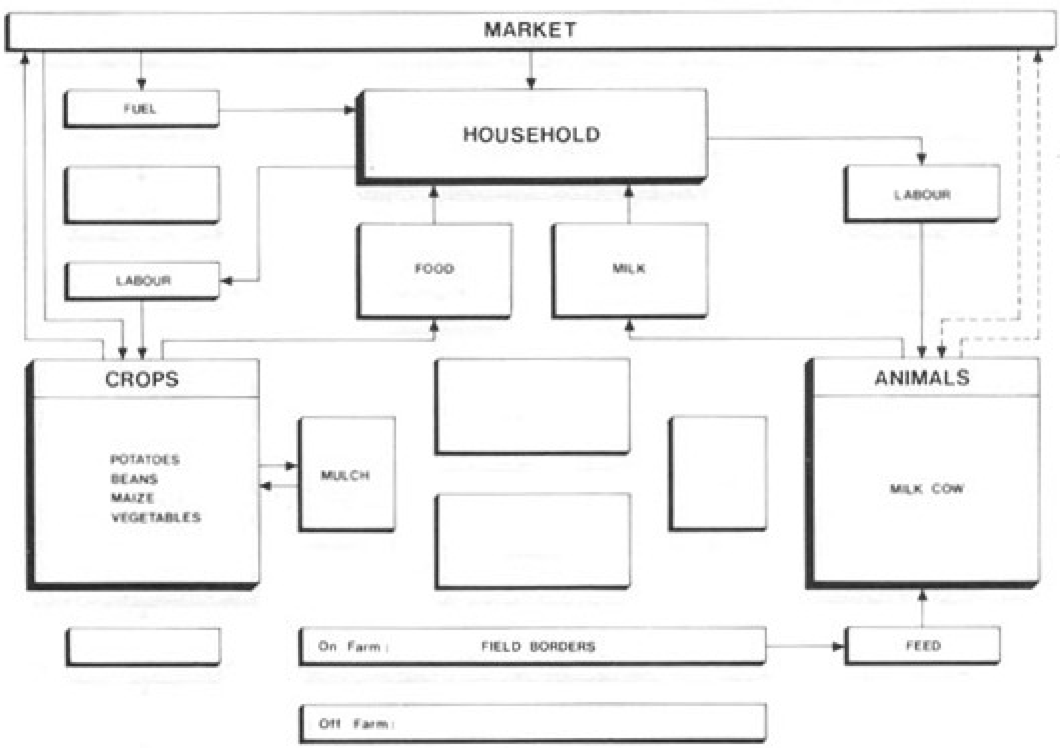


Fig. 15 Rio Negro (central highlands of Colombia), specialized area, permanent cropping, almost no integration of crops and livestock
Source: McDowell and Hildebrand, 1980

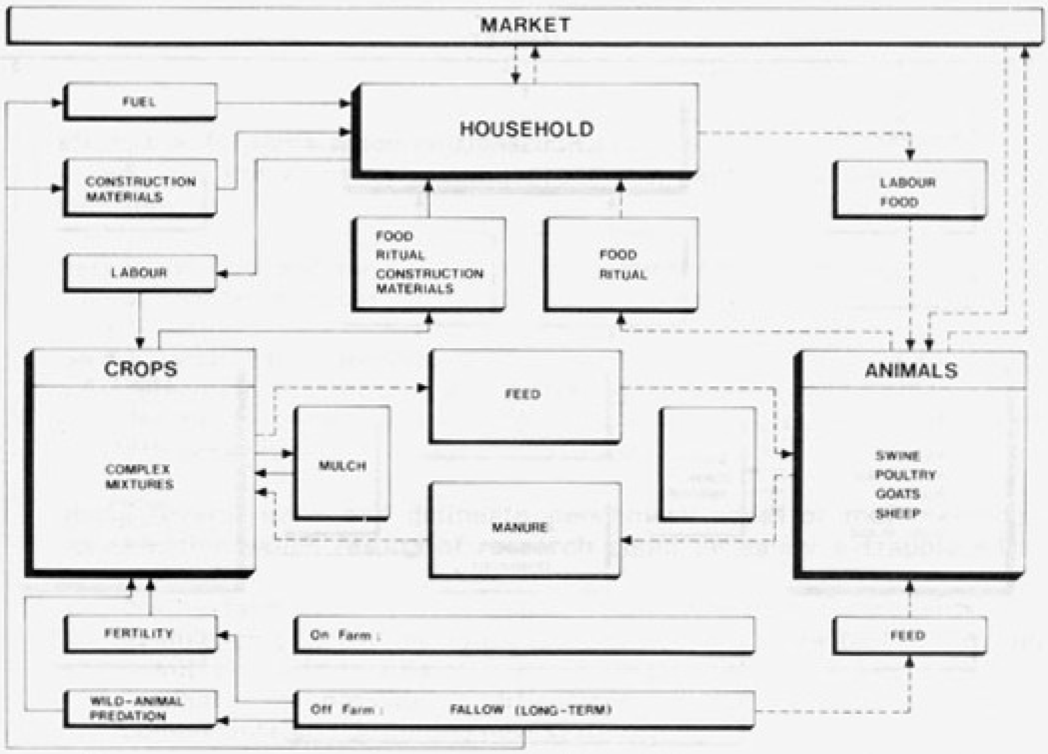


Fig. 16 Swidden farming system in Asia, shifting agriculture, low integration of crops and animals (animals free-roving or tethered)
Source: McDowell and Hildebrand, 1980

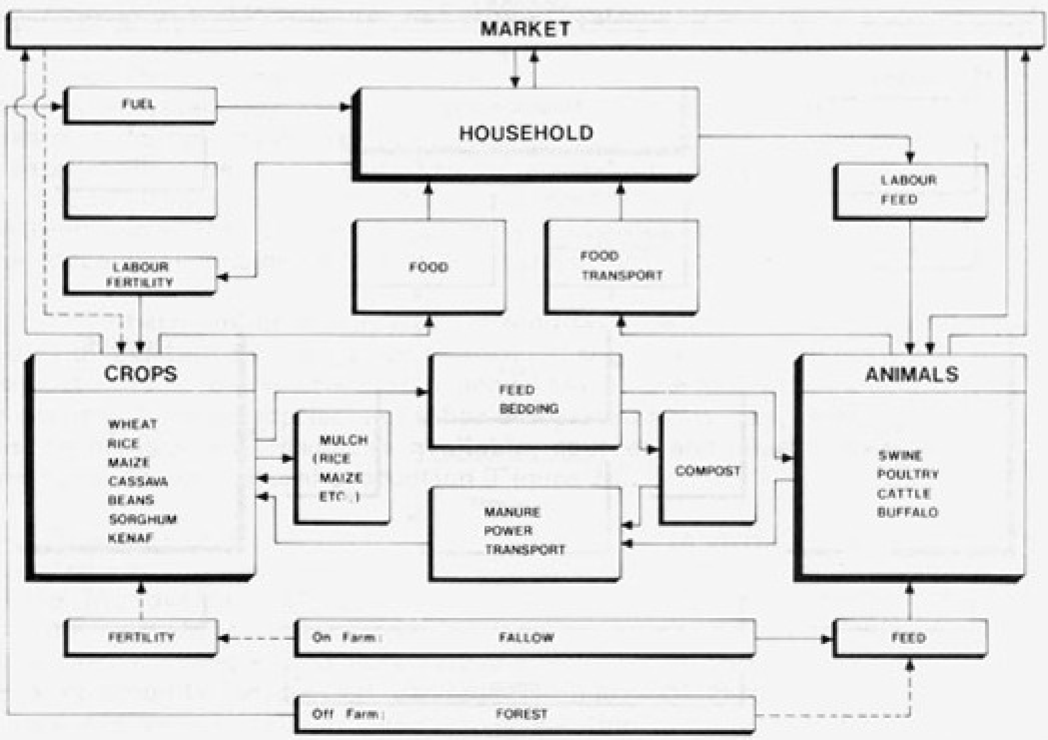


Fig. 17 Humid-upland farming system in Asia, permanent cropping, moderate integration of crops and animals (animals tethered or herded)
Source: McDowell and Hildebrand, 1980

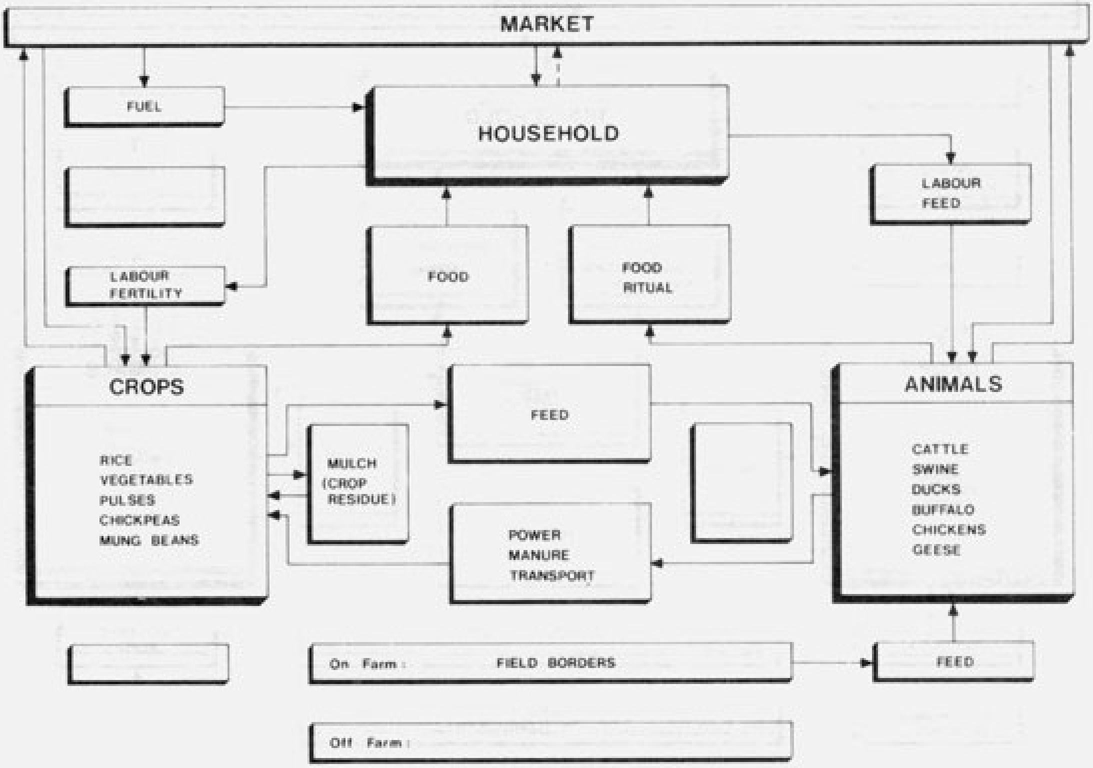


Fig. 18 Lowland rice system in Asia, permanent cropping, high integration of crops and animals (animals confined)
Source: McDowell and Hildebrand, 1980

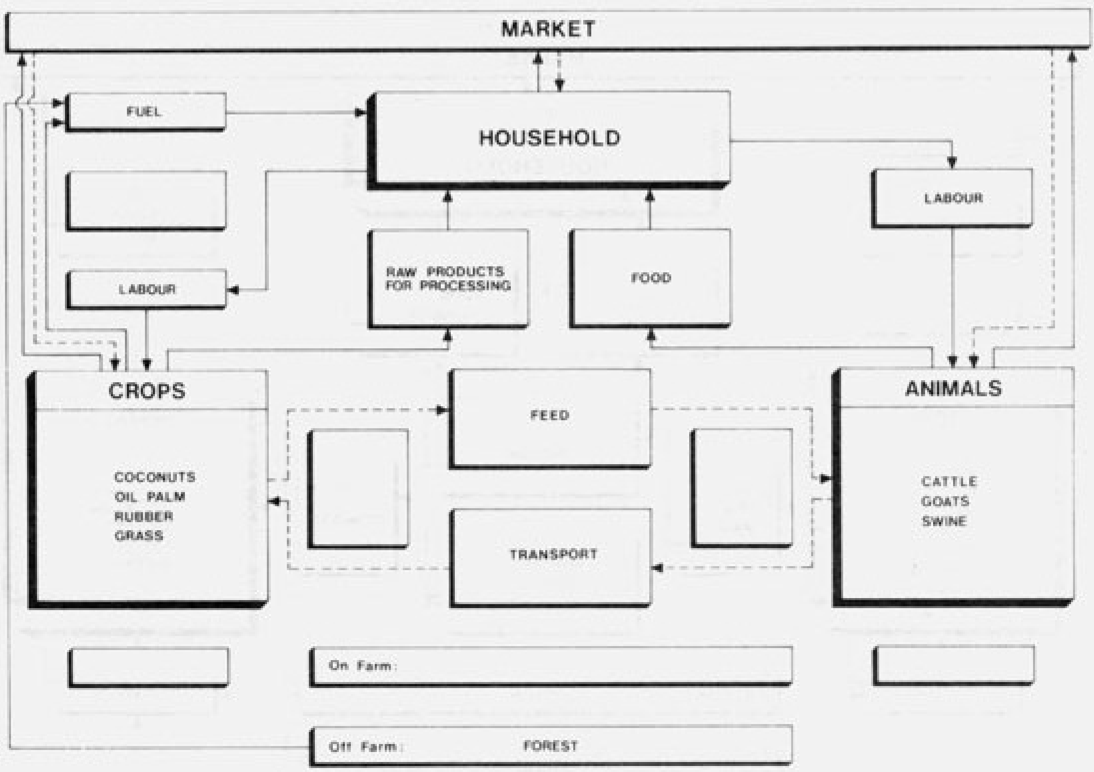


Fig. 19 Tree-crop farming in Asia, long-term cropping, low to moderate integration of crops and animals (animals tethered or roving)
Source: McDowell and Hildebrand, 1980

country;

ii. study the farmer's resource base, structure and functioning of the farm enterprise, the decision making processes, objectives and input/output relations;

iii. determine farmers' constraints in agricultural production and in the adoption of new technology;

iv. on the basis of the foregoing:
   a. determine strategies and priorities in research, and
   b. design, test and evaluate innovations and improved farming system components on the experiment station.

v. study several sites and delineate benchmark areas or major ecological zones within which results of research could be easily extrapolated as a basis for:
   a. on-the-farm evaluation of new technology, system components, etc.;
   b. evaluation of problems and rates of adoption of new technology; and
   c. monitoring of changes in farming systems so as to obtain necessary feedback for possible modifications of the technology or system components and designing new systems.

Research which accomplishes the above objectives usually ensures that new technologies developed at any one time and place are relevant to the farmer's situation and needs, are economically viable, culturally acceptable and within the farmer's ability to adopt, maintain, use or hire.

Principles and Procedures in Farming Systems Research

Since the systems approach to agricultural production and farming systems research is relatively new, principles and methodology of farming systems research have not crystallized as have, for example, the principles and methods of experimental design and analysis of agronomic experiments. It is, however, now becoming a common practice that research in farming systems involves 'upstream' (on-farm studies and problem identification), research station and 'downstream' (technology adoption and evaluation) activities.

The 'upstream' component of farming systems research consists of baseline studies of existing farming systems through secondary data sources and surveys. These studies give the scientist a good idea of the overall environment of the farmer, the farm enterprise and other associated activities, management objectives, technology and resources available, sources and magnitude of income arid constraints in agricultural production (Figure 20).

Research or experiment station studies involve studies and experiments on subsystems and system components. For example, cropping systems studies may involve improvement of maize for high yield and disease resistance, tillage, planting methods and dates, spacing, fertilizer practices, weed control methods, harvesting, storage, etc. The results of these studies facilitate recommendations for a commodity production package including (i) cropping patterns (combinations and sequences), (ii) livestock production system or (iii) integrated livestock/cropping pattern mixed farm system designed, tested and evaluated on the experiment station.

'Downstream' activities involve the testing in farmer's fields of packages of production technology or subsystem components developed at the experiment station. These trials vary from those under the control of the farming systems

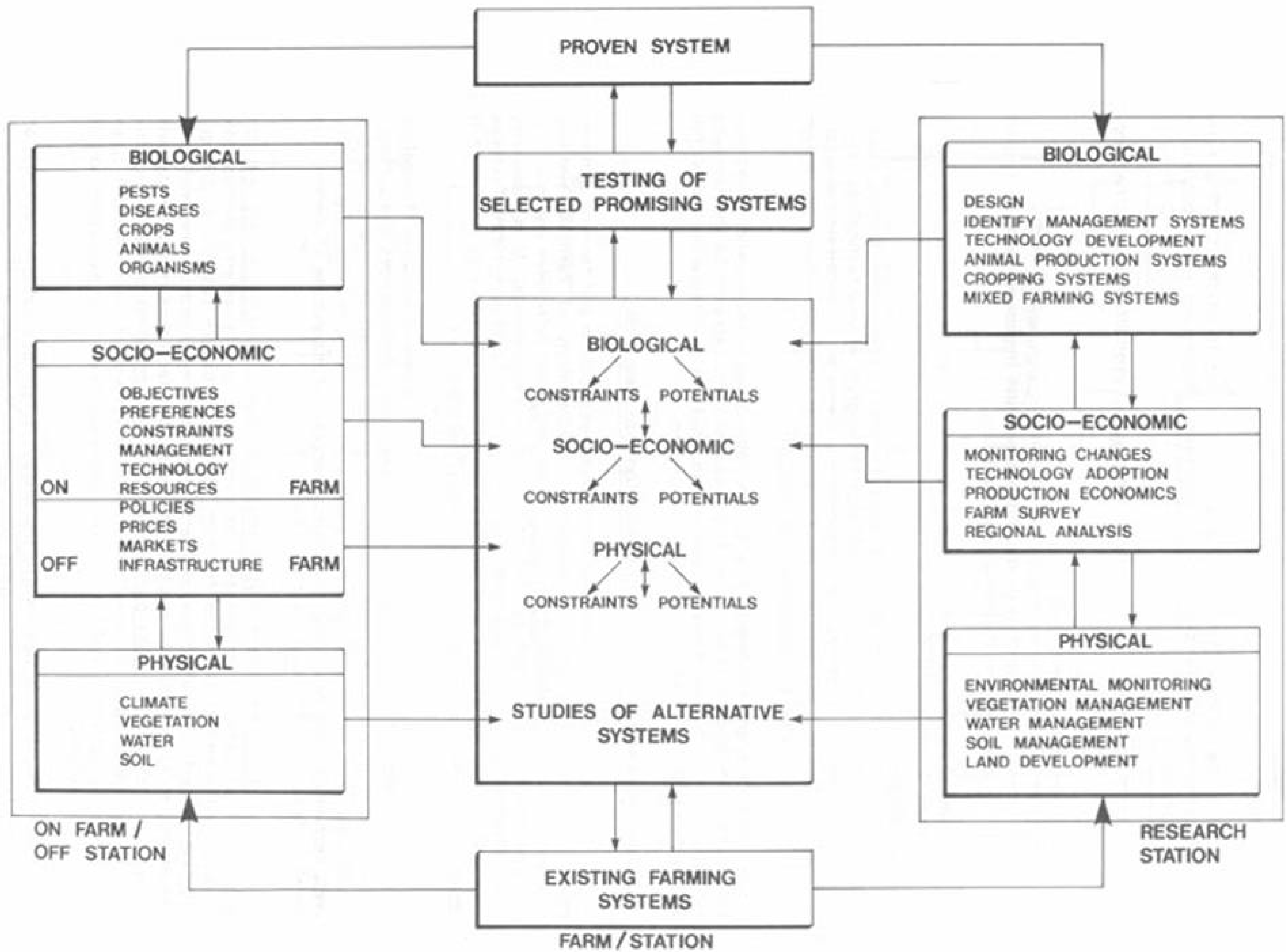


Fig. 20 Upstream component of farming systems research
Source: Okigbo, 1981

researcher to those under the control of the farmer with minimum guidance of the scientist. The adoption process may also be evaluated on the farm level and some feedback is obtained on the performance of the technology package. Usually, the test site of the technology packages is in selected benchmark areas determined on the basis of baseline data analysis and village level studies. The benchmark areas correspond to major ecological zones and represent areas within which results of tests of new technology or system components can be extrapolated with a high degree of confidence that similar results will again be obtained if the same trials are conducted in several locations. The same sites or benchmark areas used for evaluation of new technology are often used to monitor progress and problems of the adoption process and changes in farming systems. Information from observations on the adoption process and changes in farming systems are taken into account in the design of new farming systems and in the development of new technology. A given benchmark site will thus be used for the continuing improvement of the farming systems which should change as circumstances require. Well-designed and coordinated experiments on a range of ecological zones over a wide area constitute a farming systems research network. It enhances the establishment of principles which apply across ecological zones, detection of peculiarities of different ecological zones and evaluation of performance of various inputs and technology packages. At the same time, it gives due emphasis to local preferences, socio-cultural idiosyncrasies, needs and conditions. In this regard, IRRI has developed an effective cropping systems network in Southeast Asia and IITA is currently planning a farming systems research network in West Africa.

In farming systems research, it must be borne in mind that it is not always possible to develop complete packages of new technology before making them available to the farmer. A new package of technology may only involve a new element in the package. But it often happens that such a component may have synergistic effects on production or at least enhance significant improvement in yield and overall economic benefits accruing to the farmer. There is a place for application of linear programming and computer simulation modelling techniques in farming systems research but these would be most useful in advanced stages when scientists have gained a clear understanding of the variables and how they interact. It should also be emphasized that methodology in farming systems research is still developing. It may take one or more decades to perfect current methods and to place them in routine use.

JUSTIFICATIONS, BENEFITS AND CONSTRAINTS IN FARMING SYSTEMS RESEARCH ORIENTATION

Justification for Farming Systems Research

The CGIAR/TAC (1978) review of farming systems gives the following reasons for adopting a farming systems research orientation in developing countries:

i. most research workers need a better understanding of the skills, preferences, aspirations and existing management practices of the farmer, in particular of small-scale farmers;

ii. the diversity of the natural conditions of production, in particular in the tropics, and often also the need to use available labour supplies by intensive land use, result in strong interactions among the elements of a farm system and this leads to very complex situations;

iii. most of the farmers in developing countries have neither the power nor the means to identify and communicate their needs to research agencies;

iv. the array of agricultural services available to farmers in developing countries is limited; additionally, many technologies made available to them are not adapted to their conditions and their needs;

v. there is generally a wide gap between the results achieved on research stations and those obtained by the farmer, and therefore a need to determine why certain practices shown to be highly productive in experiment stations are either not adopted or, if adopted, may not at times be equally productive in the farmer's fields.

Benefits of a Farming Systems Research Orientation

The advantages of a farming systems research orientation, according to the CGIAR/TAC (1978) review, include:

i. although development agencies and other groups continuously express particular interest in small farmers and their problems, in reality agencies have little basis for understanding them, their production methods, or their needs;

ii. in the past, most agricultural research in developing countries has been based on narrow disciplinary approaches, and integration and application of new information by the farmer has been difficult. FSR provides a structure within which researchers examine problems in a farm system context, and attempt to achieve solutions which will fit into that farm system, given the farmer's capabilities and needs ;

iii. FSR can provide a basis for developing improved technology and its transfer because it recognizes the need to understand the farmer's system, to categorize the natural resource base on which the system operates, and to provide a basis for a focused research programme on major factors limiting performance of a given system. FSR should also assist in understanding and testing location specificity of certain practices;

iv. by concentrating on crop or animal production systems, rather than discrete factors without regard to their interactions, FSR provides an opportunity to study various crop mixtures, natural resource management practices, or other important components on a large-scale basis and under conditions which allow more complete technical and economic analysis. Furthermore, good FSR should lead to improved management assistance to the farmer. Presently, in most cases, farmers are offered diverse bits of · information concerning new management opportunities without the benefit of even experimental trials on these practices at the production field level.

Constraints in Farming Systems Research

Various constraints have been encountered or foreseen in this early stage of adoption of a farming systems approach, especially in the developing countries. Okigbo (1981) listed the following constraints:

i. the need for reorientation of scientists traditionally trained within disciplines, towards thinking and participating in problem-oriented multidisciplinary research teams;

ii. the management of research teams in projects that require contributions from individual disciplines in their own right, at the same time interactions among disciplines;

iii. the need for and difficulties in establishing a suitable structural organization for teamwork that allows flexibility which facilitates interaction among research teams, programmes and institutions;

iv. a shortage of high-level manpower in the relevant disciplines;

v. the detrimental effects of teamwork to the career opportunities of young scientists;

vi. consequently, many national agricultural systems cannot afford the skills, tact and experience in research management required to determine priorities in relation to available resources, so as to avoid study of too many details at the same time. (It also calls for coordinated regional programmes of which, until recently, most newly independent countries failed to recognize the merits and even now face socio-economic obstacles in their organization and execution.)

Norman (1978) has observed that in current farming systems oriented research programmes (a) priority has been given to crop production enterprises without due consideration of livestock production systems which affect crops and off-farm enterprises and activities outside the farm gate, such as marketing; (b) there has often been some bias towards the short-term as compared to the long-term objectives of farming systems research; (c) considerable time may be taken to identify the problems, find effective solutions and finally attain their adoption at the farm level; (d) frequently the scientists involved in farming systems research are trained and knowledgeable only about large-scale and well endowed farm production systems of the temperate countries with very little or no background in the socio-economic conditions of farmers in the developing countries of the tropics; (e) limited conscious effort has been made to ensure that there is a balance in the development of principles that may apply across several benchmark areas as compared to location-specific practices and technology of limited extrapolation beyond the ecological zones in which they were generated. The bias being given to cropping systems in farming systems research, the need to rectify this deficiency by recognizing the prevalence of integrated crop and livestock production systems that already exist in tropical Asia, Central and South America and Africa have been reviewed in McDowell and Hildebrand (1980).

The effective solution to the problem resulting from (e) above is the development of a well-coordinated research network involving several regions and benchmark areas so that comparative evaluation of results of various treatments can give an idea of those effects which are inherent to the materials or technologies under test as compared to those that are location-specific.

The above constraints can be considerably minimized if, in farming systems research for finding alternatives for shifting cultivation, priority is given to:

a. emphasis on manpower development and research training schemes aimed at assisting the developing countries in rapidly developing capabilities in farming systems research;

b. developing mechanisms in the research programmes on shifting cultivation to ensure early linkage of research with extension and development projects;

c. effective coordination of the scientists in the different but relevant disciplines in inter-disciplinary research teams that balance individual contributions in teamwork with career opportunities while effectively ensuring that priority is given to the specified objectives of the project. This is especially crucial in the case of young scientists who are expected, early in their careers, to contribute to the growth of knowledge or development of new techniques in their disciplines thereby attaining some status as scientists in their own right.

STATUS OF CURRENT KNOWLEDGE OF FARMING SYSTEMS OF THE TROPICS

Agriculture is the business, science and art of growing crops and rearing animals to satisfy human needs for food, shelter, fibre, industrial and miscellaneous products. Sometimes it is defined broadly to include forestry and fisheries activities. In the restricted definition, agricultural systems are synonymous with farming systems. Diverse farming systems such as shifting cultivation have evolved in different parts of the world among various peoples. Agricultural systems or farming systems are differentiated on the basis of various factors: physico-chemical (water, rainfall, light, temperature, soil conditions, wind, etc.); biotic plants, animals, pathogens, weeds, nitrogen-fixing bacteria, etc.); socio-economic (supply, demand, markets, political background and processes, local preferences, etc.); technological (knowledge, tools and equipment, practices, etc.); and managerial decision-making process, experience, etc.). These interact in a unique and complex manner to satisfy in varying degrees the farmer’s needs in a given environmental setting (Okigbo,1980). The integrity of the farmer as a manager depends on knowledge of the things around him or her, and general experience by which he or she uniquely orchestrates the available resources and inputs to ensure a satisfactory level of agricultural production both qualitatively and quantitatively. According to Shultz (1957), the productivity of each agricultural system and the cultural landscape are manifestations of the state of the art in a given geographical location. Agricultural production as already observed is, therefore, location specific with each farmer being able to determine the number, amounts, timing, sequences and how to apply inputs and manipulate the environment to attain reasonable levels of agricultural production. The extent to which he or she attains optimum yields depends on experience, abilities, resources and technologies available and the vicissitudes of the environment during the course of the life cycle of the crop(s) or animal(s). It follows also that each farm constitutes a unique entity and theoretically there would be at least as many farming systems as there are individual farmers (or in some cases farm families), multiplied by the number of commodities and the different unique ways in which they are being produced. No two farms producing the same commodity or commodities are ever the same. There are differences in soils, rainfall, pests, diseases, management and so on.

In order to study, understand, describe and carry out comparative evaluations of various farming or agricultural systems, attempts have been made to classify them. There is at present no generally accepted typology for the classification of farming systems. Various classifications have been used for different purposes. The earliest classification is that of the major agricultural regions of Whittlesey (1935) on which is based the related classification of the International Geographic Union. Duckham and Masefield (1970) also reported a classification of farming systems of the world in relation to perennial, arable crops, horticultural and livestock production systems in addition to the intensity of cultivation (see Table 7). In this paper, only aspects of classification of farming systems of relevance to shifting cultivation and related fallow systems in the tropics are considered. Boserup (1970) recognized five more or less arbitrary systems of land use of increasing intensity of cultivation consisting of:

Table 7

CLASSIFICATION OF FARMING SYSTEMS

	Tree crops		Tillage with or without livestock		Alternating tillage with grass, bush or forest		Grassland or Grazing of land consistently in 'indigenous' or man-made pasture	
	Temperate	*Tropical*	*Temperate*	*Tropical*	*Temperate*	*Tropical*	*Temperate*	*Tropical*
Very Extensive	Cork collection from Maquis in southern France	Collection from wild trees, e.g. shea butter	—	—	Shifting cultivation in Negev Desert, Israel	Shifting cultivation in Zambia	Reindeer herding in Lapland. Nomadic pastoralism in Afghanistan	Camel-herding in Arabia and Somalia
Extensive Examples	Self-sown or planted blueberries in the north-east of the U.S.A.	Self-sown oil palms in West Africa	Cereal growing in Interior Plains of North America, pampas of South America, in unirrigated areas, e.g. Syria	Unirrigated cereals in central Sudan		Shifting cultivation in the more arid parts of Africa	Wool-growing in Australia. Hill sheep in the U.K. (Sheep in Iceland.) Cattle ranching in the U.S.A.	Nomadic cattle-herding in East and West Africa. Llamas in South America
Semi-Intensive Examples	Cider apple orchards in the U.K. Some vineyards in France	Cocoa in West Africa. Coffee in Brazil	Dry cereal farming in Israel or Texas, U.S.A.	Continuous cropping in congested areas of Africa. Rice in S.E. Asia	Cotton or tobacco with livestock in the south-east of the U.S.A. Wheat with leys and sheep in Australia	Shifting cultivation in much of tropical Africa	Upland sheep country in North Island, New Zealand	Cattle and buffaloes in mixed farming in India and Africa
Intensive Examples	Citrus in California or Israel	Rubber in S.E. Asia. Tea in India and Ceylon	Corn Belt of the U.S.A. Continuous barley growing in the U.K.	Rice and vegetable growing in south China. Sugar-cane plantations throughout tropics	Irrigated rice and grass beef farms in Australia. Much of the east and south of the U.K., the Netherlands, northern France, Denmark, southern Sweden	Experiment stations and scattered settlement schemes	Parts of the Netherlands, New Zealand and England	Dairying in Kenya and Rhodesia highlands
Typical Food Chains	A	A	A, B	A	A, B, C, D	A (C)	C (D)	C

Source: Duckham and Masefield, 1970

i. forest-fallow cultivation with cultivation periods of one or two years followed by long fallow periods of twenty or more years;

ii. bush-fallow cultivation with cultivation periods of one to six or eight years and fallows of six to eight years;

iii. short-fallow cultivation with fallows of only one or two years;

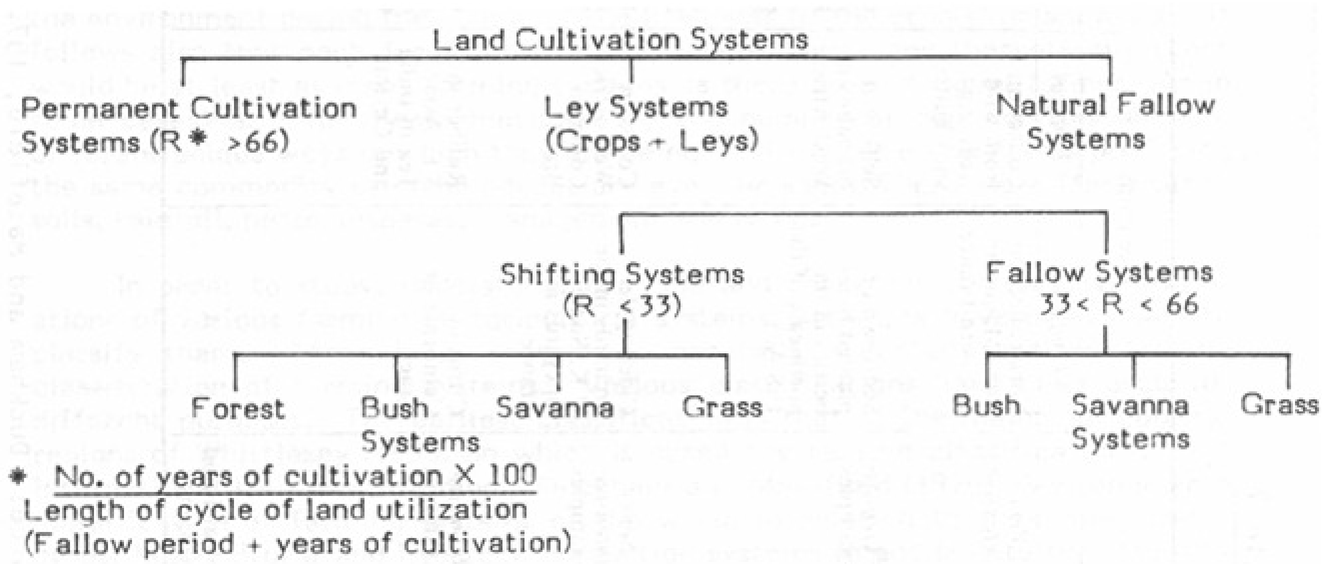
iv. annual cropping involving only several months of fallow but including annual rotational sequences;

v. multi-cropping involving the most intensive system of land use in which successive plantings follow successive harvests.

Boserup noted that recent shifts from the more extensive to the intensive systems have been ushered in by increasing population pressure. Ruthenberg (1971 and 1980) reviewed the different classifications used in the agriculture of the tropics and recognized the following main categories:

A. Collecting
B. Cultivation Systems
C. Grassland Utilization Systems

Collecting is used to designate the main preoccupation of prehistoric people when they relied on hunting and gathering for subsistence. Hunting and gathering is now restricted to some primitive tribes such as the Tasaday of Mindanao Island, and parts of the Kalahari, and the Amazon Basin. However, some of the cultivators in various parts of the tropics practising advanced forms of shifting cultivation and sedentary agriculture still depend on some collection for supplementing food grown on the farm. Ruthenberg (1971, 1980) also noted that in parts of West Africa palm products continue to be collected from wild oil palms. Similar practices exist in parts of Southeast Asia and Central and South America. Under cultivation systems Ruthenberg (1971, 1980) reviewed different fallow systems, field systems and systems with perennial crops on the basis of the R (cultivation and land use intensity) index of Joosten (1962) in addition to the FAO/SIDA (1974) cultivation systems classification presented below:



Ruthenberg (1971, 1980) also considered classifications related to the intensity of rotations, water supply, cropping pattern, animal activities, implements used for cultivation, degree of commercialization and grassland utilization. A detailed treatment of shifting cultivation systems was presented in relation to vegetation (forest, bush, savanna and grassland) types; fallows; migration (direction, frequency, and distance) systems; rotation (classical long fallow, long-term fallow, medium-term fallow and short-term fallow systems), clearance systems in relation to burning, hoeing, cutting, tree killing and refuse or debris utilization methods; cropping systems, and tools (digging sticks, hoes, plough, etc.) systems. Spedding (1975) presents a simplified version of Ruthenberg's classification (Figure 21a).

Various attempts to classify shifting cultivation also reviewed by Ruthenberg (1980) and considered in greater detail by FAO/SIDA (1974) include those of Allan (1966) and Greenland (1974). Both systems are related in terms of the use of intensity or frequency of cultivation as the main criterion. Classification of cultivation systems by Allan (1966) in comparison with others is shown in Table 8. That of Greenland and Okigbo (1980) is presented in Table 9. The various categories designate different degrees of intensification of cultivation which can best be evaluated on the basis of the land use factor (L) with:

$$L = \frac{C+F}{F}$$

where C = no. of years of cultivation
F = no. of years of fallow

During the early stages of shifting cultivation, when fallow periods are long, L > 10, but when a sedentary and permanent cultivation stage is reached as on the compound farm, L = l. The cutoff points for the different kinds of recurrent cultivation are more or less arbitrary. Moreover, in Africa, the various systems of shifting cultivation are interwoven in the agricultural landscape. For example, one farmer or farm family operates a compound farm which is a permanent system with various crops and livestock with L = 1 or less, a field or fields on which is practised bush fallow system of the rudimentary sedentary or recurrent cultivation type with L = 4 close to the homestead and further away a field or fields system with a bush fallow cropping system where L = 7-10. Moreover, in different parts of Africa, governments, private enterprise and individuals are experimenting with different farming or cultivation systems. It is in consideration of these different activities in different field systems and on the basis of Allan (1966), Greenland (1974), Benneh (1972) and various other classifications that the classification of farming systems in tropical Africa, shown in Table 10 and based on Okigbo and Greenland (1976), was prepared. Classification of farming systems by Spedding (1975) is presented in Figure 21b.

Harwood (1976) presented a classification of the farming systems of tropical Asia based on the various stages of their development and consisting of the following:

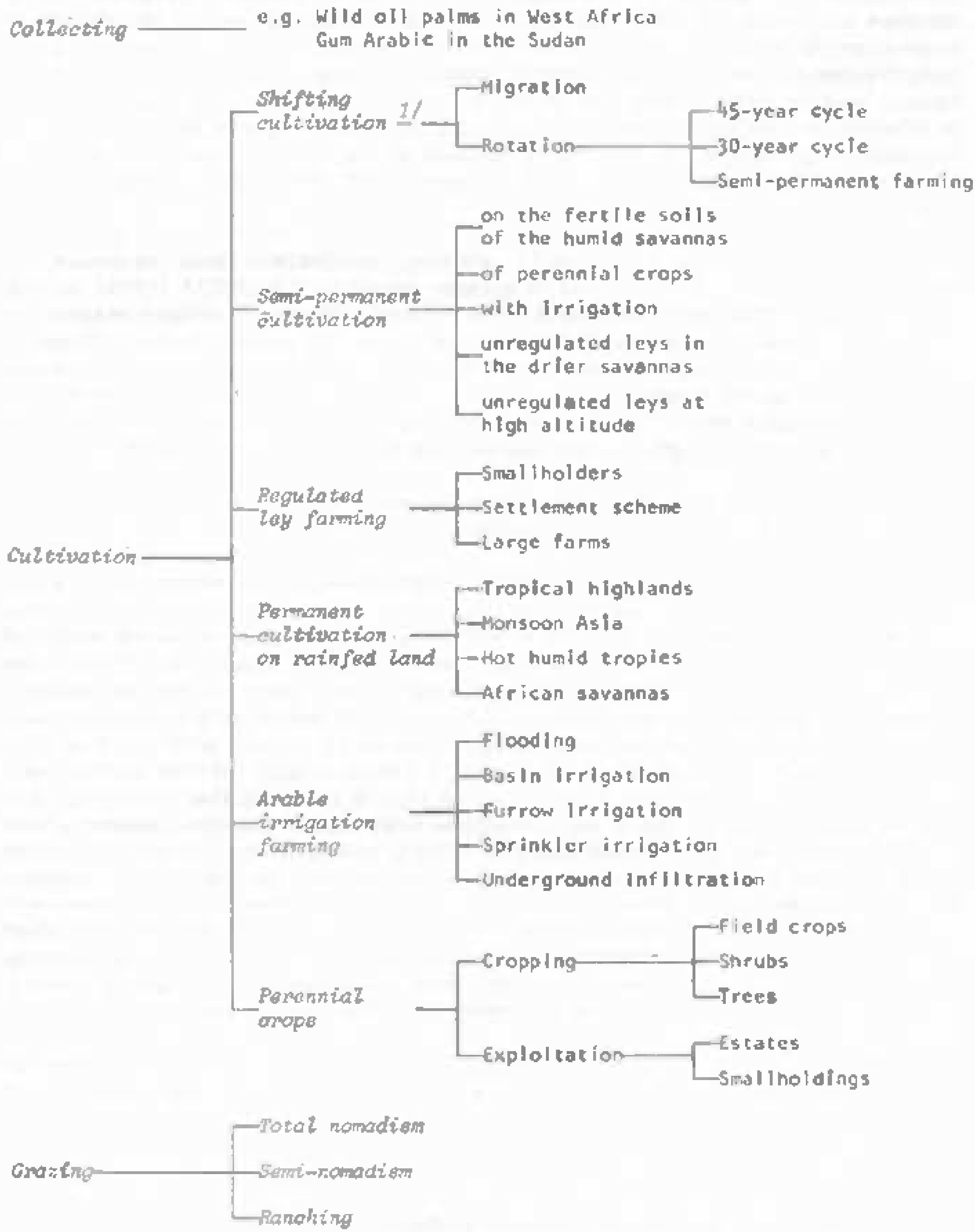
i. Primitive hunting and gathering

ii. Subsistence level - crop and animal husbandry

iii. Early consumer stage

iv. Primary mechanization stage (see Table 11)

The primitive hunting and gathering stage is no longer widespread, being practised, as indicated above, by the Tasaday of Mindanao. The subsistence farmers practise shifting cultivation which in Asia covers about 40 percent of the crop area and constitutes about the same number as practising sedentary or more or less permanent agriculture. The subsistence farmers produce a great variety of crops (30-40 species) and rear 5-6 species of animals. About



1/ Also classified by vegetation and by method of clearance

Fig. 21a Classification of farming systems in the tropics (after Ruthenberg, 1971)
Source: Spedding, 1975

Table 8 PEASANT AGRICULTURAL SYSTEMS

Allan [a]	Boserup [b]	Benneh [c]	Morgan [d]	Ruthenberg [e]
Pastoral	-	-	Pastoral	Grazing
Shifting cultivation	Forest fallow	Shifting cultivation	Shifting cultivation	Shifting cultivation
Recurrent cultivation	Bush fallow	Bush fallow	Rotational bush fallow	
Semi-permanent cultivation	Short fallow	Planted fallow	Semi-permanent cultivation	Semi-permanent cultivation
				Ley farming
Permanent cultivation	Annual cropping	Permanent small-scale cultivation [f]	Permanent cultivation	Permanent rainfed cultivation
-	Multi-cropping	-	-	Perennial cultivation
-	-	Floodland cultivation	Floodland cultivation	Irrigation farming

a Allan, 1965
b Boserup, 1965
c Benneh, 1972
d Morgan, 1969a
e Ruthenberg, 1971
f Includes compound farming, mixed farming, specialized horticulture, and tree cropping.

Source: Knight and Newman (eds), 1976

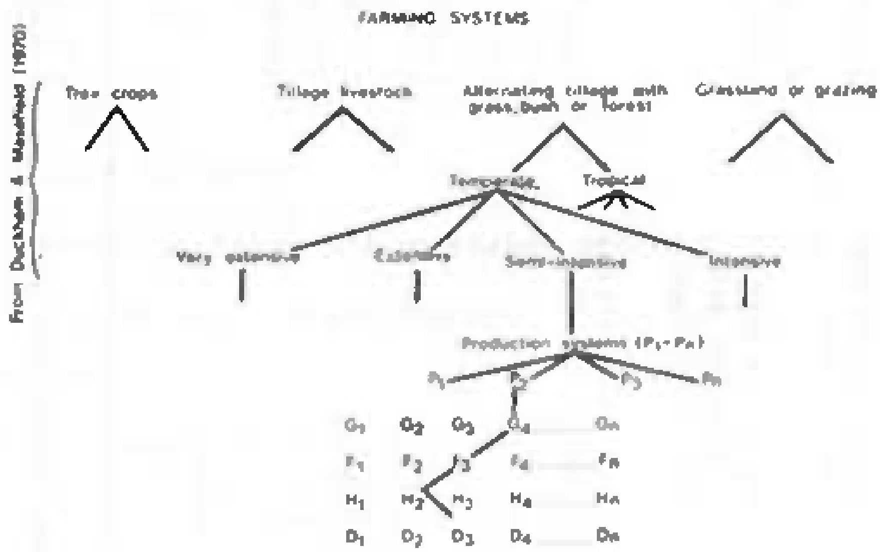


Fig. 21b Classification of agricultural systems (greatly abbreviated)
Source: Spedding, 1975

Table 9 PHASES OF SHIFTING CULTIVATION (GREENLAND, 1974) AND TENTATIVE RELATIONSHIPS WITH LAND CATEGORIES (ALLAN, 1965) AND SOIL ORDERS

	Phase I	Phase II		Phase III	Phase IV
The Phases of land cultivation	Simple shifting cultivation Dwellings and cultivated area shift together	Recurrent cultivation May be complex, with several field types		Recurrent cultivation with continuously cultivated plots Always complex, with several field types	Continuous cultivation May involve alternate husbandry with planted and cultivated pastures or fallow crops
Land categories	Shifting cultivation land L > 10*	Recurrent cultivation land			Permanent (L<2) and semi-permanent land, L < 2-3
		Long-term recurrent cultivation L=7-10	Medium-term recurrent cultivation L=5-7	Short-term recurrent cultivation L=3-5	
Principal soil order with which associated (very tentative)	Any	Alfisols Ultisols Oxisols	Alfisols Deeper Ultisols	Alfisols Deeper Ultisols Andepts	Rhodustalfs Andepts

* L = Land Use Factor, defined as $L = \frac{C + F}{C}$ where C = length of cropping period in years,
F = length of fallow period in years (Allan, 1965)

Source: Greenland and Okigbo, 1980.

Table 10 CLASSIFICATION OF FARMING SYSTEMS IN TROPICAL AFRICA

A. Traditional and Transitional Systems

1. Nomadic herding:
   shifting cultivation (Phase I), $L > 10^2$

2. Bush fallowing or land rotation:
   shifting cultivation (Phase II), $L = 5\text{-}10$

3. Rudimentary sedentary agriculture:
   shifting cultivation (Phase III), $L = 2\text{-}4$

4. Compound farming and extensive subsistence agriculture:
   shifting cultivation (Phase IV), $L < 2$

5. Terrace farming and floodland agriculture

6. Mediterranean agriculture (traditional)

B. Modern Farming Systems and their Local Adaptations

1. Mixed farming

2. Livestock ranching

3. Intensive livestock production (poultry, pigs, dairying)

4. Large-scale farms and plantations:
   a. Large-scale food and arable crop farms based on natural rainfall
   b. Irrigation projects involving crop production
   c. Large-scale tree crop plantations

5. Specialized horticulture:
   a. Market gardening
   b. Truck gardening and fruit plantations
   c. Commercial fruit and vegetable production for processing

6. Mediterranean agriculture (modern)

$^2L = C + F/C$, where C = Cropping period
F = Fallow period
L = Land use factor

Source: Okigbo and Greenland, 1976

Table 11 CHARACTERISTICS OF DEVELOPMENT STAGES IN AGRICULTURE (FOR FARMS WITH A RELATIVELY HIGH LEVEL OF RESOURCE USE FOR THEIR DEVELOPMENT STAGE)

	Shifting cultiv-tion	Permanent agriculture (subsistence)		Commercial family farms	Corporate or state farms
		Less than 10% sales	10-50%	over 50% sales	
Proportion of farmers involved	- - - - - over 40% - - - - - -			less than 50%	less than 3%
Predominant labour activities:					
Land clearing	x				
Tillage by hand	x	x	x		
Tillage by animal		x	x	x	
Tillage by machine				x	x
Animal tending		x	x	x	
Crop tending	x	x	x	x	x
Nutrient cycling		x	x		
Harvesting	x	x	x	x	x
Marketing			x	x	
Types of farming systems					
Monoculture crops	no	yes	yes	yes	yes
Intercropping	yes	yes	yes	rarely	no
Draft animals	none	yes	yes	yes	none[1]
Pigs untended	yes	no	no	no	none[1]
Poultry untended	yes	yes	yes	yes	none[1]
Complementarity of interactions between crops & between crops & animals	slight[2]	very high	high	moderate	slight
Importance of farmstead to family nutrition	slight	very high	high	moderate	slight

[1] Animals and cultivated crops are usually not mixed on corporate farms in the tropics.

[2] Negative when animals compete with people for food.

Source: Harwood, 1976.

90 percent of the farm produce or more is consumed on the farm. The early consumer stage involves farmers who market 10-30 percent of their farm produce and with the cash buy more manufactured goods, rather than making them themselves as do subsistence farmers.

A large proportion of the shifting cultivators in the tropics belong to the subsistence and early consumer stage since, according to Wharton (1969) cited by Harwood (1976), about 60 percent of the world's farmers market less than 50 percent of their produce. Farmers in the early consumer stage grow some tree crops, vegetables, tobacco, rice, etc. for sale and, in addition to their crop and animal husbandry skills, engage in a diversity of non-agricultural enterprises. In the primary mechanization stage, the farmers have begun to rent or purchase mechanical power and the number of crops and enterprises are lower as compared to the other previous categories of farmers. Where labour is scarce, mechanization helps increase productivity and sometimes frees farm hands for off-farm employment. Most of the machinery on the farm is used in tillage and transportation, while mechanization of cultivation, planting, harvesting and processing occurs at a secondary mechanization stage. Classification of the various stages of farming systems development and different operations involved are presented in Table 11.

As a result of farming systems research, regional analysis and baseline studies by scientists in various international and national institutions, a preliminary review of the majority of small farm production systems in Africa, Asia and Latin America has been presented in McDowell and Hildebrand (1980). Listings of these are presented in Tables 12, 13, and 14. Large-scale commercial farms and farms specializing only in one or two perennial or arable crops or only livestock are not included since these are practised by a very small proportion of farmers, most of whom are not shifting cultivators. The complexity of these farming systems, the interrelationships among the various components in addition to the interactions among the various physical, environmental and social elements in the system are shown in Figures 8-19 for selected systems on different ecological zones in Africa, Asia and Latin America. The characteristics of small farm production systems which involve shifting cultivation and related fallow systems, changes in shifting cultivation and their causes and, finally, a review of constraints to increased agricultural production in tropical Africa are considered below.

CHARACTERISTICS OF SHIFTING CULTIVATION AND SMALL FARM PRODUCTION SYSTEMS

The diverse shifting cultivation and related bush fallow systems practised in different parts of the world by various peoples involve different tools, practices, crops/livestock enterprise mixes on soils of different fertility capabilites on a range of topographic situations. They also vary in the proportion of produce used for subsistence or sold and in the amount and range of supplementary foodstuffs harvested from the wild. According to Wharton (1968) farmers are regarded as subsistence when 50 percent or less of their farm produce is offered for sale, and as commercial when more than 50 percent of the produce is sold. Despite the variability that exists among the different shifting cultivation and intermittent production systems that exist on any one continent, there are many similarities in several characteristics of these farming systems. On the basis of studies of farming systems of tropical Africa and their comparison with the main features of similar systems reported from other parts of the tropical world, main characteristics of note include:

Farming objective: Shifting cultivators farm mainly for subsistence with varying

Table 12 PREVAILING SYSTEMS OF AGRICULTURE ON SMALL FARMS, MAIN REGIONS OF USE, MAJOR CROPS AND ANIMAL SPECIES, AND FEED SOURCES FOR ANIMALS OF AFRICA

Farming system	Major crops	Major animals	Main regions *	Feed sources
1. Pastoral herding (Phase I, L>10 ²)* animals very important (symbiotic relationships)	Vegetables (compound)	Cattle, goats, sheep	Savanna (Southern Guinea)	Natural rangelands, tree forage
	Millet, vegetables	Cattle, goats, sheep	Savanna (Northern Guinea and Sahel)	Natural rangelands, tree forage, crop residues
2. Bush fallow (shifting cultivation, Phase II, L = 5-10), animals not important	Rice/Yams/Plaintains maize, cassava, vegetables, tree crops, cocoyams, yams	Goats, sheep	Humid tropics	Fallow, crop residues
	Sorghum/Millet maize, sesame, soybeans, cassava, sugarcane, tree crops, cowpeas, vegetables, yams	Cattle, goats, sheep, poultry, horses	Transition forest/ savanna Southern Guinea Northern Guinea and Sahel	Fallow, straws, stover, vines, cull roots, sesame cake
3. Rudimentary sedentary agriculture (shifting cultivation, Phase III, L = 2-4) animals important	Rice/Yams/Plaintains maize, cassava, vegetables, tree crops, cocoyams	Goats, sheep, poultry, swine	Humid tropics	Rice bran, cull roots, straws, crop residues, vines, stover
	Sorghum/Millet maize, sesame, cotton, sugarcane, tree crops, cowpeas, yams, tobacco, groundnuts, vegetables	Cattle, goats, sheep, poultry	Transition forest/ savanna Savanna (Guinea and Sahel)	Stover, vines, sugarcane tops, cull roots, or tubers, tree forage, groundnut cake, brans
4. Compound farming and intensive subsistence agriculture (shifting cultivation, Phase IV, L=<2), animals important	Rice/Yams/Plaintains maize, cassava, vegetables, tree crops, cocoyams, yams	Goats, sheep, swine, poultry	Humid tropics,	Rice straw, rice bran, vegetable waste, fallow, vines, cull tubers or roots, stover, tree-crop by-products, palm oil cake
	Vegetables sugarcane, tobacco, sesame, maize, tree crops, groundnuts	Goats, sheep, poultry, swine	Transition forest/ savanna	Vines, stover, tree-crop by-products, groundnut cake
	Vegetable/Millet cassava, cowpeas, tobacco, cotton, groundnuts, tree crops	Cattle	Savanna (Guinea and Sahel)	Vines, tree-crop by-products, cassava leaves, fallow
5. Highland agriculture, animals important	Rice/Yams/Plaintains maize, cassava, vegetables, plantain, cocoyams	Goats, sheep, poultry, swine	Humid tropics	Fallow, leaves, stover, rice by-products, cull tubers, cassava leaves, vegetables residues
	Sorghum soybeans, cowpeas, cassava, maize, millet, groundnuts	Cattle, goats, sheep, poultry	Transition forest/ savanna	Stover, vines, groundnut cake
	Millet/Sorghum maize, groundnuts, cowpeas, sesame, tobacco, cotton, vegetables, cassava, yams	Cattle, goats, sheep, poultry, horses, donkeys	Savanna (Guinea and Sahel)	Crop residues, some oil cake, brans, stover, vines, cull tubers

Source: McDowell and Hildebrand, 1980.

Table 12 (continued)

Farming system	Major crops	Major animals	Main regions	Feed sources
6. Flood land and valley bottom agriculture, animals of some importance	Rice/Yams/Plantains maize, vegetables, sugarcane, rice, yams, cocoyams, millet, groundnuts	Goats, poultry	Humid tropics	Crop residues, vines, grazing
	Rice vegetables, maize, millet, groundnuts plantain, sugarcane, cocoyams	Cattle, goats, sheep, poultry, swine, horses, donkeys	Transition forest/ savanna	Straw, stover, molasses, brans, groundnut cake
	Yams/Sugarcane maize, cowpeas, cocoyams, groundnuts, vegetables, plantains, rice, yams	Cattle, goats, sheep, poultry, swine, horses, donkeys	Savanna (Guinea and Sahel)	Vines, brans, cull tubers, molasses, sugarcane tops
7. Mixed farming (farm size variable; animals important)	Rice/Yams/Plantains	2 or more species (widely variable)	Humid tropics	Fallow, straw, brans, vines
	Rice/Vegetables yams, cocoyams	Some cattle	Transition forest/ savanna	Fallow, vines, straw
	Sorghum/Millet groundnuts, cotton, tobacco, maize, cowpeas, vegetables	Cattle, goats, sheep, poultry, horses, donkeys, camels	Savanna (Guinea and Sahel)	Stover, vines, fallow
8. Plantation crops, East Africa (small holdings), animals of some importance	Coconuts vegetables, maize, plantains, cocoyams, cassava	Cattle, horses, donkeys	Humid tropics Transition forest/ savanna	Grazing or cut and carry
9. Plantation crops, (compound farms, etc.), animals of some importance	Cacao vegetables, maize, plantains	Goats, sheep, poultry, swine	Humid tropics	Grazing or cut and carry, stover
	Tree crops sugarcane, plantains	Goats, sheep, poultry, swine	Transition forest/ savanna	Grazing or cut and carry, sugarcane tops
10. Market gardening (animals may or may not be present)	Vegetables	Variable	Humid tropics	Natural rangelands, crop residues, browse plants, range forbs

[a] $L = C + F/C$; L = land-use factor; C = area of cultivation; F = area in fallow.

[b] Enclosed areas around household or village.

[c] Present or absent, depends on area.

Table 13

PREVAILING SYSTEMS OF AGRICULTURE ON SMALL FARMS, MAIN REGIONS OF USE, MAJOR CROPS AND ANIMAL SPECIES, AND FEED SOURCES FOR ANIMALS OF LATIN AMERICA

Farming system	Major crops	Major animals	Main regions*	Feed sources
1. Perennial mixtures (large farms; livestock relatively unimportant)	Coconuts, coffee, cacao, plantains, bananas, oil palm, sugarcane, rubber	Cattle, swine	All	Natural pastures, by-products, cull material
2. Commercial annual crops (medium to large farms, livestock moderately important)	Rice, maize, sorghum, soybeans, small grains	Swine, cattle, poultry	All except CI	Pasture, crop residues, grain
3. Commerical livestock				
a. Extensive Large to very large, livestock dominant	None are important	Cattle (beef)	C, V, Br, Bo, G, CA	Natural grasslands
b. Intensive Medium to large, livestock dominant	Improved pasture, some grains	Cattle (dairy), swine, poultry	All	Natural and improved pasture, feed grains, by-products
4. Mixed cropping Small size in settled areas Medium size in frontier areas Subsistence of monetized economy Livestock relatively important	Rice, maize, sorghum, beans, wheat, cacao, plantains, coffee, tobacco	Cattle, poultry, goats, sheep, donkeys, horses, mules, swine	All	Natural pastures, crop residues, cut feed

*All, all countries; Bo, Bolivia; Br, Brazil; C, Colombia; CA, Central America; CI, Caribbean Islands; E, Ecuador; G, Guyanas; P, Peru; V, Venezuela.

Source: McDowell and Hildebrand, 1980.

Table 14. PREVAILING SYSTEMS OF AGRICULTURE ON SMALL FARMS, MAIN REGIONS OF USE, MAJOR CROPS AND ANIMAL SPECIES, AND FEED SOURCES FOR ANIMALS OF ASIA

Farming system	Major crops	Major animals	Main regions*	Feed sources
1. Coastal fishing and farming complexes, livestock relatively important	Coconuts, cassava, cacao, rice	Swine	P, T	Coconut by-products, rice bran
		Ducks	TW, T, M, P, I	Marine products, rice bran
		Cattle and goats	SL, P, M, I	Pasture with coconuts
2. Low elevation, intensive vegetable and swine, livestock important	Vegetables	Swine	C, TW, HK	Sweet potato residues, rice bran, fermented residues from vegetable crops
		Ducks	HK	Crop residues, imported feeds
		Swine, fish	TW, M	Crop residues, rice bran
3. Highland vegetables and mixed cropping (intensive), livestock important	Vegetables, rice, sugarcane, sweet potatoes, Irish potatoes	Buffalo, cattle	P, T	Crop residues, rice bran, cut forage, sugarcane tops
	Vegetables	Swine	P	Crop residues, waste vegetables
	Rice	Cattle, buffalo	Asia	Crop residues
4. Upland crops of semi-arid tropics livestock important	Maize, cassava, sorghum, kenaf, wheat, millet, pulses, oilseeds, peanuts, etc.	Cattle, buffalo, goats, sheep, poultry, swine	IN, T	Bran, oilseed cake, straw, stovers, vines, hulls, hay
5. Humid uplands, livestock important	Rice, maize, cassava, wheat, kenaf, sorghum, beans	Swine, poultry, cattle, buffalo	Asia (>1000 mm rain)	Stover, weeds, by-products, sugarcane tops
	Sugarcane	Cattle, buffalo	T, P, I	Sugarcane tops, crop residues
6. Lowland rice, intensive livestock	Rice, vegetables, pulses, chick-peas, mung-bean, sugarcane	Cattle, buffalo, swine, ducks, fish	Asia	Crop residues, weeds, by-products, sugarcane tops
7. Multistory (perennial mixtures), livestock some importance	Coconuts, cassava, bananas, mangoes, coffee	Cattle, goats, sheep	P, IN	Cut and carry feeds from croplands
	Pineapple	Cattle	P, I	Crop residue, by-products
8. Tree crops (mixed orchard and rubber), livestock some importance	Orchard, trees, rubber, oil palm	Cattle, goats, swine	P, M, South T	Grazing or cut and carry
9. Swidden, livestock important	Maize, rice, beans, peanuts, vegetables	Swine, poultry, goats, sheep	Asia	Animals scavenge
10. Animal-based	Fodder crops	Cattle, buffalo, goats, sheep	I, M, IN	Cut and carry fodder, crop residue

*C, China; HK, Hong Kong; IN, India; I, Indonesia; M, Malaysia; P, Philippines; SL, Sri Lanka; TW, Taiwan; T, Thailand.

Source: McDowell and Hildebrand, 1980.

proportions of produce available for sale. Although there is increasing commercialization of agriculture, this is often limited to cash crops such as cocoa, cotton and groundnuts. Limited surpluses of food crops, especially close to urban centers, are usually offered for sale.

Farm size: Farms are small. About 70 percent or more of the farms are below 2 ha in the rain forest or below 5 ha in the savanna areas of Africa. Over 70 percent are less than 2 ha in Southeast Asia and Oceania and less than 7 ha in South America (Harwood 1976, Okigbo and Greenland 1976, Pinchinat et al., 1976).

Labour and tools: In areas under shifting cultivation and related fallow systems, over 70 percent of the labour force or population is usually engaged in agriculture. Farming involves much manual labour and the use of simple farm tools. Draught animals can be used for work only in savanna areas free of tse-tse and in high altitude tropical areas of Africa as compared to Asia and South and Central America where trypanomiasis does not prevent the use of draught animals. Tools range from digging sticks, machetes and axes, to animal drawn ploughs. Mechanization of agriculture is not yet widespread but varies from one continent to another.

Despite high rates of under-employment in areas under shifting cultivation, an acute labour shortage hampers major agricultural production considerably due to competition for labour between agriculture and industry, other development activities and especially high seasonal peaks of labour demand in agriculture. Usually, the longer the fallow period, the more the labour required to clear a unit area of land and, consequently, the smaller the area the farm family can cultivate in any one year. Recent attempts to increase agricultural production in parts of West Africa by partial mechanization of clearing, pre-planting cultivations and tillage with tractor hiring units and the development of highly mechanized large-scale farms have had disastrous consequences because of erosion and soil degradation.

Timin of farm operations: In areas under shifting cultivation, forest clearing, tillage, planting, various operations and cropping patterns are usually related to the onset, duration and intensity of the prevailing rainfall. Irrigation is not usually practised except where some hydraulic systems of cultivation have been developed in the floodplains of rivers such as the Nile, the Amazon and the Niger, and their tributaries.

Crops, cropping systems and rotation: In most areas under shifting cultivation, farmers no longer grow only indigenous crops since several exotic species have been introduced during the last two centuries and integrated or grafted into the production systems of indigenous domesticates. Cropping patterns usually involve growing crops in mixed culture through intercropping and relay cropping systems. There is, however, a tendency for cash crops to be grown more in pure culture than in subsistence stable food crops.

No stabilized crop rotation systems are practised. In areas of low population density where long periods of fallow are practised, there is no guarantee that the farmer returns to the original farmed area in a definite period of Cime. Where population pressure is high, fallow periods are drastically reduced and the farmer returns to the same piece of land in less than ten years of fallow, leading to what is sometimes designated as land rotating. With increasing population pressure and the growing of perennial crops, there is a tendency for shifting cultivators to practise sedentary agriculture and there is no constant moving of homesteads to newly opened farm sites. In some instances, however, temporary huts may be constructed in each newly cleared farm located at some distance from the homestead.

Use of modern inputs and technoloqy: Since shifting cultivators are smallholders with limited capital or credit for the purchase of costly inputs, not much use is made of fertilizers and pesticides. Moreover, research and extension services are poorly developed and the traditional farmers are unable to adopt modern technologies. Consequently, it often happens that yields obtained in farmer's fields constitute only a fraction of what is obtained from trials in experiment stations. Even where research and extension services have been in existence for some time, limited attention has been given to food crops. As a result, new technologies are either fragmentary or unrelated to the smallholder's needs and situations. For these reasons, increasing the area under cultivation continues to be the dominant strategy for increasing food production by shifting cultivators.

Changes in Farming Systems in Areas under Shifting Cultivation

With the development of sedentary agriculture where shifting cultivation was the vogue, socio-economic pressures are associated with changes in the farming systems. As a result, complex farming systems are developed involving several field systems associated with and at varying distances from the homestead gardens. The homestead garden constitutes the centre of activities of the various field systems. In the humid tropics, it attains the highest complexity in the form of a multistoried agro-ecosystem in which tree crops are grown in association with arable crops and usually rearing of animals.

There is increased diversification of production aimed at satisfying both commercial and subsistence requirements. Moreover, the farmer and members of the farm family are also involved in some hunting and gathering and several nonfarm activities such as basket weaving, palm wine tapping, etc.

CHANGES IN AREAS OF SHIFTING CULTIVATION, THEIR CAUSES AND ASSOCIATED PROBLEMS

Shifting cultivators are increasingly being subjected to socio-economic pressures that have brought about changes in the traditional shifting cultivation practices. Some of these changes threaten the existence of the system as a means of attaining economic levels of agricultural production on a sustained basis. Coupled with changes in the cultivation systems are environmental changes associated with cultivation per se. The severity of these changes is related to the overall environmental factors in an area including: the vegetation on land where shifting cultivation is practised in relation to whether it is virgin forest, secondary forest or bush, savanna woodland or grassland in addition to the • methods of clearing; the kinds of crops grown; the frequency or intensity of cultivation in relation to the fallow period and method of soil fertility maintenance.

Demographic Pressure

In most developing countries where shifting cultivation and related fallow systems are practised, the annual rate of population growth ranges from 2 to 3 percent. Consequently, their populations are doubling every 20 to 30 years. The increase in population density results in pressures on available land resources, and in parts of tropical Africa, there is not enough land available to facilitate adherence to the most suitable and effective lengths of fallow of from 10 to 25 years (Table 15). The current population pressure is the culmination of several sequential and often interacting historical developments.

Table 15 PROJECTED WORLD POPULATION, POTENTIAL ARABLE AND POTENTIAL LAND USED PER CAPUT FOR FOUR REGIONS OF THE WORLD

Region	Population (millions)			Total land area	Potential arable land (million ha
	1975 AD	1990 AD	2000 AD		
Africa	325 (2.6)[1]	501 (3)	67 (3)[1]	2 503[2]	637
Far East	1 135 (2.5)	1 592	190 (1.8)	1 117	352
Latin America	319 (2.8)	475	602 (2.4)	2 057	651
Near East	189 (2.7)	286	366 (2.5)	1 207	130

	Arable land used per caput			Potential arable land per caput		
Africa	0.55	0.46	0.38	1.71	1.27	0.95
Far East	0.21	0.18	0.16	0.28	0.22	0.19
Latin America	0.52	0.50	0.48	1.79	1.38	1.09
Near East	0.39	0.31	0.25	0.60	0.45	0.36

[1] Population growth rates.
[2] Anderson (1969). World food production. In Man, Food and Nutrition. M. Rochigl. Cleveland, Chemical Rubber Co.

Source: FAO. Agriculture Toward 2000 AD (1979).

In tropical Africa, for example, initial increases in population occurred as people became assured of more regular sources of food through the domestication of plants and rearing of animals, followed by introduction of Asian and later American crops. The development of agriculture ushered in an era of more reliable food supplies than were possible with hunting and gathering alone. Advances in the control of major epidemic and infectious diseases, vectors of disease, parasites and other pests, inculcation of better sanitation habits and measures, and advances in medicine made it possible to cure or contain a host of hu m an diseases and significantly reduce the very high rates of infant and premature adult mortalities. The result is that more people today reach reproductive age.

Moreover, the earlier population growth and socio-economic pressures in the developed countries of Europe and improved means of transportation, despite the dangers they pose in the spread of disease organisms, pests and parasites from one part of the world to another, also resulted in colonization of sparsely populated areas where shifting cultivation prevailed. This resulted in the estahlishment of colonial spheres of influence, spread of influences of developmenCs in medicine and science, and various agricultural, industrial and general development activities. These tended to restrict the areas of movement at the disposal of shifting cultivators. With the exception of those areas where contacts with colonizers had adverse effects on population growth, the overall effects of rapid population growth and restriction of frontiers of movement were the marked prolongation of the period of cultivation and drastic shortening of the fallow period. The increased range of annual and perennial crops at the disposal of the farmer encouraged sedentary culture and made frequent migration of the farmer and his household unnecessary and inconvenient. In many areas of shifting cultivation, the shortening of periods of fallow was so pronounced that fallows became ineffective in maintaining soil fertility and productivity (Figures 22 and 23). Demographic pressures in some areas also resulted in the expansion of cultivation into marginal areas that were not suitable for farming or even grazing.

High priority and incentives were given to cash crop production to satisfy the industrial needs of developed colonial powers of Europe and later other developed countries in North America and elsewhere when it became obvious that (1) the extractive forest industries of developing countries were unable to meet the increasing industrial needs of the developed countries and (2) some newly introduced crops had as good and often greater production potentials in their new homes in other parts of the world than in their centres of origin. Thus, South American rubber and cocoa constituted the basis of plantation agriculture in West Africa and Southeast Asia. So did sugarcane, cotton and groundnuts in various parts of the tropics and sub-tropics. Commercialization of production of certain commodities such as cocoa and groundnuts not only disrupted the traditional farming systems but often did so at the expense of food crops. It also resulted in the practice of cultivation of one crop year in, year out (i.e. monoculture) on the same piece of land, often in pure culture instead of the traditional mixed cropping. Where annual staples were grown as row crops, loss of soil fertility and structural degradation of the soil resulted more quickly, due to lack of suitable rotations for sustaining production with minimum hazard to the environment. Many of the commercial crops were being produced on large-scale farms or with a greater range of costly inputs for continuous production than shifting cultivators could afford. Thus, not only were traditional farming systems disrupted but returns from cash cropping were so attractive as to lure farmers into increasingly longer periods of cultivation than the shortened fallow periods could support. Sole cropping associated with increased commercialization of production, also resulted in greater erosion hazard than traditional intercropping systems.

Labour Shortage and Mechanization

Several decades ago in Africa, traditional farmers were able Co harness the labour of the entire family in various aspects of agricultural production with its attendant high seasonal labour requirements at peak periods of clearing, planting, weeding and harvesting. Nowadays, the smallholder, despite increases in population, is facing serious shortages in farm labour caused by (a) division of labour between the sexes resulting in the labour resources of both men and women members of the family not being easily harnessed in all farm operations during peak periods of demand, (b) changes in social organization which have made it difficult for traditional cooperative assistance through age groups and similar arrangements to facilitate groups of farmers rendering mutual assistance to each other in ensuring timely accomplishment of certain operations beyond what available farm family resources can carry out, (c) schooling of young boys and girls which makes them unavailable for work on the farms for most of the year, (d) low returns to agricultural labour in relation to the amount of drudgery involved and the prevailing lack of appreciation of the dignity of labour, all of which encourage rural/urban migration, (e) limited social services and amenities in rural as compared to urban areas, increasingly contributing also to the unattractiveness of rural life and further fueling of the urge to migrate to urban areas among the rural youth, and (f) limited industrial employment opportunities

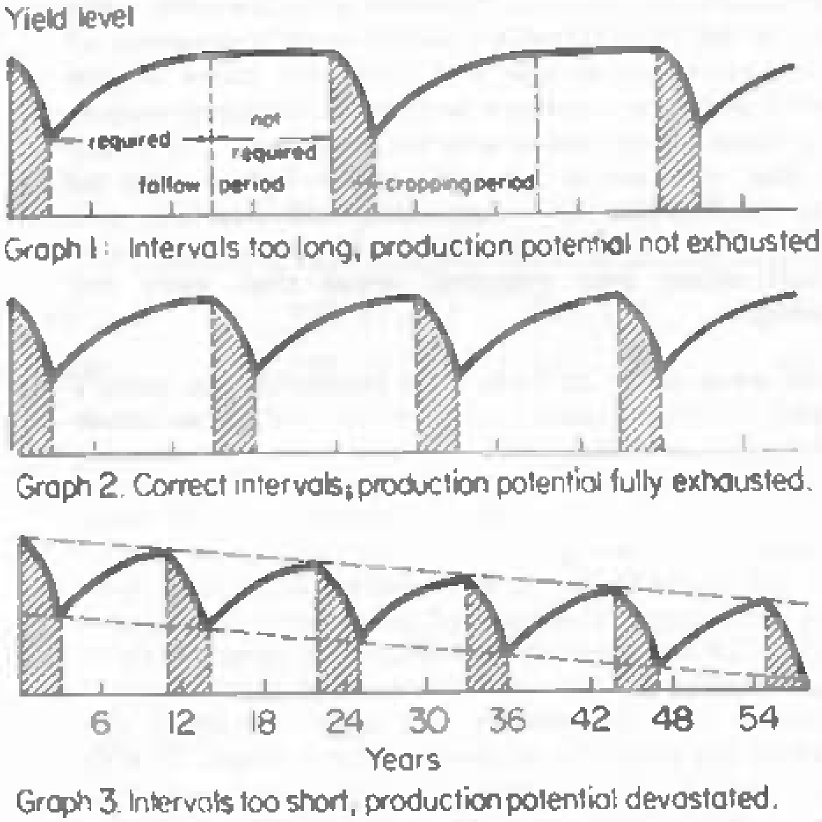


Fig. 22
Crop yields after shifting cultivation in relation to the cropping interval (Ruthenberg, 1965)
Source: Andreae, 1972

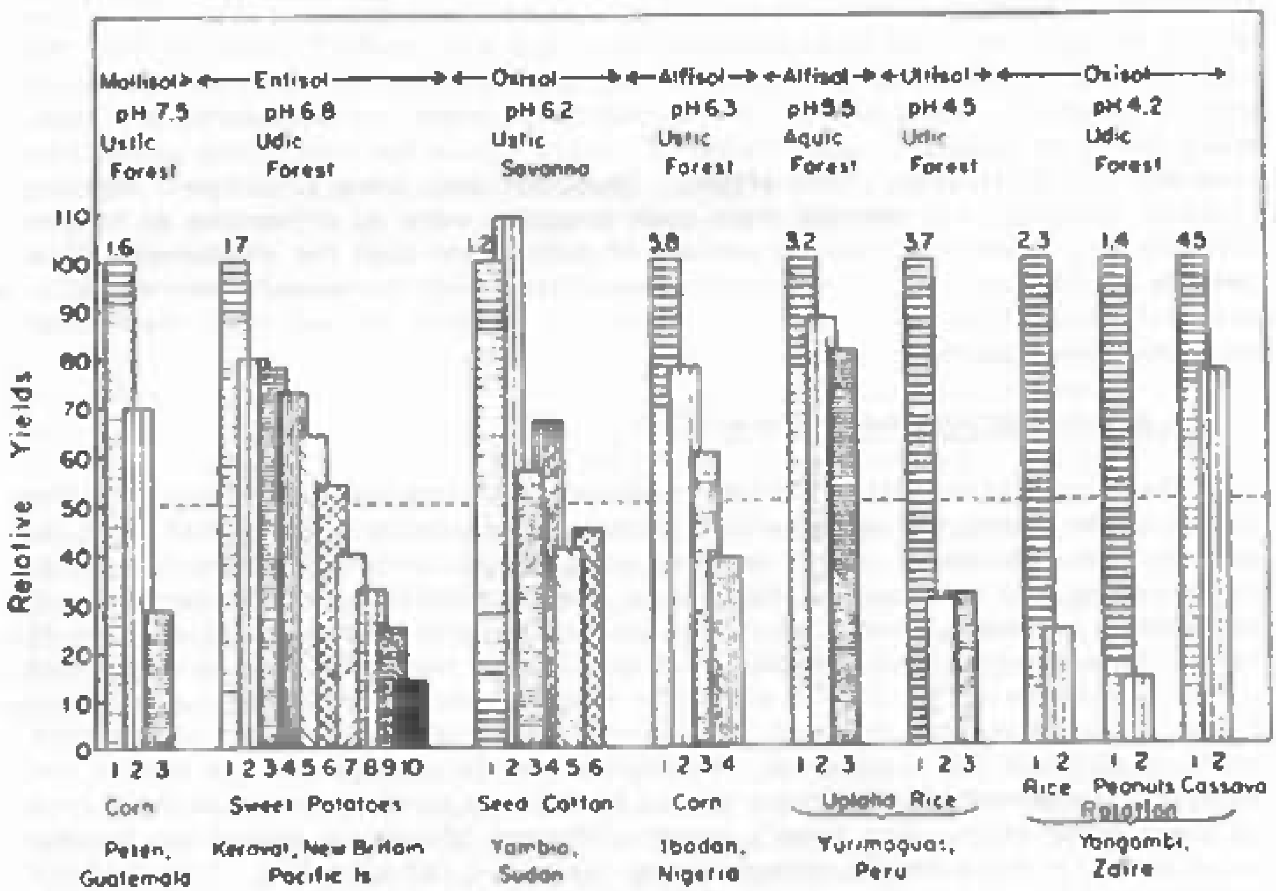


Fig. 23 Examples of yield declines under continuous cropping without fertilization in shifting cultivation areas as a function of soil, climate and vegetation. Numbers on top of histograms refer to economic crop yields (tons/ha). Numbers on x-axis refer to consecutive crops (from Sanchez, 1976)

in rural areas. In addition to these, the increasing availability of construction jobs, which pay higher wages than are obtainable on farms, has made it more difficult for the farmers to hire labour for farm work in some countries of Africa such as Nigeria since the petroleum boom. Thus, farming is increasingly being left in the hands of both old men and women who are no longer able to increase productivity significantly by clearing more land and maintaining the regular fallow periods. This usually involves higher frequencies of clearing more dense vegetation than traditional farmers can afford to do with the resources available to them. Labour shortages can encourage the farmer to either unwittingly increase the length of the cultivation period or shorten the fallow period so as to minimize the labour costs of clearing which increases as fallow lengthens. In general, labour shortages in some countries, especially for clearing large areas of land in large-scale agricultural projects, or for timely clearing of dense forest for smallholders has resulted in increasing mechanization of clearing and tillage operations. It is not uncommon for ministries of agriculture to assist farmers in clearing and tillage through tractor hiring units. These have, in turn, often resulted in increased deforestation and disruption of soil physical structure and other properties to an extent that has caused more erosion, irreversible degradation and loss of fertility and productivity than traditional manual methods. The removal of vegetation and disruption of soil structure also reduce infiltration while markedly increasing runoff and erosion especially under row crops. Comparative yield and erosion effects of different methods of clearing and subsequent cropping practices observed at Ibadan in Nigeria are presented in Table 16.

Table 16 LAND CLEARING: EFFECTS OF METHODS OF DEFORESTATION AND TILLAGE SYSTEMS ON SOIL AND WATER LOSS, GRAIN YIELD, AND TONS OF SOIL LOST PER TON OF GRAIN PRODUCED

	Soil loss erosion (t/ha)	Water loss runoff (mm)	Grain yield (t/ha)	Soil loss (t) / (t) grain yield
Traditional method	0.01	2.64	0.5 a	0.02
Manual clearing - no tillage	0.37	15.50	1.6 b*	0.23
Manual clearing - conventional tillage	4.64	54.30	1.6 b	2.90
Crawler tractor (shear blade) - no tillage	3.82	85.66	2.0 b	1.91
Crawler tractor (tree pusher/ root rake) - no tillage	15.36	153.06	1.4 b	10.97
Crawler tractor (tree pusher/ root rake) - conventional tillage	l9.57	250.33	1.8 b	10.87

* Figures followed by the same letter are not different at a 5 percent level of significance.

Changes Caused by Continuous Cultivation

During each clearing and cultivation phase, various farm operations result in changes in soil properties and in the farm environment. Clearing and burning associated with cultivation in traditional shifting cultivation and related fallow systems cause (l) loss of most of the nitrogen, sulphur and carbon in gases during burning and rendering a lot of plant nutrients more available to the crop and prone to loss through leaching and erosion, (2) destruction of humus and adverse soil physical and textural characteristics where intense burning is achieved in thick wood piles as is used in the chitemene system of central Africa, and (3) adverse effects on soil macrofauna and destruction of soil microflora and fauna (Mouttapa, 1974). In undisturbed soils under adequate vegetation cover, microbial activities are vital in decomposition and mineral cycling processes, maintenance of favourable soil structure and textural characteristics and attainment of dynamic equilibrium in the eco-system.

Changes during each cropping phase of shifting cultivation and traditional fallow systems include (1) multiplication of pests and diseases, (2) rapid increase in weed growth, (3) erosion of top soil, (4) deterioration in soil physical conditions, (5) deterioration of nutrient status of the soil and changes in the number and composition of soil organisms (Nye and Greenland, 1960; Ahn, 1974). With increased cropping intensity, these changes are accentuated. Above all, there is rapid loss of soil organic matter which causes loss in crumb structure of top soil, reduction in total porosity and macro-porosity, poorer aeration, poor infiltration of rain water, increased runoff and erosion, reduction in cation exchange capacity, changes in exchangeable bases and base saturation resulting also in change in pH, and lower release of nutrients due to lower amounts of humus mineralized (Ahn, 1974). More specifically, also removal of vegetation and continuous cultivation accentuate physical changes in the soil related to changes in soil structure and aggregate stability. Bulk density also changes with depth in relation to porosity changes referred to above. There is downward movement of clay particles and sometimes formation of clay pans in the subsoil. Reduction in permeability of the soil and water retention capacity causes decreases in field capacity and wilting point which in turn increases the chances of drought stress, even in the rainy season. For effects of prolonged cultivation on soil composition and crop yields, see Figure 23 and Table 17. In fact, it is mainly because of the above adverse changes during cropping, which are often manifested in lower yields and incessant weed growth, that the farmer is forced to terminate cropping and encourage natural vegetation regrowth during the fallow period.

Constraints to Increased Agricultural Production in Tropical Africa

Agricultural production in tropical Africa as already indicated above is mainly in the hands of shifting cultivators, over 90 percent of whom are smallholders who produce almost all the food not imported. On the basis of studies of farming systems in West Africa, the main physical, biotic and socio-economic constraints they face as reported by Flinn, Jellema and Robinson (1976), Ruthenberg (1980) and Okigbo (1981) are listed below:

i. Physical Constraints

(a) Climatic
- (i) unreliability of rainfall in onset, duration and intensity;
- (ii) unpredictable periods of drought and flood;
- (iii) reduced effective rainfall in sandy soils and steep slopes;
- (iv) high soil temperature for some crops and biological processes (e.g. N fixation);
- (v) high rates of decompostiion and low OM level;
- (vi) cloudiness and reduced photosynthetic efficiency;
- (vii) acute moisture deficits during several months of the year where dry months exceed 3 months;

(b) Soil: Most soils of the humid and sub-humid tropics are:
- (i) weathered, sandy, low in clay;

Table 17 CHANGES IN SOIL PROPERTIES FOLLOWING CLEARING, BURNING AND CULTIVATION OF SOILS IN TROPICAL FOREST REGIONS

A. Changes in chemical properties

		Site	Before	Immed.	After 1 year	After 2 years	After 3 years
pH		1	5.2	8.1	6.8	6.6	-
		2	6.6	9.0	-	-	-
		3	4.0	4.5	4.5	4.1	4.4
Exch. Ca (meq/100 g)		1	7.2	21.2	20.5	14.5	-
		2	9.4	33.5	-	-	-
		3	0.2	0.9	0.8	0.8	0.5
Exch. K (meq/100 g)		1	0.5	2.5	0.6	0.3	-
		2	0.5	11.8	-	-	-
		3	0.1	0.3	0.1	0.1	0.1
Total N (%)		1	0.26	0.25	0.24	0.19	-
		2	0.35	0.41	-	-	-
		3	0.12	0.14	0.09	-	-
Readily estimated P (μg/g)	(Truog)	1	10	30	-	-	-
	(Bray 1)	2	5	-	-	-	-
	(Olsen)	3	5	16	11	15	5

B. Changes in physical properties

		Site		Before	Immed.	After 1 year	After 2 years
Bulk density g/cm³	Hand clearing	2	(0-3 cm)	0.63	0.94		
			(3-5 cm)	0.80	1.17		
	Bull-dozer clearing	2	(0-3 cm)	0.63	1.11		
			(3-5 cm)	0.91	1.46		
Infiltration cm/hr	Hand clearing	2	Capacity	88	44		
			Rate	21	-	21	22*
	Bull-dozer clearing	2	Capacity	115	17		
			Rate				
	Hand clearing	3	Rate	(210)	10		
	Bull-dozer clearing	3	Rate	(210)	0.5		

Site 1 = Kade, Ghana (Nye and Greenland, 1960, 1964)
Site 2 = IITA, Ibadan, Nigeria (Lal and Cummings, 1979)
Site 3 = Yurimaguas, Peru (NCSU, 1975; Sanchez, 1979)

* Capacity refers to water entry when lateral flow above B horizon prevented.
Rate refers to water entry when lateral flow above B horizon prevented.

Rate data are for a similar site near Ibadan, reported by Wilkinson and Aina, 1976.

Source: Greenland, 1980.

(ii) of low CEC, hence colloidal complex less active
(;
iii) of low inherent fertility except on hydromorphic and young volcanic soils;
(iv) high in soil acidity;
(v) subject to multiple nutrient deficiencies and toxieities under continuous cultivation;
(vi) high in P-fixation;
(vii) subject to intense leaching and of hiqh erosion hazard under prevailing rainstorms.

ii. Biological Constraints

(a) unimproved crops and livestock;
(b) low yields - low potential;
(c) susceptibility to disease and pests;
(d) high incidence of diseases, pests, weeds due to favourable environment;
(e) drastic environmental changes resulting from human activities with adverse effects on ecological equilibrium or balance in nature.

iii. Socio-Economic Constraints

(a) small farm size more drastically reduced by population pressure;
(b) unfavourable land tenure systems often resulting in fragmentation of holdings;
(c) shortage of labour;
(d) lack of credit, low income;
(e) poor marketing facilities and pricing structure;
(f) unavailability and high cost of inputs;
(g) poor extension services;
(h) illiteracy and superstition sometimes hampering adoption process;
(i) poor transportation facilities;
(j) shortage and inappropriateness of inputs;
(k) until recently, lack of package approach to production systems, technology, design, evaluation and use;
(1) lack of effective farmer organizations and political ‘voice’.

PROGRESS IN FARMING SYSTEMS RESEARCH AND DEVELOPMENT OF ALTERNATIVES TO SHIFTING CULTIVATION

Although the systems approach to agricultural research is relatively new and no clear cut and generally acceptable research methodologies are uniformly adhered to the world over, some priority areas of research have been identified. These priority areas of research at IITA include (1) base data and regional analyses and socio-economic studies, (2) land development and soil management, (3) crop improvement and cropping systems, and (4) appropriate technology for small farmers. It should, however, be emphasized that although the systems approach calls for interdisciplinary problem - oriented research that simultaneously tackles all aspects of the farmer’s production problems, research and related activities in farming systems rarely involve whole farm systems. Consequently, farming systems research at IITA and elsewhere involve subsystems research on major components of the farming system. Research at IITA gives emphasis to components of the cropping systems. Of the above four priority areas of research, it is only in base data and regional analysis that studies of whole farm systems are possible.

Base DaCa, Regional Analyses, and Socio-Economic Studies

This is a complex area of interdisciplinary team research aimed at understanding the physical, biological and socio-economic environment of farmers and the management and operation of existing farming systems so as to (a) understand the structure and interaction of various components in the farm enterprise, (b) determine the farmers’ objectives and needs, (c) identify constraints on increasing productivity, (d) determine constraints to the farmers’ adoption of new or improved technology, (e) identify prevailing farming systems and potentials of major ecological zones of the humid and subhumid tropics as a basis for determining the strategies and priorities in farming systems research.

Considerable progress has been made in these studies which are largely based on secondary sources, farm level surveys, benchmark soil studies, and evaluation of rates of technology adoption in addition to monitoring of changes in farming systems. Briefly, progress in this area of farming systems research includes (Okigbo 1981):

i. characterization of the climate (rainfall amount, duration, temperatures, etc.), soils and other environmental conditions;

ü. identification of the main features of existing traditional and transitional farming systems with emphasis on the dominant cropping systems;

iii. identification of the biological, physical and socio-economic constraints to increased agricultural production.

In addition to these, farm level surveys and other studies have also shown that (a) farmers may spend as much as 30-40 percent of their cash income on food, (b) farmers in tree crop areas where land is not a very serious constraint face less cash flow problems than those in the derived savanna mixed grain and tuber crop areas, (c) non-farm income from various activities such as trading, handicrafts, gifts, wine tapping, etc. contribute substantially to the farmer’s income, (d) trees and small livestock may contribute substantially to farm income and stability of production in the system - the livestock population increasing with increases in population density, (e) weeding may take up to 40-80 percent of the farmer’s time, (f) local preferences for certain cultivars for certain uses may be more important to the farmer than high yield (e.g. maize for eating boiled or roasted off the cob versus improved high yielding maize) and (g) the traditional farm(s) operated by one farmer or farm family not only involves different crop and/or livestock enterprises but also environments which must be regarded as targets in crop improvement, cropping systems research and on-farm testing.

LAND DEVELOPMENT AND SOIL MANAGEMENT

Increased food and agricultural production can be achieved either by increasing the area of land under cultivation or by various ways of ensuring increased productivity per unit area. The former constitutes the most important method of increasing food production in tropical Africa. The effectiveness of this method will depend on availability of land and labour for clearing new land each year. The current high rates of population growth and related pressures on land, fragmentation of holdings resulting from the prevailing land tenure systems, and fallow systems which tie up land have resulted in decreasing farm sizes in most of tropical West Africa as compared to other parts of tropical, central and east Africa with lower population densities. At the same time, there are increasing demands on land for various development activities. Consequently, methods of soil fertility maintenance, elimination or drastic reduction of periods of bush fallows as components of permanent cultivation systems must be found if farm sizes are to be increased and the current trend of decreasing farm sizes halted. Land-saving technologies are therefore imperative if the demands of numerous competing interests are to be met.

Since gaining independence a little more than two decades ago, many African governments have planned and executed crop production projects based on production systems involving practices and equipment developed in temperate countries of Europe and North America. Faced with increasing food import bills and the challenge of bringing about dramatic changes in agricultural production and development within the short period that a party may be in power, large-scale highly mechanized agricultural production projects have been introduced. Results of these projects have often been disappointing, and it is possible to cite many examples of miscalculated ventures.

It is clear from the foregoing that both in development of more efficient production systems and in the execution of mechanized large-scale commercial projects, suitable techniques of land development and soil management during subsequent cropping of already cleared land should be given high priority. Mechanized forest clearing often associated with soil disturbance and even total clearing with hand tools and intense burning result in destruction of a naturally balanced ecosystem and its replacement with a more fragile agro-ecosystem, soil erosion, decline in soil organic matter, deterioration of soil structure, increase in soil acidity, plant nutrient losses, decrease in water-holding capacity, rampant weed growth and infestation of crops by disease organisms and pests. Even where suitable land development techniques have been used, continuous cultivation without adequate amounts of fertilizers, poor soil conservation practices and monocultural row crop production systems also result in increased soil acidity, soil erosion, nutrient imbalances and toxicities and rapid decline in soil productivity. Research at IITA and elsewhere has led to the following guidelines for land development (IITA, 1978):

i. Use of clearing methods and equipment that cause minimum soil disturbance.

ii. Choice of clearing method and extent of forest or vegetation removal and tillage system should he related to subsequent crop(s) to be grown.

iii. Manual clearing or shearing of trees with K/G blade (a V-shaped cutting blade) that cuts the trees very close to the soil surface have been found to cause least soil disturbance in land development for maize and some arable crops on Alfisols in the forest zone in Nigeria.

iv. Forest cover removed by clearing should be replaced by good ground cover that gives adequate protection to the soil. Selected crop combinations and sequences may be used to ensure adequate soil cover throughout the year.

v. About 4-6 t/ha of crop residues left on the soil surface ensure that (a) the soil is protected against raindrop impact, (b) fluctuations in soil temperature are reduced, (c) biological activities of soil organisms are enhanced and, above all, (d) adequate levels of soil organic matter are maintained.

vi. Zero tillage production of such crops as maize, pigeon pea, rice, and soybeans achieves guidelines (iv) and (v) above but of these crops, only maize and tree type pigeon pea produce enough residues for a second crop of the same or other species.

Table 18 SOIL FERTILITY CAPABILITY GROUPINGS OF ALFISOLS, ULTISOLS IN WEST AND CENTRAL AFRICA

Soils (great group)	Parent materials or rocks	Land form or topography	Textural type 1/	Condition modifiers 1/
		I. Alfisols		
Paleustalfs Plinthustults	Granitic gneisses Granites Quartz-schists	Rolling to undulating	LL or LLR	e t* m *r w d
Paleustalfs	Coastal sediments	Flat to undulating	LL	e t* w d
		II. Alfisols and Oxisols		
Paleusutults Plinthustults	Coastal sediments Sandstones, shales	Undulating to rolling	LL or SL LL or SL	e h k w d r t*
Paleudults	Coastal sediments	Flat to undulating	LL or SL	e h k a* k t*
Paleudults Tropudults	Granites Quartz-schists Acid Gneisses	Rolling	LL, SL, LLR	e h k a* t *r
Tropohumults Tropudults Tropohumox	Basalts Diabases Amphibolites	Rolling to hilly	LC, CC	e k i h*
Haplorthox	Old alluvium	Level river terrace Small upland plateau	LL, CC	e k h a* t *
		III. Hydromorphic Soils		
Aquolls Aqualfs	Colluvium or alluvium	Inland valleys	SLR, LLR, LL	q f
Aquults Aquox	Colluvium or alluvium	Inland valleys or lower river terrace	LL, LC, CC	q h f e
Aquents Aquepts	Alluvium	Inland valleys and swamps; river deltas and flood plains, mangrove swamps	LL, SL, LC LLR, SLR, CC	q, other modifiers vary widely

Source: Juo and Kang, 1979

1/ See next page for explanation.

Table 18 continued

Textural types (0-20 cm and 20-50 cm)

S = Sandy, >85 percent sand

L = Loamy texture, <35 percent clay

C = Clayey texture, <35 percent clay

R = Quartz or ironstone gravels or other hard root-restricting layer present in 20-50 cm depth

Condition modifiers

e = Low effective CEC (<4 meq/100 g of soil) between 0-50 cm depth

h = Acidic exchangeable Al saturation (10-45 percent), pH (H_2O) less than 5.5

a = Al toxic, exchangeable Al saturation greater than 45 percent

k = K deficient, exchangeable K less than 0.15 meq/100 g of soil, less than weatherable minerals in silt and sand fraction

i = High P fixation, standard P requirement at 0.2 ppm in solution greater than 30 $\mu g/g$

m = Mn toxicity, soil pH below 5.0 for soils derived from high Mn-containing parent rocks

t = Secondary and micronutrient deficiencies (i.e. Mg, S, Zn)

w = Low available water reserve (i.e. less than 50 mm)

d = Dry, Ustic or Xeric environment, soil remains dry for more than 60 consecutive days per year within 20-60 cm depth

r = High erosion hazard, unsuitable for large-scale food crop farming

q = Wet, or a quick soil moisture regime. The profile is saturated during most part of the growing season

f = Fe toxicity in wet-land rice

* = Soil fertility constraints resulting from continuous cropping with moderate to high rates of chemical fertilization and inadequate soil management.

vii. A zero tillage maize production package usually involves a pre-emergent herbicide to kill weed regrowth prior to seeding followed by atrazine shortly after planting maize and suitable zero tillage equipment (with choice of herbicide related to crops to be grown and weed composition).

viii. Other possible zero tillage systems may involve the use of leguminous cover crops as short term fallow crops or'live mulches'.

Benchmark soil capability studies, greenhouse and field experiments have been used to identify main problems of soil management under continuous cultivation for major soil groups in relation to soil acidity, aluminium and iron toxicities, nutrient deficiencies etc. (Table 18, Figures 24 and 25).

The importance of relating soil management in cropping systems is best illustrated by cropping sequence experiments indicating that the cowpea is a more suitable legume to be grown in sequence with maize as compared to soybeans under Ibadan conditions especially with respect to soil fertility maintenance and reduction in amount of nitrogen used (Table 19). In Nigeria, cowpea also commands higher market prices than soybean, which is a relatively new crop.

Table 19 EFFECT OF N-RATES AND ROTATION ON GRAIN YIELD OF MAIZE VARIETY TZPB GROWN ON EGBEDA SOIL (OXIC PALEUSTALF) 1/

Treatment N-rate	Maize - Maize			Maize - Soybean			Maize - Cowpea		
kg N/ha	FS	SS	Total	FS	SS	Total	FS	SS	Total
	- - kg/ha - - -			- - - kg/ha - - -			- - - kg/ha - - -		
0	812	826	1638	1045	1222	2267	1732	1046	2778
45	2556	1947	4503	3015	2710	5725	3044	1046	2778
90	3289	2648	5937	3427	2448	5875	3351	2318	5669
Mean	2219	1807		2496	2126		2709	1830	

LSD .05 Between rotation means: FS = 348; SS = 280

Between fertilizer means within rotation: FS = 489; SS = 385

Between fertilizer means between rotation: FS = 529; SS = 421

FS = First Season maize grain yield following previous year second season maize, soybean or cowpea crops.

SS = Second Season maize grain yield following first season maize, soybean or cowpea crops.

1/ Unpublished data.

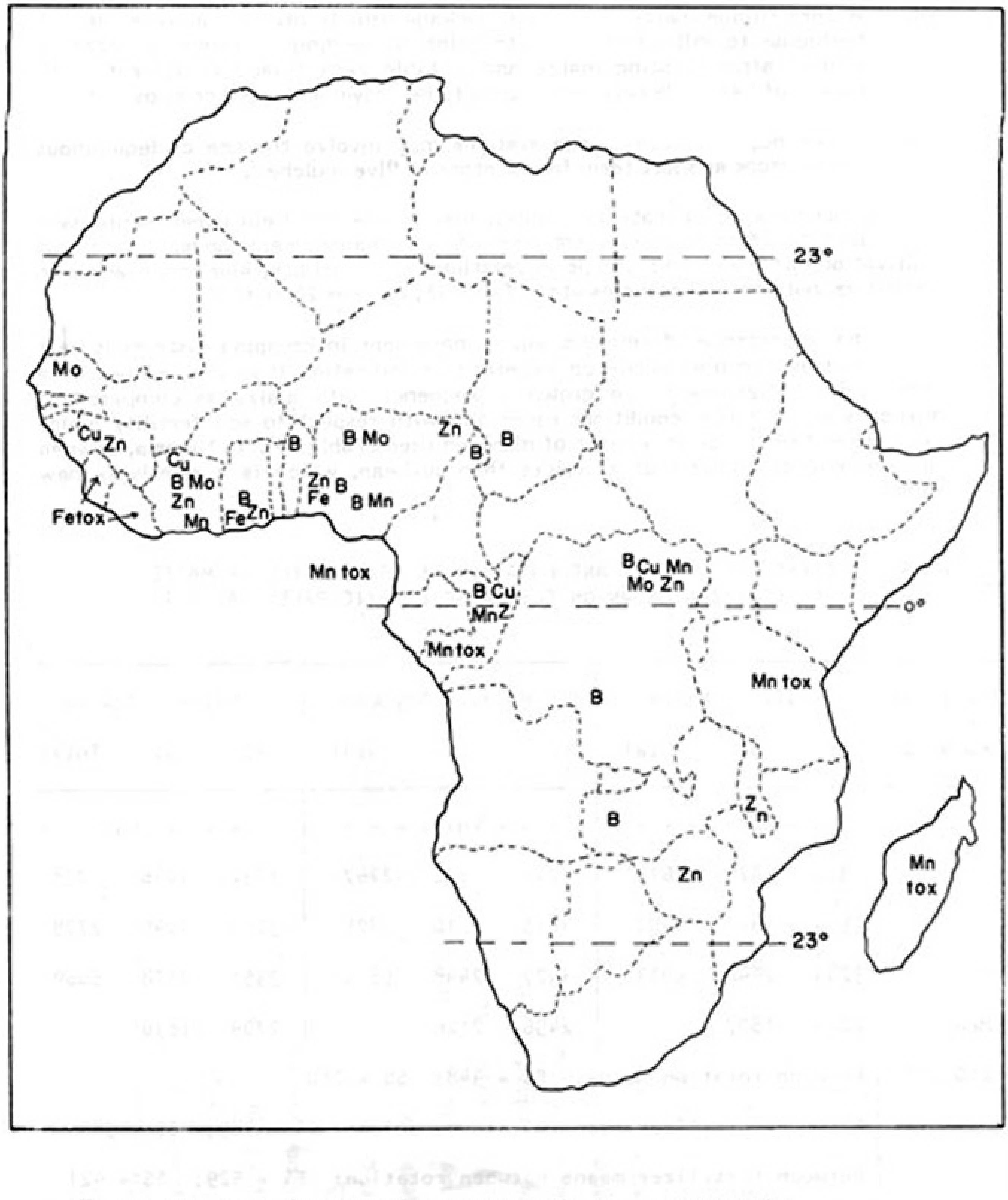


Fig. 24 Location of micronutrient deficiencies in tropical Africa

(Kang, unpublished)

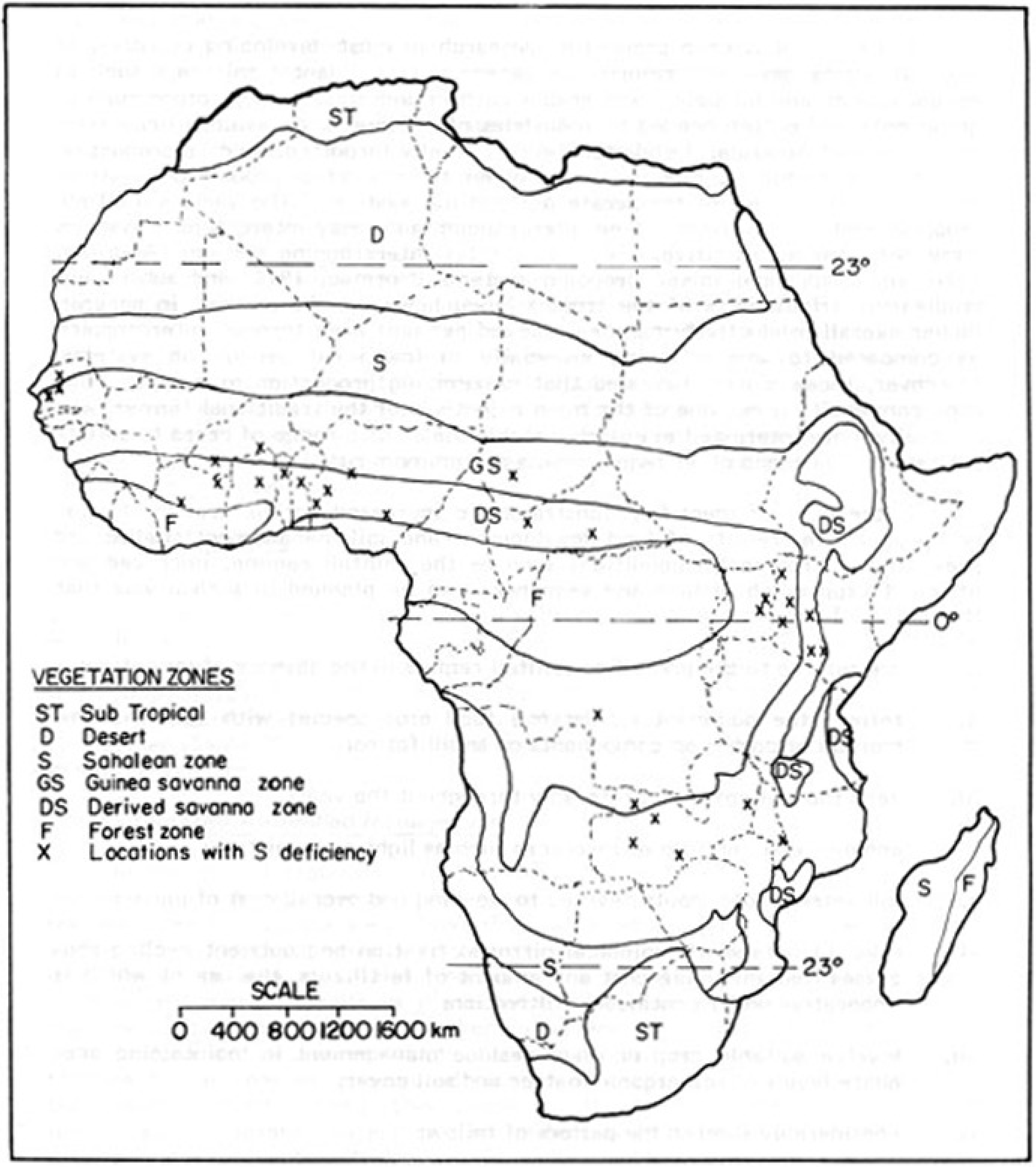


Fig. 25 Location of sulphur deficient areas in tropical Africa

(Kang, unpublished)

CROPPING SYSTEMS

Until recently, crop production research in most developing countries of tropical Africa gave hiqh priority to perennial tree (plantation) crops such as cocoa, rubber and oil palms and arable cash or industrial export crops such as groundnuts and cotton needed by industries of colonial and developed countries of Europe and America. Food crops were virtually forqotten. In crop production research methodology, emphasis was given to sole crop production systems patterned after those of temperate agricultural systems. The various multiple cropping systems involvinq mixed intercropping and relay intercropping systems were regarded as primitive. Studies of relay intercropping systems (Andrews, 1970) and traditional mixed cropping systems (Norman, 1974) and subsequent studies in various parts of the tropics have, however, shown that, in general, higher overall productivity can be achieved per unit area through intercropping as compared to sole cropping especially in low input production systems. Moreover, these studies revealed that maximizing production of a given food crop commodity is not one of the main objectives of the traditional farmer, who is usually more interested in ensuring stable yields of a ranqe of crops to satisfy subsistence, cash and other requirements at minimum risk.

In the light of identified constraints to increased agricultural production reviewed above, results of land development and soil management studies and prevailing environmental conditions such as the rainfall regime, improved and efficient crop combinations and sequences can be planned in such a way that they:

i. are related to the prevailing rainfall regime in the absence of irrigation;

ii. reflect the dominant subsistence food crop species with built-in commercial or cash crop components on small farms;

iii. keep the soil covered, preferably throughout the year;

iv. enhance efficient use of resources such as light and moisture;

v. minimize labour inputs devoted to weedinq and overall cost of inputs;

vi. take advantaqe of bioloqical nitroqen fixation and nutrient cycling processes that minimize cost and amount of fertilizers, the use of which is imperative under continuous cultivation;

vii. involve suitable crop or plant residue management in maintaininq adequate levels of soil organic matter and soil cover;

viii. considerably shorten the periods of fallow;

ix. qive due consideration to sound ecological principles approximating those found in nature in soil conservation and stability of aqro-ecosystems;

x. make greater use, wherever possible, of more productive hydromorphic or valley bnttom soils as has been achieved in the highly efficient wet rice production systems of Southeast Asia for centuries, and

xi. take advantaqe of appropriate technologies in all phases of crop production from clearinq and preplantinq to harvesting and postharvest handling of crops.

When all these points are taken into consideration the problem of cropping systems boils down to the development of efficient, stable crop combinations and sequences that are sensitive to the prevailing physico-chemical, biological and socio-economic conditions of a majority of farmers. Moreover, it is also obvious that on small farms with limited resource endowments on which almost all the food crops in tropical Africa are produced, more emphasis should be given to mixed and relay intercropping systems that satisfy most of the farmer’s subsistence and increasing cash requirements despite the difficulties in their mechanization and use of certain inputs such as fertilizers. Even then, research at IITA has shown that not only can suitable herbicide treatments be developed for mixed crops but certain crop combinations can be also used to minimize weed infestation and to control problems. While emphasizing the improvement of cropping systems for small-scale farmers, improved sole crop production systems and rotations should also be developed for large-scale farms which can achieve phenomenal increases in yields of major staples under favourable environmental conditions and higher cost of inputs that are necessary to ensure sustained high yields. It is also imperative that in achieving these objectives crop improvement programmes should give high priority to requirements of the various cropping systems. At IITA some of the improved cropping systems that may be used to achieve the above objectives include cassava, maize, yams, rice and plantain-based cropping systems.

Alley Cropping

A recent development in cropping systems is alley cropping. It takes advantage of traditional fallow systems and is based on the use of fast growing leguminous shrubs or trees as nutrient pumps which act at the same time as a source of plant residues or fuelwood, or as supports for crops such as yams. At IITA, this system has been used in the production of maize and yams and promises to almost eliminate the fallow, thus increasing land area available to the farmer (Table 20, Figure 26). It also considerably reduces the cost of staking in yam production.

Integrated Watershed Management

In the humid tropics of Africa, land tenure often constitutes a major problem in rural development. Moreover, the growinq of a particular crop species, over a toposequence or land of variable terrain rarely achieves optimum yields. This is because when a single crop species or cropping sequence is used over the whole area, it entails growing of the specified crop or crops on both suitable and marginal soils in the catena association or toposequence. It is possible throuqh integrated watershed management to design a range of crop combinations and sequences which not only diversifies production but ensures that each crop species or selected number of crops are grown in contours or toposequences most suited to their production (Fiqure 27). The cropping sytems used in such integrated watershed management systems not only take advantage of the highly productive hydromorphic valley bottom soils but are also less sensitive to problems of land tenure in rural development projects. Of course, they require higher inputs in planning and supervision than in non-integrated watershed projects involving only one crop.

APPROPRIATE TECHNOLOGY

In tropical Africa, the decline in food and agricultural production is in no smmall measure related to the relatively lower returns from farminq in relation to the amount of labour and drudgery involved in agricultural production which in turn discourages younq men and women from goinq into farming. The eventual result is a hiqh rate of rural-urban miqration. This leaves farminq increasinqly

Table 20 EFFECT OF APPLICATION OF LEUCAENA PRUNINGS AND INORGANIC NITROGEN ON MAIZE GRAIN YIELD

Leucaena rate tons ha^{-1}	N rate kg N ha^{-1}	kg ha^{-1} Incorporated	Mulch	Mean
		1978		
0	0	2538	2676	2607
	50	3352	3110	3231
	100	4657	4421	4539
5	0	2781	3114	2947
	50	4142	3443	3792
	100	4824	4677	4751
10	0	3443	3488	3466
	50	4195	3626	3910
	100	4553	4250	4404
Mean		3832	3645	

LSD 0.05 Between methods of Leucaena placement 335
Between treatment (Leucaena and inorganic N rates) 654
Between treatments within same Leucaena placement method 926
Between treatments in different Leucaena placement methods 938

Leucaena rate tons ha^{-1}	N rate kg N ha^{-1}	Incorporated	Mulch	Mean
		1979		
0	0	1283	1740	1511
	50	2093	2218	2155
	100	3315	3138	3226
5	0	2313	2013	2163
	50	3035	2300	2668
	100	3453	3028	3240
10	0	3213	1855	2534
	50	2578	2338	2458
	100	3068	3023	3046
Mean		2705	2406	

LSD 0.05 Between methods of Leucaena placement 688
Between treatment (Leucaena and inorganic N rates) 709
Between treatments within Leucaena placement method 1002
Between treatments in different Leucaena placement methods 1146

Fig. 26 Alley cropping with *Leucaena* and maize

to old men and women. Even where there are low population densities and large areas of cultivable land, farm sizes may remain small due to the technology available for clearing, preplanting cultivation, planting, weeding, pest control, harvesting and post-harvest handling of produce. Consequently, to minimize labour and related bottlenecks, research aimed at developing appropriate technology for various stages of crop production constitutes an indispensable component in farminq systems research. By appropriate technology is meant all environmental, resource and input manipulations that minimize drudgery and enhance productivity but are within the means of farmers to own, use, repair, hire and maintain. In other words these are technologies adapted to the needs and socio-economic environments of the farmer.

Appropriate technologies are in no way limited to mechanical, unsophisticated and simple techniques and practices. For example, a Controlled Droplet Applicator (CDA) which is used to apply herbicides in zero tillage is not unsophisticated even though it is relatively inexpensive, does not require as much water as conventional spraying devices but requires greater precautions in handling hiqh concentrations of herbicides. At the same time, its use is a component of qood plant residue management which minimizes weed infestation thus eliminating tillaqe and mechanical weed control equipment, as well as

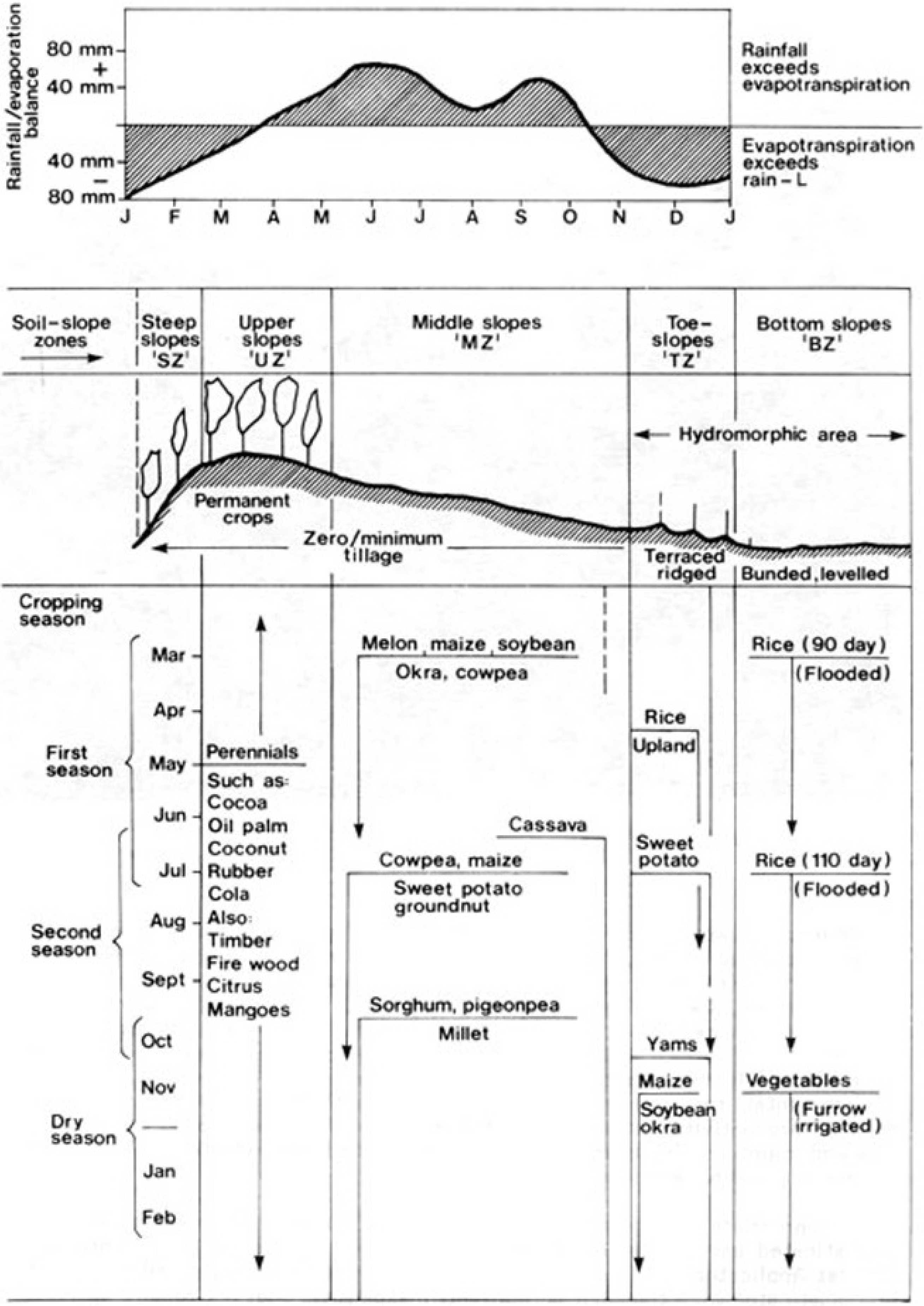


Fig. 27 Illustration of rainfall pattern providing two rainfed seasons and also a potentially more productive dry season

providing soil organic matter.

At IITA, appropriate technoloqies tested and/or developed in the farming systems programme include:

i. CDA sprayers (solar or battery powered, and hand or small tractor mounted);

ii. jab planters (hand fed and auto-feed types) facilitating seeding through crop residues;

iii. rollinq jab planters (hand and small tractor mounted) for planting through plant residues;

iv. hand-operated cassava harvester;

v. modified potato harvester for cassava harvesting;

vi. cheap, locally constructed cribs for maize storage;

vii. maize shellers that can be locally constructed (Okigbo, 1981).

Appropriate technology is not limited to small farm production requirements. For example, a special tractor-mounted planter is used for large-scale zero tillaqe maize production. Other machines under development include a stripper harvester and cowpea harvester.

GUIDELINES FOR DEVELOPING ALTERNATIVES TO SHIFTING CULTIVATION

On the basis of the characteristics of smallholder shifting cultivation systems, the changes which they are undergoing and associated problems, the following are guidelines for the development of improved alternatives to shifting cultivation, emphasizing tropical Africa.

i. Need for greater emphasis on food crops

Research, training, extension and infrastructural support in most develop ing countries have been biased in favour of cash crops and development of farming systems patterned after those of developed temperate countries. Consequently, the needs, conditions and problems of shiftinq cultivators and smallholders practising related fallow systems have been orossly neglected. It is necessary to redress this imbalance in the process of development of alternatives to shiftinq cultivation, but to achieve this would require a higher priority for the development of more efficient food production systems that enhance qualitative and quantitative increase in food production on a sustained basis. This would also entail givinq higher priority to smallholder farming systems on which over 90 percent of the food crops of most countries in tropical Africa are produced. Moreover, such a policy would become even more imperative when the current high rate of urbanization in developinq countries is considered.

ii. Priority on the elimination of rural poverty and improved nutritional status

Shifting cultivators are among the world’s poorest, hut they are a silent majority in the tropics. They are found in some of the world’s least developed countries with the lowest per capita income, high rates of illiteracy and very poorly developed industrial sectors. Of the world’s 31 least developed countries, 21 are in Africa. There are high rates of unemployment and under-employment _vis _à _vis labour shortages already indicated earlier. Priority in these countries should primarily be given to ensuring that the farmers can produce enough for their own and family consumption, in addition to a significant marketable surplus for paying school fees, medical bills and a range of basic needs and services that contribute to general well-being.

ii. Emphasis on the needs of small farmers

Smallholders lack capital and credit for purchase of costly inputs such as fertilizers, pesticides, farm machinery and so on. Research should, therefore, give high priority to the needs and situations of small-scale farmers, rather than only to those of large-scale farmers. This calls for priority to be placed on development of low cost technologies that are more attractive to most farmers.

v. Need for a systems approach and cooperation

When, as is all too often the case, research on cash and plantation crops is executed on single commodity basis along individual disciplinary lines, especially on an experiment station, the lack of a systems approach in research does not adversely affect the development of packages of improved production technology for the crop. However, research in developing alternatives for shifting cultivation will involve several food crops, crop/animal, forest or tree crops, and/or animal production systems based on a systems approach. The systems approach must also be adhered to in the planning, research and testing of these alternative systems to ensure that technologies developed are relevant to the farmer’s needs and environment. Such technologies should be within the means of the farmer to hire or own, use, maintain and repair - hence they must be appropriate. Here, appropriate technologies consist of practices, materials, environmental resource manipulations of sufficient scope that provide answers to problems of shifting cultivators rather than being limited to the so-called intermediate technology that is so narrowly defined. The systems approach in the development of alternatives to shifting cultivation will not only involve interdisciplinary cooperation but also interdepartmental, inter-institutional, national and international cooperation in which an agency such as FAO will play a leading role in initiating action and in providing a clearinghouse for all available information on results of relevant experiments and records of pertinent experience so as to minimize duplication, eliminate unnecessary basic research and facilitate finding effective solutions within a reasonable time. Time is running out in our efforts to develop effective ways of producing enough food to meet current demands in the developing countries.

v. Problems of labour shortage and appropriate technologies

A shortage of labour among African shifting cultivators is a major problem, not only because it minimizes the area they can bring into cultivation and hence limits their productivity, but because the amount of drudgery in farm work in relation to its returns encourages rural-urban migration with its attendant social ills. Moreover, the shifting cultivator’s inability to perform farm operations as needed is a major cause of low productivity. Therefore, appropriate technologies being generated as alternatives to shifting cultivation must provide solutions to this labour constraint.

vi. Importance of energy and environmental consciousness

In areas under shifting cultivation, most countries are facing acute deficits in foreign exchange due to high petroleum and food import hills. Moreover, even the usually reliable renewable energy sources such as fuelwood are either in short supply or are being exhausted. With the current concern about depletion of non-renewable mineral resources, industrialization based on them in the developing countries faces a very uncertain future. Research in the development of alternatives to shifting cultivation should, therefore, give high priority to the development of improved farming systems that integrate production of food crops with tree crops as sources of food, fuelwood, timber, industrial and other products. Where possible, consideration should also be given to the integration of animal production with crop production. Since industrialization based on mineral resources may face an uncertain future, agro-based industries using renewable plant or forest products that can be produced with food crops or in areas unsuitable to food crops should receive some attention. At best, each country should aim to strike a balance between basing the development of industries on renewable resources and on non-renewable resources.

Mechanization is necessary to minimize drudgery in farm work, so that farm operations can be performed when most needed, and to bring more areas under cultivation. Appropriate technologies that are energy-sensitive and within the means of farmers to own, operate or hire should be considered.

vii. Problems of clearing, land development and soil management

In the tropics, where most shifting cultivators are found, soils are highly weathered and especially under rainfall are of low inherent productivity. Such soils under natural vegetation cover appear deceptively fertile. It should be borne in mind that tropical soils are very fragile especially when the natural vegetation cover is removed and when they are under continuous cultivation with row crops such as maize or cotton with a high erosion hazard. Where continuous cultivation is to be practised, care must be taken from the clearing stage to minimize structural disturbance of the soil and to ensure subsequent good soil management and suitable cultural practices including the use of good and tested crop combinations and sequences that ensure that the soil is adequately covered almost all the year. Where soils are unduly disturbed through mechanical clearing, and inadequate levels of soil organic matter and poor vegetation cover. are maintained, irreversible degradation of the soil, loss of nutrients, erosion and other adverse changes may occur to the extent that fertility is lost and very low productivity results.

Consequently, any attempt to intensify cultivation on a continuing basis should be made with the understanding that use of fertilizers is imperative, but it would be necessary to develop practices which minimize the amount of fertilizer used by ensuring minimum loss of fertilizers applied and reliance on such processes as biological nitrogen fixation and supplementation of fertilizers with animal manures wherever and whenever convenient. Maintenance of adequate levels of organic matter and minimization of nutrient loss may be achieved through efficient residue mmanagement. In development of appropriate methods of clearing, land development and subsequent cropping and soil management, due consideration should he given to the prevailing ecological and socio-economic conditions but especially to the soils and topographic situations which affect their capabilities for various uses.

viii. Need for intensification of production per unit area or input

Technologies for increasing food production based on expanding the area under cultivation must be supplemented quickly and eventually replaced, by others that attain increased food production per unit area. This is also a land saving device that enhances multiple land use. This could facilitate not only increased availability of land for food crops when fallow periods are shortened considerably, but also make more land available for production of non-food industrial crops, fuelwood, other forest products and other competing land uses. The increased production of industrial crops and utilization of many forest products should be given priority since the reliance on industries based on non-renewable resources is risky. Developing countries should balance industries based on non-renewable resources with industries based on renewable resources of agricultural origin. This should include, for example, farming systems for the production of arable crops that are associated with, for example, horticultural tree crops, plantation crops and even forest trees production systems that ensure adequate supplies of sufficient fuelwood, timber, etc.

ix. Homestead garden improvement

Most field systems associated with traditional shifting cultivation and related fallow systems tend to break down under high population pressure and continuous cultivation. Exceptions to this include the lowland rice production systems of the Asian tropics and the compound farms or homestead gardens which appear to be reliably stable, efficient production systems. On the homestead gardens of Southeast Asia and humid areas of West Africa, a multistoried highly diversified production system has been achieved through concentration of nutrients from the surrounding areas directly in crop residues and kitchen refuse and indirectly through the use of animal manures and sometimes human waste. The homestead gardens in the tropics have received little or no attention as targets for improvement in research and development. Special studies are needed, to ensure maximum subsistence production from the compound farm system wherever possible, in addition to various cash production elements that may be obtained from fruit trees, other plant products and animals. In relation to this, much higher priority should also be given to the study, design, testing and development of multistoried cropping systems that take advantage of horizontal and vertical space dimensions with the full benefits of mixed cropping which, in addition to maximizing production, also protect the soil from erosion and degradation.

x. Potentials of agroforestry

Especially in the humid tropics of West Africa, it has not been possible readily to replace natural and planted fallow systems involving trees and shrubs with herbaceous leguminous cover crops or green manure crops. Traditional fallow trees and shrubs are used not only in highly effective nutrient cycling processes which could minimize fertilizer requirements, but are also used in miscellaneous ways as structural materials for staking, buildings, etc., in addition to their being used as browse plants, medicinal plants and so on. It would, therefore, be necessary to give high priority to various aspects of agroforestry systems that could enhance the associated production of arable food crops with tree crops. This promotes more rational resource use, increasing mutually beneficial interactions among resources and helps to preserve the environment.

xi. Integrated watershed development

Related to point viii above is the problem of failures of agricultural production projects on smallholder and large-scale farms involving the imposition of production of certain commodities on marginal soils, or in topographic situations with low capability for their production. This requires an integrated watershed management approach by which different commodities, including annual crops, tree crops, pasture plants and animals may be produced on toposequences or contours to which they are most adapted and where conditions for their growth and development are optimal. This ensures that each commodity is most efficiently produced where it has maximum economic advantage over other crops, with minimum environmental hazards. Moreover, it would also improve diversification of production on small farms where as far as possible both subsistence and commercial production take place.

xii. Need for communit and government commitment in projects to replace shifting cultivation

Where alternatives to shifting cultivation and related fallow systems have been developed or identified for field trial, effort should be made to ensure that there is national and local political commitment to the project so that appropriate and effective rural infastructure is available. Without this, the full cash returns of the commercial components of the farming system cannot be realized by the farmer. It may also make it possible for existing research institutions to provide the necessary back-up for the solution of problems that may arise during the project’s execution.

xiii. Role of international and regional agricultural research institutes in assisting national institutions in testing and development

In areas of shifting cultivation and related fallow systems, national institutions do not possess the research capability for developing effective alternatives to shifting cultivation that are ready for extension to farmers. Where much research has been carried out, all of the alternatives developed may not be relevant to the needs and situations of small-scale farmers in developing countries. Moreover, many national institutions are not yet linked in a workable farming systems research network with any of the international agricultural research institutes where significant progress has been made in farming systems research in developing alternatives to shifting cultivation. There are also national or regional research institutions, such as CATIE, where progress has been made in developing workable alternatives to shifting cultivation.

xiv. Problems of migration and settlement of itinerant farmers

In some areas of shifting cultivation already bedevilled by high population densities, it is not always best to plan migration to less populated areas. People may be slow or loath to adapt to farming systems unfamiliar to them, even though the systems are efficient and within their ability to execute and manage. Related are problems of nomadic herders who also practice an extensive agricultural production system which may be put under stress by increasing population densities of both humans and animals. Here, consideration should be given to ways of improving existing systems and to trying systems that have worked in similar situations, before resorting to wholesale migration and drastic changes in farming systems. Even then, these should first be attempted on a small scale at the farmers' level before involving whole communities.

Because collaboration is needed in the development, testing and extension of alternatives to shifting cultivation, it is therefore suggested that FAO mount a cooperative research project aimed at finding alternatives to sthifting cultivation, based on current achievements in different parts of the world. The immproved potential alternatives to shifting cultivation should be evaluated at the farm level as early as possible, to enhance their relevance and rapid adoption. The project should be regionally organized and coordinated by FAO, and should involve cooperation between FAO and international and national institutions. The scope of each regional project should be related to advances in research in the international and national institutions in the area. Priority should also be given to helping national institutions develop research and extension in farming systems research giving highest priority to alternatives to shifting_ cultivation and related fallow systems.

AGRO-ECOLOGICAL AND SOCIO-ECONOMIC BASIS FOR ALTERNATIVE PERMANENT FARMING SYSTEMS

It is generally recognized that the prevailing farming systems in a given area are location specific, for each system results from interaction among a unique set of physical, biological, socio-economic and managerial factors. Consequently, more effective permanent agricultural production systems that can effectively replace existing systems must be designed, developed and evaluated on a sound agro-ecological and socio economic basis. In other words, alternative farming systems used to replace 'shifting cultivation' must be designed and developed in relation to climate, soil, biological, and socio-economic criteria and the farmer's management capability.

Climate

Climatic factors that by and large determine the soil types , vegetation and farming systems anywhere on the earth's surface include temperature, rainfall, evapotranspiration, radiation and winds. Temperature is important in determining the rate of biological and chemical processes and the extent of its diurnal and seasonal fluctuations limits the existence, growth and development of various species and varieties of plants and animals. Critical aspects of rainfall include amounts, intensity, duration, spatial distribution and overall reliability with respect to onset and cessation and fluctuations in amount and duration throughout the year, as calculated over several decades or preferably even longer periods. The crops that are grown and the vegetation in a given area depend on the amount and distribution of rainfall (Figures 3 and 5).

Evapotranspiration is the amnunt of water lost from plants and the earth's surface. This depends on temperature, relative humidity, wind, etc. Where temperatures are high and there are several months of dry season, there may be so much evapotranspiration that mo'isture may be insufficient during most of the year, even though total annual rainfall may be high (see Figure 3).

Sunlight intensity, guality and duration affect crop growth. The importance of solar radiation in farming systems stems from the dependence of all life on earth, as we know it today, on the green plant's ability Co capture solar energy and transform simple substances from the atmosphere and soil into food and miscellaneous useful products. Fven in the humid tropics where both temperature and moisture favour plant growth, sunlight may be limited by constant cloud cover. The biomass production potential in any particular location depends on rainfall and incident radiation. In addition to radiation intensity, daylength is also an important factor, because photoperiod insensitive plants can be more flexibly fitted into a range of cropping systems than photoperiod sensitive plants which must be planted at specific times of the year for good performance. The traditional farmer sometimes takes full advantage of both photoperiod insensitivity and photoperiod sensitivity. For example, in southern Nigeria, late okra (Abelmoschus esculenta), when planted with early okra in March/April will not flower until August or September while early okra flowers in May to June. Farmers plant both of these at the same time to ensure that okra is available during both the early and late parts of the year.

The wind system is also important since it determines where and with what intensity it rains, the extent of crop lodging, the erosion hazard of rainstorms and the kind of precipitation. The overall effects of these climatic factors on the environment is manifested in the kinds of soils and vegetation that occur in any location.

Soil

Soil is the natural anchor for land plants and their source of nutrients. Soil, according to Jenny (1941), is a function of climate, organisms (including vegetation), topography, parent material and time. The aggregation of different kinds of micropedons in addition to the atmosphere above it constitutes land - a major factor in production. The physical and chemical characteristics, depth, texture, topography, etc., of a soil determine to what extent it is fertile and the overall level of productivity of the soil, with or without fertilizers. Soils of the tropics, on which shifting cultivation and related bush fallow systems are widespread, are generally of low inherent productivity as a result of the following (Donahue,1970):

i. deeper and more intensely weathered pedons with fewer remaining weatherable minerals;

ii. a lower percentage of silicon;

iii. a higher percentage of iron and aluminium;

iv. a higher percentage of kaolinite and a smaller percentage of montmorillonite;

v. lower cation exchange capacity but higher anion exchange capacity;

vi. lower buffer capacity;

vii. lower available water capacity;

viii. a laterite (plinthite) layer in some soils hardening on continuous exposure to cycles of wetting and drying as would occur under continuous cultivation;

ix. higher degree of friability;

x. less accumulation of leaf litter due to more rapid decomposition;

xi. smaller reserves of total and available nutrients.

IC is no wonder then that most of the major soil groups (oxisols, Alfisols and Ultisols) have lower inherent fertility than some of their counterparts in the temperate regions. Despite this, soils of the tropics may be fertile when formed on younger volcanic material, in valley bottom lands where hydromorphic and flood plain soils are generally more fertile than in any other situations in most of the tropics. For these reasons, soil capability studies and chemical analyses are needed before determining where to locate agricultural projects, which commodities to produce, and how to manage the soils. Usually, the more marginal a soil is for a given commodity the more expensive it is to render it suitable for sustained high yields. However, this may not always be economical (Figure 28).

The routine collection and analysis of climatic data, pedological studies and soil chemical analysis are necessary in the design of farming systems. There are now a number of soil benchmark projects involving pedological, chemical and fertility studies of soils in different parts of the world. The objective of these projects is to determine to what extent the results obtained on soils in a given ecological zone can be extrapolated or confirmed on similar soils in other ecological zones. Such studies, conducted at IITA cooperatively with the Universities of Reading and Louvain, provided the data for Table 19 and for determining solutions to nutrient deficiencies and/or toxicities (Figures 24 and 25) that may be encountered on different soils under arable crop cultivation. The value of climatic and soil data in farming systems can be seen in the following examples.

Traditiona! farming systems of Asia and tropical Africa are determined by rainfall duration and amounts. Thus, according to Harwood (1976), dry areas of India with less than 1 000 mm of annual rainfall have mainly sorghum and millet-based cropping systems. Maize-based cropping systems predominate in the driest areas of Southeast Asia with 1000 to 1 500 mm annual rainfall. Most of eastern Asia, where annual rainfall amounts to 1 500 mm or more and at least 200 mm/month rainfall in at least 3 consecutive months, is suitable for rice-based cropping systems (Figure 29). In rice growing areas, the type and intensity of the cropping pattern depends on the specific characteristics of the rainfall regime. In this regard, Coulter _et _al (1974) developed a rainfall classification based on cropping potential (Harwood, 1976). In this classification, the actual numbers of months of dry weather or wet weather, whether the rainfall is unimodal or bimodal and whether the end of the rains is gradual or sharp are indicated. Rainfall data are useful in determining where supplementary or complete irrigation would be necessary in the production of a crop and in relation to its moisture requirements during different growth phases.

According to Harwood (1976), soil conditions also influence cropping patterns especially in relation to water movement, drainage and tillage capability under high rainfall. Thus, in high rainfall areas, soils high in clay can only be used for rice at the monsoon peak when tillage is not possible and only paddy • (flooded) conditions prevail. Where upland areas have rolling topography, upland rice may be grown only where the soil has good internal drainage. The suitability of fresh water alluvial areas, having high calcium levels, for upland crops such as sugarcane, depends largely on improved internal drainage as in the northern shores of Java (Harwood, 1976). The potentials for growing a second or third upland crop after rice, in areas where rainfall is inadequate for additional rice crop, depends on the capability for converting the soil from puddled to ‘upland’ conditions. Conversion of puddled to upland soils is possible where there is much silt where the puddled soil can be tilled at a relatively high moisture level. The type of clay in the soil makes a difference with respect to drainage and conversion from puddled to upland conditions.

The Biotic Environment

This consists of all living organisms in the biosphere, including human

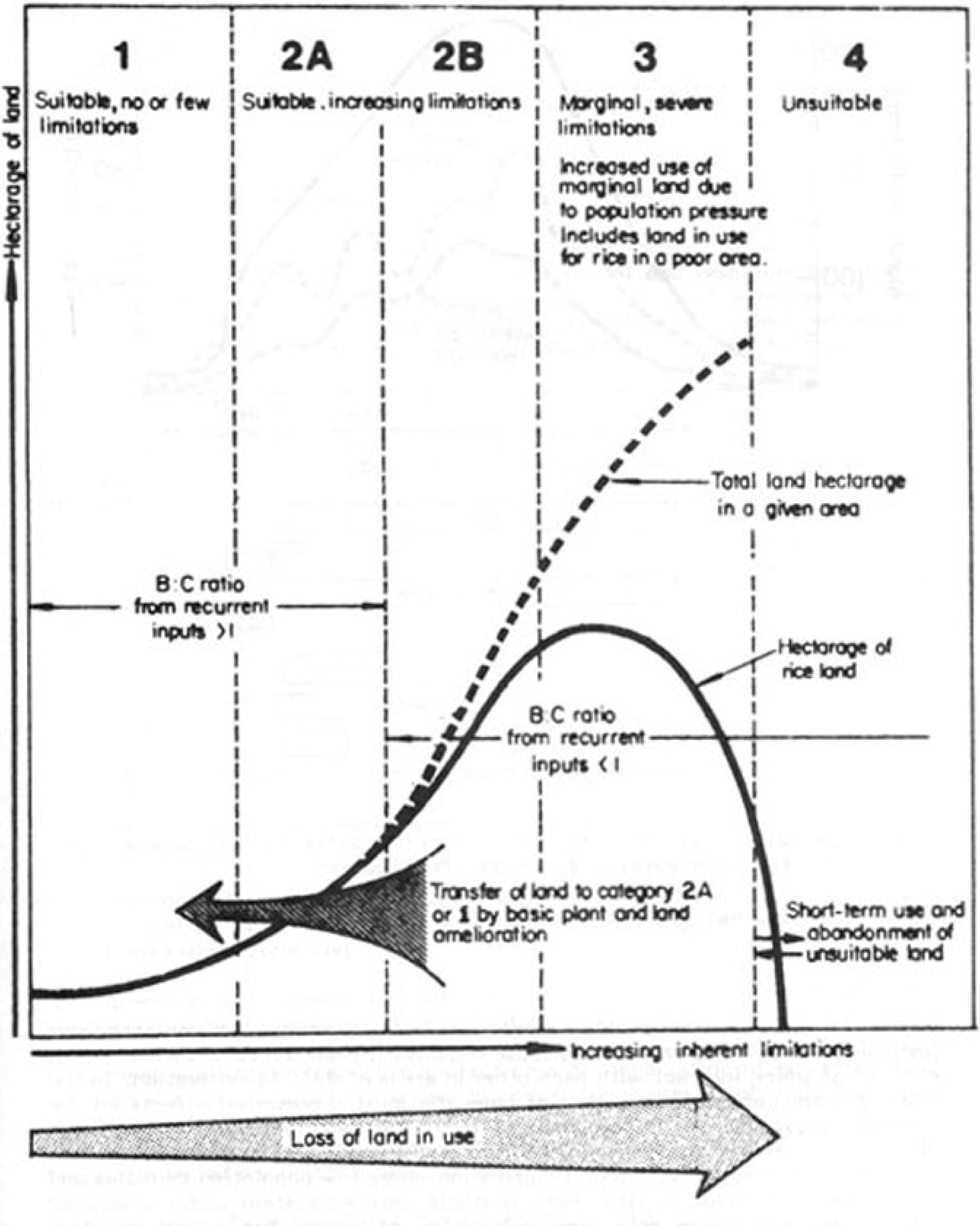


Fig. 28 Model showing the relationship of land quality to land use for rice growing

Source: Moorman and Van Breemen, 1978

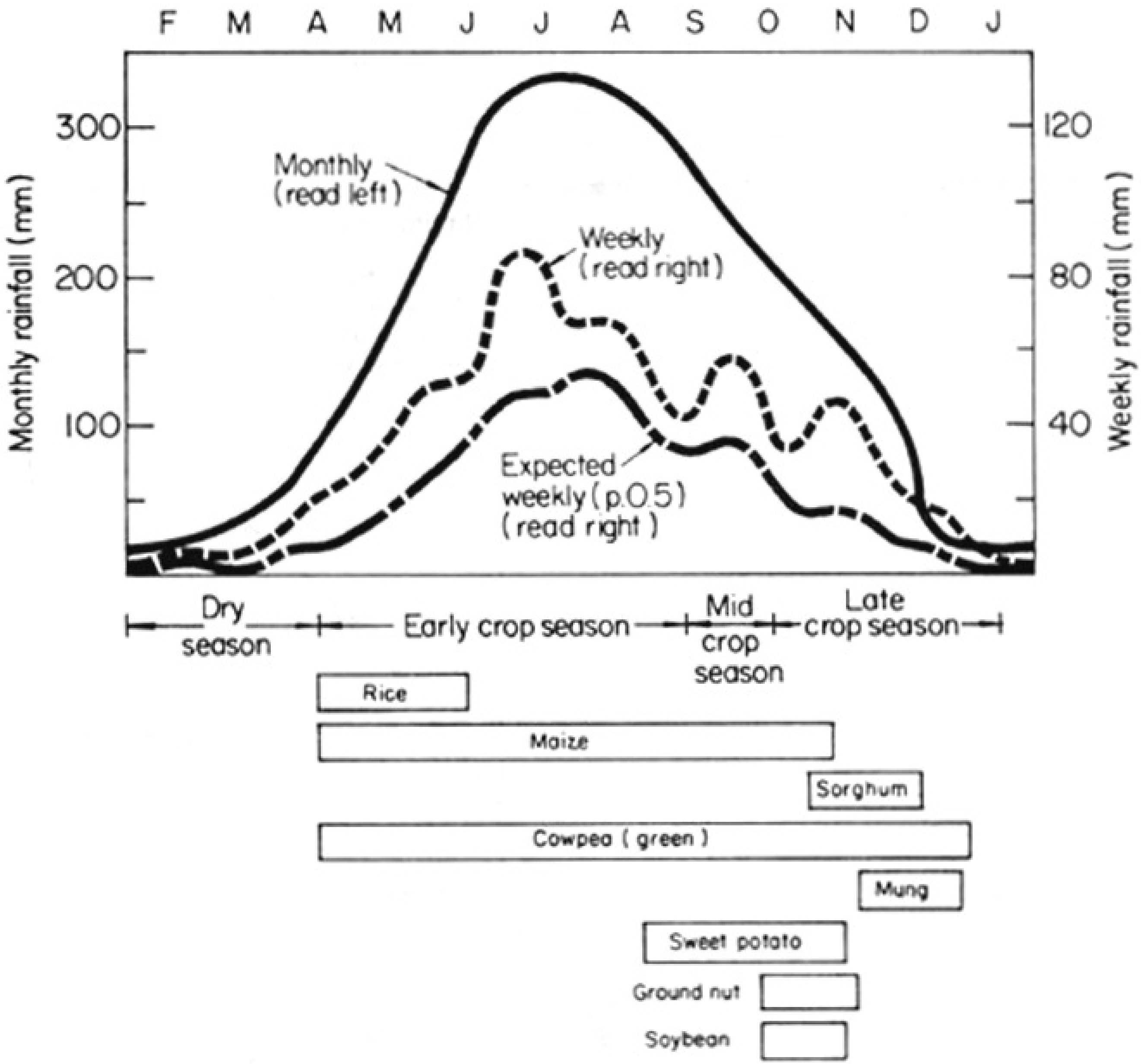


Fig. 29 Water availability and field crop patterns for upland rice farms in eastern Batangas, Philippines

Source: Harwood, 1976

beings. It includes crops, other plants and weeds, animals, micro-organisms (including saprophites, parasites, disease organisms, their vectors, various pests, etc.) all of which interact with each other in areas of shifting cultivation. In the biotic environment, human activities have the most pronounced effects on the cultural landscape. It is the changes from the dynamic equilibrium of the climatic climax vegetation ecosystems and the relatively more stable agro-ecosystems of traditional shifting cultivation under low population densities and long periods of fallow to the more unstable agro-ecosystem under shortened fallows and continuous sole crop cultivation of today that is our greatest concern. Knowledge of the biotic environment is essential to the development of alternatives to shifting cultivation and related bush fallow systems. A natural resources survey in addition to studies of vegetation, dominant crops and cropping systems, livestock and their production systems, pests, diseases and parasites of important economic species should go a long way towards ensuring the development of scientifically sound and efficient management of our natural resources.

A recent welcome development which will facilitate use of agro-ecological data in designing alternatives to intermittent agricultural production systems is the current FAO Agro-ecological Zones Project, Volume 1 report on 'Methodology and Results for Africa' (FAO, 1978). This presents charts (an example is given in Table 21) and maps on the agro-climatic suitability classifications for 14 crops in addition to a review of the methodology for arriving at the classification.

Socio-Economic Environment

This consists of the customs, religion, local preferences and political institutions of a people. It also includes educational and research institutions which are important in the development, evaluation and adoption of new technology. Experience has shown that local preferences, religion and culture may have adverse effects on the development and adoption of new technology.

The Farmer's Management Capability

According to Harwood (1974) this entails decision making, performing of technical operations that require exceptional skills and supervision of certain farm operations. It is a capability related to labour availability and is often overlooked. Some care and experience are required in the clearing, cultivation, planting, weeding, pest control, harvesting, primary processing and marketing of various commodities grown on the farm. The more intensive the farming systems, the more the technical skill and care required in planning, design of systems, securing of inputs and scheduling of various activities and management of scarce resources for efficient production.

Five elements of a socio-economic nature are essential for agricultural development (Mosher, 1976):

i. effective marketing systems for agricultural products;

ii. continuous and systematic research developing new technology required in agriculture;

iii. presence of adequate production incentives for farmers to increase their production or for operators of agricultural support services to perform their tasks efficiently;

iv. presence, maintenance and operation of efficient transportation and communication systems that reach most farms;

v. local availability through manufacturing or importation of equipment and other inputs required by farmers at reasonable process (Mosher, 1976).

Related to these essential elements are what Mosher (1970) termed "accelerators" of agricultural development:

a. presence of adequate educational and training facilities for the production of agricultural technicians and experts for all supporting services;
b. availability of production inputs;
c. organization to enhance group action by farmers through cooperatives, social organizations, etc.;
d. means for improving and/or expanding agricultural land under cultivation;
e. mechanisms for planning and directing agricultural development

Table 2: AGRO-CLIMATIC SUITABILITY CLASSIFICATION AND YIELD (WITH CONSTRAINTS) IN T/HA OF CROPS BY LENGTHS OF GROWING PERIOD

GROUPS II AND III CROPS IN TROPICAL AND SUBTROPICAL AREAS

Crops	Input Level	Growing period (days)	75-89	90-119	120-149	150-179	180-209	210-239	240-269	270-299	300-329	330-364	365
PEARL MILLET	High	Yield	1.1-1.6	2.2-3.1	2.2-3.0	2.8-3.9	2.0-2.8	1.1-1.6	0.3-0.5	0.3-0.5	0.3-0.4	0.3-0.4	0.3-0.4
		% of maximum 1/	28 41	57 79	79	100	73	41	12	12	10	10	10
		Suitability 2/	NS	S			S	MS		NS			
	Low	Yield	0.3-0.4	0.5-0.8	0.5-0.8	0.7-1.0	0.5-0.7	0.4-0.5	0.2-0.2	0.1-0.2	0.1-0.2	0.1-0.2	0.1-0.2
		% of maximum	29 40	56 78	79	100	73	55	19	17	17	17	17
		Suitability	NS	S			S		MS		NS		
SORGHUM	High	Yield	0.5-1.3	1.8-2.6	2.7-3.8	3.5-5.1	3.4-5.0	1.8-2.7	0.8-1.2	0.6-0.9	0.4-0.6	0.4-0.6	0.4-0.6
		% of maximum	10 25	35 51	53 74	100	98	53	21	18	12	12	12
		Suitability	NS MS		S			S	MS		NS		
	Low	Yield	0.1-0.2	0.3-0.5	0.5-0.7	0.9-1.3	0.9-1.3	0.5-0.7	0.2-0.3	0.1-0.2	0.1-0.2	0.1-0.2	0.1-0.2
		% of maximum	7 19	27 39	40 56	100	98	54	27	17	17	17	16
		Suitability	NS	MS	S			S	MS		NS		
MAIZE	High	Yield	0.5-1.2	1.9-2.7	3.7-5.4	4.9-7.1	4.8-7.0	3.4-5.1	2.3-3.4	1.7-2.5	1.6-2.4	1.2-1.8	0.5-0.8
		% of maximum	7 17	27 38	52 76	100	98	72	48	35	34	25	11
		Suitability	NS	MS	S				S		MS		NS
	Low	Yield	0.1-0.2	0.4-0.5	0.7-1.0	1.2-1.8	1.2-1.7	0.9-1.3	0.7-1.0	0.7-0.9	0.6-0.9	0.5-0.7	0.2-0.3
		% of maximum	5 13	20 29	39 57	100	99	72	54	52	51	38	17
		Suitability	NS	MS	S					S		MS	NS
SOYBEAN	High	Yield	0.3-0.6	0.9-1.3	1.9-2.5	2.4-3.4	2.4-3.3	1.7-2.5	1.1-1.6	0.9-1.2	0.6-0.9	0.4-0.6	0.3-0.4
		% of maximum	9 18	28 38	56 73	100	97	73	47	35	26	18	12
		Suitability	NS	MS	S						MS		NS
	Low	Yield	0.1-0.1	0.2-0.3	0.5-0.6	0.6-0.8	0.4-0.6	0.3-0.5	0.3-0.5	0.2-0.3	0.1-0.2	0.1-0.1	0.1-0.1
		% of maximum	10 18	28 38	58 75	100	72	54	54	40	26	12	12
		Suitability	NS	MS	S						MS		NS
PHASEOLUS BEAN	High	Yield	0.3-0.6	0.9-1.3	1.9-2.5	2.4-3.4	2.4-3.3	1.7-2.5	1.1-1.6	0.9-1.2	0.6-0.9	0.4-0.6	0.3-0.4
		% of maximum	9 18	28 38	56 73	100	97	73	47	35	26	18	12
		Suitability	NS	MS							MS		NS
	Low	Yield	0.1-0.1	0.2-0.3	0.5-0.6	0.6-0.8	0.4-0.6	0.3-0.5	0.2-0.3	0.2-0.2	0.1-0.2	0.1-0.1	0.1-0.1
		% of maximum	10 18	28 38	56 75	100	72	54	36	26	26	12	12
		Suitability	NS	MS						MS		NS	
COTTON	High	Yield	0.0-0.0	0.0-0.2	0.3-0.8	1.1-1.1	1.0-1.1	0.6-0.6	0.5-0.5	0.3-0.3	0.2-0.2	0.1-0.1	0.1-0.1
		% of maximum	0 3	3 20	30 72	96 100	100	54	41	27	18	9	9
		Suitability	NS		MS					MS		NS	
	Low	Yield	.00-.01	.01-.03	.05-.11	.15-.16	.15-.16	.14-.15	.14-.15	.07-.07	.05-.05	.03-.03	.03-.03
		% of maximum	0 4	4 11	18 39	54 57	57	54	54	25	18	9	9
		Suitability	NS		MS					MS		NS	
SWEET POTATO	High	Yield	0.6-1.2	1.2-2.9	3.9-5.1	7.7-10.1	7.6-9.9	7.4-9.7	7.4-9.7	5.5-7.1	2.7-3.5	2.7-3.4	1.8-2.3
		% of maximum	6 12	12 29	39 50	76 100	98	96	96	70	35	34	23
		Suitability	NS	MS								MS	
	Low	Yield	0.2-0.3	0.3-0.7	1.0-1.3	1.9-2.5	1.9-2.5	1.8-2.4	1.4-1.8	1.4-1.8	1.4-1.8	0.9-1.2	0.7-0.9
		% of maximum	6 12	12 29	39 51	76 100	98	96	72	71	66	46	36
		Suitability	NS	MS									MS
CASSAVA	High	Yield	0.2-0.3	0.3-0.9	1.0-2.0	2.6-4.4	7.8-9.7	10.3-11.4	11.4-12.4	11.9-12.9	12.7-13.6	7.4	5.0
		% of maximum	1 2	2 7	7 15	19 33	57 71	76 84	84 91	88 95	93 100	54	37
		Suitability		NS		MS							MS
	Low	Yield	0.1-0.1	0.1-0.2	0.2-0.5	0.7-1.1	1.5-1.8	1.9-2.1	2.1-2.3	2.2-2.4	2.4-2.6	1.9	1.4
		% of maximum	1 2	2 5	10 19	19 33	43 53	57 63	63 68	66 71	70 75	56	41
		Suitability		NS		MS							

1/ Throughout this table % of maximum refers to the yields of the respective growing periods expressed as a percentage of the maximum yield attainable from any growing period, without permanent constraints.

2/ Suitability: NS = not suitable; MS = marginally suitable; S = suitable; VS = very suitable.

programmes as an integral part of overall economic development.

PROCEDURE FOR DESIGNING FARMING SYSTEMS ON THE BASIS OF AGRO-ECOLOGICAL DATA

With the exception of studies of existing farming systems, current farming systems research rarely involves complete farming systems. Farming systems research is more often focused on system components. In this discussion of the design of alternatives to shifting cultivation examples will be based on the cropping systems component. But the same procedure could be used to design various commodity-based farming systems involving mixes such as crops alone, livestock alone or integrated crop/livestock systems. There are numerous candidate production systems that could be tried out in any one area. But resources and time are limited and, therefore, it is necessary to narrow the choice only to those with high probability of success.

The first step is to select the most probable cropping system or farming system for the area, but here our emphasis is on food crops. generally, considerations should be given to various groups of farming systems including arable crop farming for food and non-food uses, livestock production and ranching, perennial tree crop production through irrigation, rainfed farming, or combinations of both. Figures 8-19 give information on the existing small farm production systems in Southeast Asia, Latin America and Africa that are adapted to various agro-ecological zones. The climatic and vegetation zones are more or less correlated with agro-ecological zones. Andreae (1980) also presented data on humid and arid months, vegetation belts and major groups of farming systems that are currently associated with the different zones (Figure 5). With these sources of data, the infinite number of farming systems that are possible in a given area can be pruned down to only those that have the greatest chance of success. While almost all possible farming systems can be cited anywhere in the world, the economic workability of any such production system depends greatly on whether it is in an area where the component commodities are not adapted or where there are adverse local environmental factors. Sprague (1975) also gives broad outlines of the major climatic and vegetation zones and the associated major land uses (Table 22).

On the basis of information in Andreae (1980) (Figure 5), it can be seen that tree crop farming, for example, which may consist of the growing of fruit trees, other useful trees such as rubber and forest trees, would be most appropriate in humid and sub-humid zones with over seven humid months. Within each main type of farming system suited to a given area, it is possible on the basis of prevailing climate, soil, topography, local preferences and farmers' resources and objectives, and socio-economic conditions to decide which individual commodities (crop variety or species) should he included in the cropping system, livestock production system or the various mixes of crop and livestock that would be meaningful and most rewarding. All too often, commodities selected on the basis of adaptability alone, without consideration of local preferences, turn out to be unacceptable to the farmer, however high the yield may be.

Okigbo (1981) listed the alternative land-use categories that should be taken into account in planning and research in Africa (Table 23). These range from special reserves for hunting, gathering, fishing, tourism and forestry to those for the production of arable food crops. The most crucial area of research in the tropics is land development and soil management for subsequent cropping patterns and cultural practices for sustained yield. Research is still needed to determine technologies for the maintenance of soil fertility on a continuing

Table 22 RAINFALL AND LAND USE

Average annual rainfall	Major land uses 1/
Over 2 000 mm	Rain forest regions. Adapted to wide range of tree crops, tilled crops and forages where soil erosion is controlled, and soil fertility maintained.
1 500 - 2 000 mm	Wet-dry tropics. Land use is limited mostly to dry seasons of 2.5 to 5 months. Annual crops and forages, and some tree fruits are well suited.
1 000 - 1 500 mm	Moderately humid. On deeper, well drained soils where erosion is controlled, rainfall will support wide range of food crops, certain tree fruits, and forages for grazing livestock.
500 - 1 000 mm	Savanna, steppe. Deeper soils may be cropped to short season grain crops, groundnuts, sesame and certain vegetables. Al1 other lands are best suited to grazing and forage for livestock.
250 - 500 mm	Semi-desert. Supports limited growth of browse and forage plants for migratory grazing. These lands require careful management. Local areas of deep soil may be cropped to millet and sorghum following sporadic rains.
0 - 250 mm	Desert. Agricultural use is limited to extensive types of livestock grazing, with careful range management. Forage growth occurs only in the few weeks after local rains occur. Will not support sustained use.

1/ Exclusive of controlled irrigation, that may be practised wherever irrigation water is available.

Source: Sprague, 1975.

basis. It is also very important to find ways of ensuring efficient use of the least amount of fertilizer needed to maintain fertility, in order to minimize the cost of fertilizers and maintenance of adequate levels of soil organic matter. These could be accomplished through effective use of biological nitrogen fixation, plant residue management, exploitation of the nutrient cycling potential of trees, shrubs and herbaceous leguminous cover crops, bearing in mind that herhaceous legume covers have so far not been attractive to farmers in tropical Africa. Some effort should be devoted to other appropriate technologies which accommodate resource limitations of small farmers in the tropics.

In selecting individual crops to be fitted into the various cropping systems of high potential in the area designated for their production, data on the agro-climatic suitability and land suitability classifications or assessments for the

Table 23 ALTERNATIVES TO SHIFTING CULTIVATION AND BUSH FALLOW SYSTEMS

In the humid and subhumid tropics, the problem of finding suitable alternatives to shifting cultivation remains more or less as intractable as ever. Yet, when all the possible alternatives are considered there is no doubt that the following alternatives exist and constitute options with varying degrees of ecological acceptability and economic viability in any one location.

1. Tree crop plantations
    a. sole crop (oil palm)
    b. mixed crop (banana + coffee, coconut + cocoa)

2. Agroforestry
    a. tree crop/arable crop combinations
        i. at early stages of tree crop plantation establishment
        ii. continuous (e.g. alley cropping)
    b. tree forage crop intercrops + livestock (e.g. coconut * pasture and livestock)

3. Planted fallow system
    a. tree and shrub fallows + arable crop sequence
    b. short-term legume + grass fallows + arable crop sequence

4. Livestock production system
    a. poultry
    b. small ruminants on improved pastures and browse plants

5. Annual or arable crop system
    a. mixed or relay crop system + short-term fallow
    b. mixed or relay crop rotations without fallows
    c. sole crop and short duration fallows
    d. sole crop continuous (e.g. rice, maize)

6. Special commercial horticulture
    a. fruit trees (same as plantations)
    b. vegetable crops especially close to urban centres or in highland tropics
    c. ornamentals

Source: Okigbo, 1981.

major crops of the tropics, prepared by the FAO Agro-ecological project (FAO, 1978), would be very useful, although available data is currently limited to Africa. 1/

Having determined alternative cropping systems that would be most profitable in a given agro-ecological zone, specifications for the design of the actual crop combinations and sequences may be carried out following the procedure outlined by Harwood (1974). Areas where crops are to be grown should each be classified for the selected crops. The design of cropping systems trials to find alternatives to shifting cultivation should take place at both regional and local levels. To start with, each target region should be split up into major ecological zones or benchmark areas. Then, in each benchmark area, a broadly representative location should be chosen for the trials. Scientists should first collect as much available environmental data as possible (on rainfall, temperature, soils, etc.) using social and anthropological studies, geographical sources, data from agricultural experiment stations, and results of agronomic experiments conducted over several years, in addition to information on local preferences, traditional practices and the socio-economic backgrounds of inhabitants. A tour of the area and consultations with farmers and other individuals knowledgeable about the area may be necessary to update some of the data. Detailed data should also be collected on rainfall and rainfall probabilities when available, depth of flooding or heights of the water table throughout the year and tillage requirements for the commodities to be grown. In many African developing countries a great deal of data useful for design of cropping systems may be obtained from FAO and/or relevant ministries or services of former colonial powers (e.g. IRAT, ORSTOM, etc). This data should be used to classify each area on the basis of the important environmental factors, such as water and soil. With knowledge of the levels of categories of each factor suitable for different phases of planting, growth and development and harvest of the crops, the potential for the production of the crop or crops can be established.

Harwood (1976) gave detailed examples of classifications for water availability for rice production in the humid tropics. In this exercise, a distinction was made between areas with more than 200 mm of rain per month and those with less. The 200 mm rainfall level corresponds to the accepted water requirement for rice grown in submerged paddies. Using the 200 mm rainfall level as a guide, various categories of rainfall or water availability below 200 mm are regarded as sub-categories that could be correlated with rice yield. However, while the monthly rainfall data was appropriate for the exercise, a lack of rain for several consecutive days during a month in which total rainfall was up to 200 mm may reduce crop yield. Consequently, for any of these factors and for a given crop, weekly, fortnightly, monthly or other practical but useful time intervals may be used. The categories of rainfall availability for rice listed by Harwood are presented below and illustrated in Figure 29.

Categories of Rainfall Availability for Rice

i. Category 1 - Areas with less than 3 months of 200 mm rain. Transplanted rice can be grown if soil puddles easily rendering soil impermeable to water percolation where runoff water from fields or paddies is available. Production risky.

_1/ Editor’s Note. Data now available covering all the world, in the series World Soil Resources Reports: 48/2 Southwest Asia, 48/3 South and Central America, 48/4 Southeast Asia.

ii. Category II - Areas with 200 mm for 3-5 months. Prime areas for single crop of rice per year of transplanted rice.

iii. Category III - Areas with 200 mm rain for 5-7 months. Two crops of early maturing rice possible in paddies. Unless rain season begins abruptly crop should be directly seeded on soil that is unpuddled.

iv. Category IV - Area with 7-9 months of 200 mm rainfall. Two crops of transplanted rice possible.

v. Category V - Area with more than 9 months of 200 mm rainfall can support continuous rice production.

Several other crop management factors should also be considered. These include tillage characteristics, planting and harvesting requirements in relation to available technologies. The crops and the rotation are included in the design so that the theoretical cropping potential is approached. Crops are chosen according to their rainfall requirements, local preferences, market potentials and various other criteria such as disease resistance. FAO (1978) and Andreae and Kestner (1980) list environmental requirements of several important tropical food crops that may be of value in cropping systems design. Figures 30 and 31 illustrate the kind of cropping patterns for upland rice for eastern Batangas in the Philippines as reported by Harwood and for some fond crops in the Ibadan area of Nigeria, that could result from a cropping system design exercise. Similar crop combinations and sequences could be designed for any benchmark areas selected for the trials.

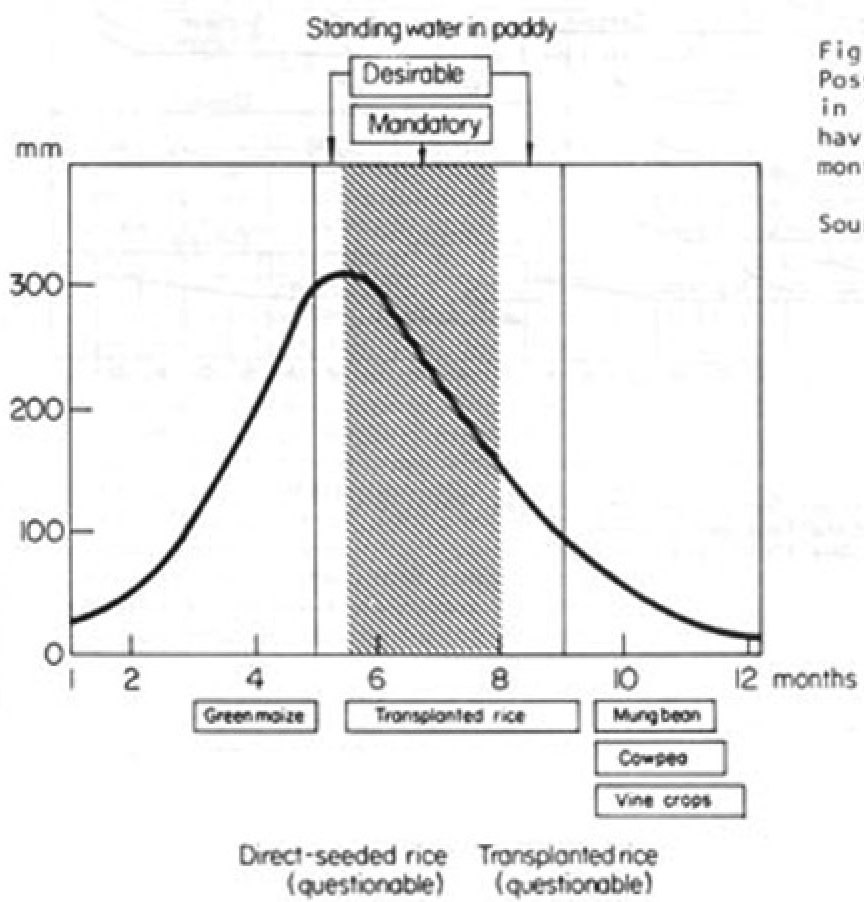


Fig. 30
Possible crop patterns in lowland rice areas having three to five months of good rainfall

Source: Harwood, 1976

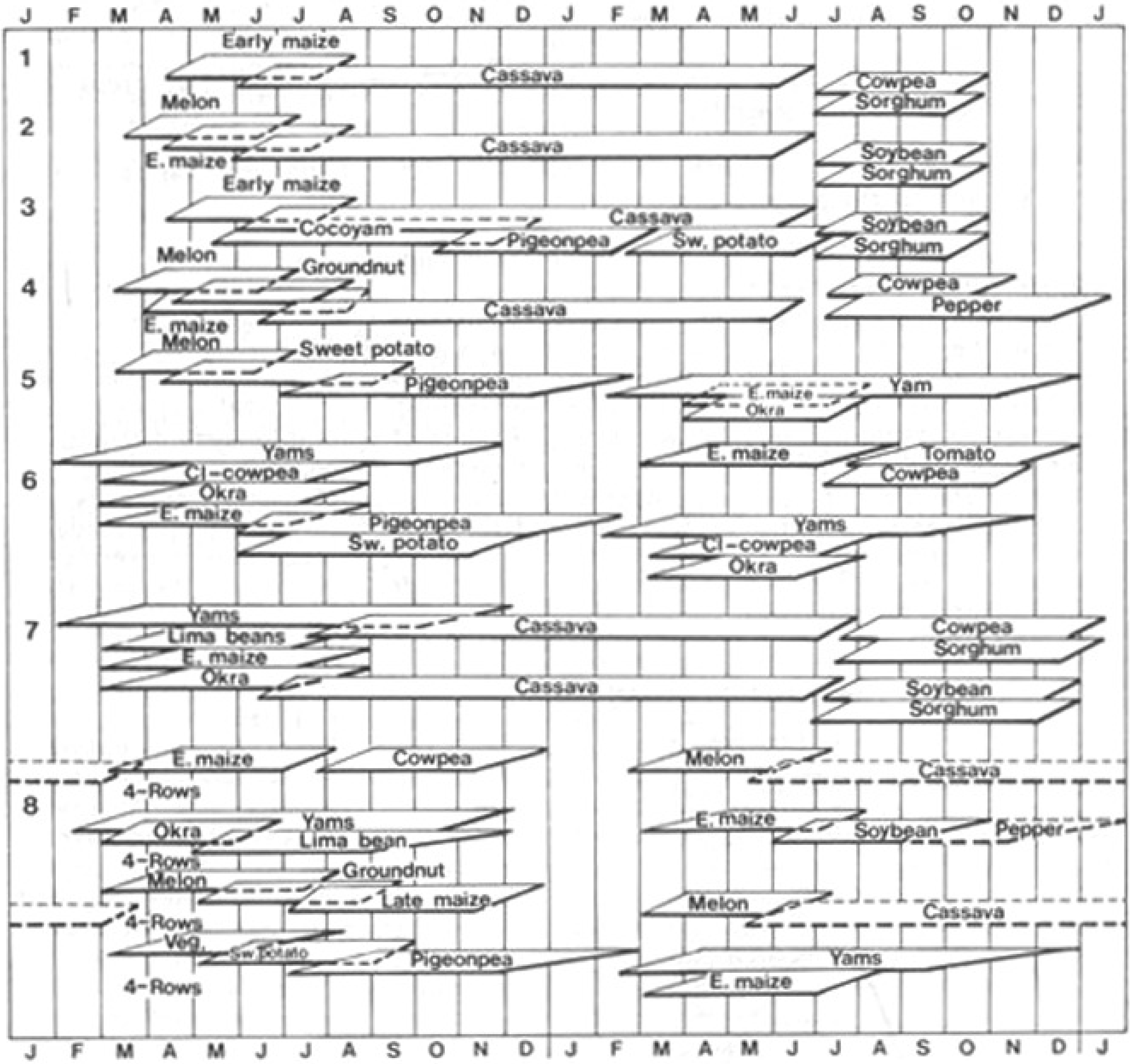


Fig. 31 Cropping calender for preliminary two year rotations
Cropping combinations and sequences
(IITA Experimental Cropping Systems
FSP, 1976.

POTENTIAL ALTERNATIVE PERMANENT PRODUCTION SYSTEMS

Shifting cultivation, nomadic herding and related extensive production systems are ecologically sound and reasonably economically rewarding as long as human population density remains low and there is no change in settlement patterns, land tenure, livestock population and various socio-economic conditions associated with modernization. Attempts to replace shifting cultivation by the corridor systems in the Congo (Zaire), which involve long term forest fallow and individual land ownership, were not very successful as a result of (a) the extent of supervision and control required; (b) the lack of sufficient land for long-term fallows where population densities were already high; (c) the high labour requirement and waste of forest resources when long term fallows are cleared. Alternative more permanent production systems, which may have considerable merit and are capable of widespread adoption under current socio-economic pressures and environmental concern, include (i) various aspects of agroforestry which combine tree crop production with food crop production; (ii) tree crop production in the humid tropics; (iii) efficient and ecologically sensitive arable crop production systems; (iv) combined livestock and crop plant production; (v) improved livestock production systems; (vi) irrigated agriculture; (vii) integrated watershed management.

Agroforest and Combined Tree Crop and Food Crop Production Systems

In the humid tropics of West Africa, short-term fallows and herhaceous legumes have either not been as effective as woody shrubs and tree fallows or have not been widely adopted. Recent experience with Luecaena leucocephala in Asia, Australia and Hawaii indicates that selected woody shrubs or tree fallows could fulfil various needs in addition to recycling minerals and fixing nitrogen which minimize fertilizer use. In such efficient cropping systems, arable crops are grown among woody shrubs and trees in a systematized rotation and/or intercropping pattern. Under such conditions, the woody trees and shrubs may also provide food, fuel and miscellaneous products useful to people. Improved tree crop and arable crop production systems which may constitute permanent cropping systerms for the replacement of shifting cultivation include (1) improved multistoried intercropping systems of the compound or home garden type; .(2) intercropping of food crops with plantation crops either only during early periods of tree crop plantation establishment, renovation or replacement on a continuous hasis: (3) systems of agroforestry involving intercropping of arable crops with quick maturing trees in such a way that food crops intercropped at various stages are adapted to the shade conditions at different stages of tree growth, then phased out as the tree canopy covers completely; (4) permanent intercropping and/or rotations involving the growing of woody plants or trees with arable crops.

The alley cropping pattern of maize with Leucaena at IITA and yields obtained are illustrated in Figure 26 and Table 20.

Although intercropping of food crops with plantation crops at early stages of plantation establishment and renovation is ecologically and economically sound, it does not constitute a permanent food crop production and agricultural system for small farmers. Where arable crops exhibiting varying shade tolerance are intercropped with quick maturing trees, a permanent production system can evolve if the farmer plans the dates of clearing and tree crop/food crop sequences so that at any one time, different staqes of the tree/arable crop intercropping system provide the range of food crops required. In such a system interplanting and harvesting of the food crop and the woody plants occur rotationally and on a continuous basis. In savanna areas, selected woody shrubs and trees can be intercropped with arable crops but the usual burning of vegetation may have to be carried out in the early part of the dry season or replaced with suitable non-burning vegetation management systems. This will enhance development of a climax vegetation not dominated by grasses.

Since, until recently, research on the replacement of shifting cultivation and related bush fallow systems has concentrated on arable crop production systems patterned after those of temperate countries, emphasis should now be given to adaptive, properly designed research projects aimed at making the aspects of agroforestry outlined above a reality. References which may be found valuable in the planning and execution of such research projects include Grinnel (1975); NAS (1979); PCARR/NAS (1977).

Tree Crop Plantations

Where land is not limited and population densities not very high, small-holder tree crop plantations of oilpalms (Elaeis guineensis), coconut (Cocos nucifera), cocoa (Theobroma cacao), rubber Hevea brasiliensis), coffee (Coffea species), etc. constitute ecologically and economically sound alternatives to shifting cultivation in the humid tropics and some highland areas where coffee or tea can be grown. Nair (1979) and Bavappa and Jacob (1981) report successful coconut based farming systems in various parts of the world. Spanaaij (1957) reported results of intercropping of arable crops with oil palms at the early stages of plantation establishment, while NIFOR (1960) _1/ recommends spacing and planting patterns for permanent intercropping of food crops with oil palms. This type of farming enterprise would be most rewarding where there are more than five hectares of land for an average farm family or at least enough land for a specific crop to ensure a reasonable standard of living. While in some situations such smallholder plantations may be more successful in association with or in close proximity to large-scale plantations, the replacement of shifting cultivation by large-scale farms on which farmers become mainly labourers or tenants may result in socially undesirable consequences and exploitation.

Arable Crop Production Systems

Most serious problems in soil and environmental deterioration occur where shifting cultivation and Innq - term fallow systems have been replaced either by drastically shortened fallows or continuous cultivation. This is often a result of the removal of vegetative cover and longer or continuous periods of cultivation without adequate fertilization and application of soil conservation principles. Another type of change in arable crop production which results in soil degra-dation and erosion is the shift from traditional intercropping to sole and row crop production systems that do not provide as effective a cover as the traditional mixed cropping. The situation is most serious where there is poor residue management. There is no doubt that improved land development, soil manage-

1/ Previously WAIFOR.

ment, and adequate plant residue management associated with efficient inter-cropping and relay crop combinations and their sequences can he used to achieve sustained yields under permanent production. Under such systems, minimum tillage techniques on certain soils have been found promising (Lal, 1979). Relay intercropping and related technologies aimed at increasing productivity per unit area are more or less imperative where farm sizes are small and there is need for diversification of production, so as to satisfy both subsistence and the increasing cash needs of the farmer. Moreover, especially where mechanization is already being introduced or practised, efficient sole crop rotations involving strip cropping can be designed to achieve crop diversification. Maintenance of adequate rotations can also minimize erosion.

To achieve continuous and efficient replacement of shifting cultivation and related bush fallow systems, high priority should be given to packages of technology that include:

i. ecologically sound land development and soil management;

ii. zero or minimum tillage wherever possible;

iii. adequate crop residue management;

iv. low cost energy technology;

v. a range of technologies that minimize the cost and amount of fertilizers and other costly inputs;

vi. effective use of biological nitrogen fixation and natural nutrient recycling processes;

vii. efficient crop combinations and/or sequences that ensure that the soil is adequately covered for most of the year and that satisfy the diversification needs of small farmers;

viii. integrated pest and disease management;

ix. appropriate technology for transporting and storing farm produce.

All the above would require changes in research strategy and a systems approach to research that ensures development of more efficient crop production systems within as short a time as possible.

Horticulture Crop Production Systems

One of the most rewarding permanent farming systems in the developing countries is market gardening close to urban centres. This is a highly intensive agricultural production system requiring high inputs of labour, manures, chemicals and miscellaneous farm requisites. Unfortunately, research for improving this system of farming in tropical Africa has been minimal. Most of the market gardens in West Africa were initially aimed at satisfying expatriate demand for subtropical vegetables during the preindependence era. With increasing rates of urhanization, demands for vegetables have continued to rise but vegetable production systems have undergone very little change.

Most of the existing vegetable production systems rely on natural rainfall and have not taken advantage of supplementary irrigation or vegetable produc tion in hydromorphic soils which facilitate production of off-season vegetables. Some aspects of vegetable production can he accommplished as a component of intercropping and rotational sequences of traditional arable crop production systems. Harwood (1976) reported vegetable gardening to be the most dominant farming system in Asia where farm sizes are small (Fi4ure 32). In addition to priority on research on the efficiency of vegetable production systems, attention needs to be given to marketing, storage and handling of vegetable crops. In Nigeria, serious losses in vegetables occur as a result of poor handling during transportation. Organized cooperative market gardening to supply raw materials for food processing plants could provide industrial employment for rural people. Moreover, vegetable production enterprises provide avenues for more efficient use of urban wastes, animal manures and certain environmental pollutants.

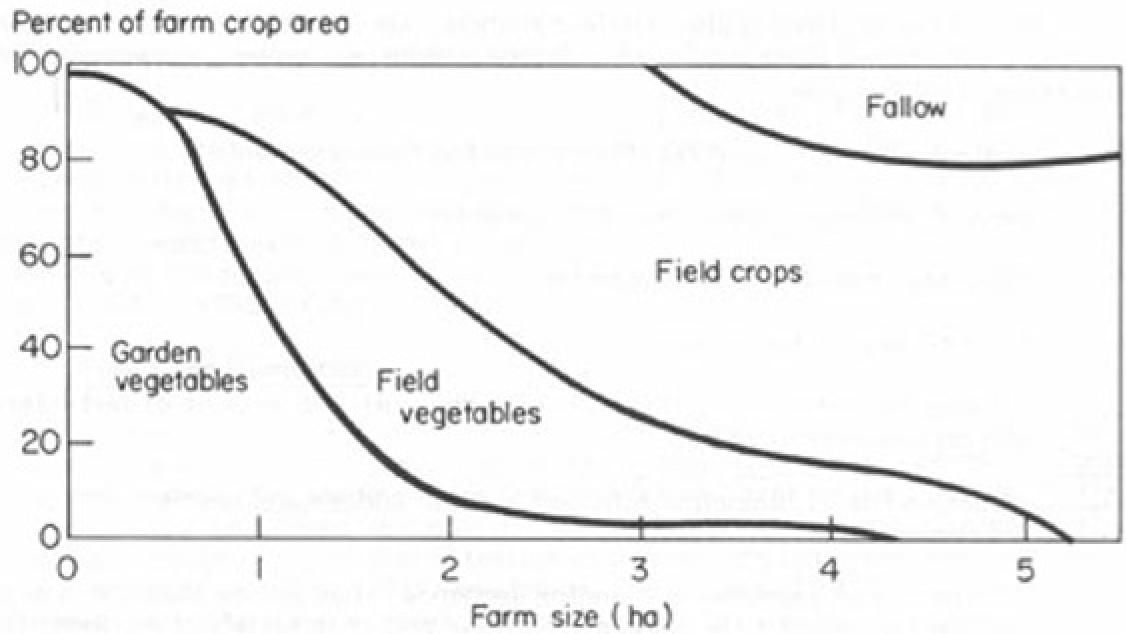


Fig. 32 Relationship between farm size and type of crop in areas of Southeast Asia having a two crop (eight month) growing season and access to markets for high-value vegetables. The family is assumed to be the primary source of labour

Source: Harwood, 1976.

Farming Systems Associating Livestock with Crop Production

Mixed farming and farming systems involving association of animal production with crop production constitute one of the most efficient permanent agricultural production systems for small farmers. In these farming systems, the animals supply manures and various other products useful to the farmer. The manure minimizes fertilization cost, while ensuring that adequate levels of soil organic matter and soil fertility are maintained. Where large animals (cattle, buffalo, donkeys, etc.) can be kept and diseases and pesCs are not limiting, animals can be used for work in mixed farming systems. This has been successful in savanna areas of West Africa, for example, around Kano in Nigeria in the 1940s. In the humid tropics where the tsetse fly and trypanosomiasis make it impossihle to rear cattle, small livestock (sheep, goats, and poultry) may be associated with vegetable gardening and arable crop production. Successful tree crop and animal production systems have been developed in Southeast Asia in which cattle graze under coconuts (Nair, 1979). Similar farming systems may be developed in other situations with suitable animals and crops such as oil palms.

There is, of course, the danger that unless the numbers of some types of livestock, such as goats, are regulated and the animals properly restricted, they may harm the environment through over-grazing. Problems may arise where livestock are kept by nomadic peoples who are not directly involved in any crop production. Even then, in some situations symbiotic relationships between cattle herders and cultivators have been arranged, leading to a situation very similar to mixed farming.

It should, however, be recognized that most traditional farming systems of the humid tropics of West Africa already involve the association of crop production with livestock production, especially on compound farms. Unfortunately, these farming systems have attracted very little attention from research workers. A very high priority should be placed on research on smallholder mixed farming systems in which animals may play a vital role by supplying meat, power, manures and other by-products and services. Permanent production systems in the humid tropics, where animal diseases can be eliminated, or minimized, with trypano-tolerant animals, may allow reasonable numbers of livestock to be kept, with reduced hazard to the environment. They should receive greater priority in research and development if they are to fulfil their potential for providing alternatives to shifting cultivation.

Livestock Production Enterprises

In savanna areas where nomadic herding constitutes an extensive kind of farming, as shifting cultivation does in tropical regions in humid areas, permanent sedentary agricultural systems could be developed through improved range management, restriction of movement of people and stock and ensuring that even in improved range conditions, the carrying capacities of the ranges are not exceeded. While this constitutes an ideal, successful programmes of this type are rare, probably because of the drastic changes in socio-economic conditions and because, in many parts of the tropics with this kind of farming system, nomads will much more readily adopt measures to combat diseases and parasites than they will practice commercial ranching. Among nomadic herders in parts of Africa, livestock whose numbers contribute to the status and prestige of the farmer are usually not disposed of regularly as in commercial ranching enterprises, to ensure that the carrying capacity of the range is not exceeded. Associated with these are land tenure problems and the non-sedentary culture of nomads.

In more humid areas of the tropics, successful livestock-only enterprises • have been developed as successful farming systems and alternatives to shifting cultivation. Examples of successful poultry enterprises even in the humid tropics can be cited. Similarly, dairy enterprises have developed in tropical highlands but, in most cases, improved and intensive livestock production systems tend to be adopted by the better endowed and richer farmers. Unless the problem of animal feed production in Nigeria is solved, it may not be as attractive for smallholders to keep poultry or to be engaged in livestock-only enterprises as compared to mixed farming. In this regard, ruminants are more attractive than non-ruminants such as poultry, which may compete with human beings for food grains such as maize.

Integrated Watershed Development and Irrigation

A very useful strategy in the development of alternatives to shifting cultivation is that of integrated watershed development. It uses as many farming or cropping systems as can be compatibly located on different topo-sequences or contours, each using an appropriate farming or cropping system with economic advantage.

For example, a small rural watershed can be developed in an integrated manner with cropping systems ranging from rotations of one or two crops of rice followed by dry season vegetables in hydromorphic or valley bottom soils through upland crops such as cassava and rmaize in the upper slopes to tree crops on the steep and uppermost slopes (Figure 27). In this manner, a whole watershed may be cooperatively developed by a community achieving high productivity and diversification of production, without requiring major changes in land tenure. Moreover, integrated watershed development also constitutes a very efficient way of achieving multiple land use with minimum hazard to the environment.

STRATEGY FOR DEVELOPMENT AND INTRODUCTION OF ALTERNATIVE PRODUCTION SYSTEMS

Guidelines for improving smallholder production systems as alternatives to shifting cultivation, already reviewed, also constitute components of an effective strategy for replacing shifting cultivation and related bush fallow systems. Since time is a major constraint in providing immediate solutions to the problems of shifting cultivation, there is a need to (i) adopt a systems approach involving collaboration among disciplines and institutions at the national and international level, especially in relation to the multidisciplinary nature of the problem; (ii) change research priorities; (iii) arrange field and other farm testing and evaluation of alternatives to shifting cultivation in order to determine which alternatives are best suited for an area; (iv) reorganize, reorient and possibly retrain extension personnel on the new approaches and improved package of technology generated in research; (v) ensure that FAO and other bodies play a crucial role in supporting of research and development activities to ensure that national research and extension programmes are able to benefit from the project in the minimum possible time.

Need For a Systems Approach and Cooperation

The multidisciplinary nature of agricultural production has been emphasized by Millikan and Hapgood (1967), Mosher (1971) and Okigbo (1976). Moreover, experience with the Green Revolution has shown that increased productivity can be most rapidly achieved not just by making new varieties available to farmers but rather by making available to prepared farmers a whole package of improved production technology in such a way that right amounts of the critical inputs are provided at the right time and in the right sequence. Second generation problems associated with the Green Revolution also emphasize the need for interaction among scientists in the development of new production technology and also the need to ensure effective participation of social scientists from the onset. This will go a long way towards facilitating designing, testing and evaluation of improved technology relevant to the needs and environment of small farmers. It also ensures that developments are properly monitored, facilitating feedback and timely identification of major constraints to adoption.

If suitable packages of improved technology are to be developed to replace shifting cultivation, the various physical, biological and socio-economic aspects of farming systems should be tackled simultaneously. Since this process involves a race against time, adaptive and problem-oriented research is needed which (i) reviews the status of research and studies on shifting cultivation and related farming systems, (ii) identifies gaps in our knowledge of existing systems and (iii) ensures that a critical number of personnel and the critical amount of resources are allocated to the problem. Although specialization is so imperative in this age of exploding knowledge, a systems approach which involves maximum interdisciplinary interaction in research and related activities is sine qua non.

The diversity of countries practising shifting cultivation, differences in historical background, environmental conditions and political organization necessitate not only cooperation among disciplines but also among institutions and agencies in different parts of the world. For example, farming systems research programmes have been most effectively developed in the research programmes of institutes in the International Agricultural Research Centers network as compared to national agricultural institutes, only a handful of which are adopting this approach.

There is need for international cooperation among research institutes, especially in manpower development and establishment of strategy, principles and methodology for farming systems research.

Different research results and experiences in attempts to replace shifting cultivation have been obtained in various countries in different regions. Cooperation in sharing this information and experience will save time significantly and ensure efficient use of resources.

Of all existing bodies and agencies, the FAO is the organization that has direct contact with or involves all countries in areas practising shifting cultivation and related farming systems. FAO also constitutes a repository of knowledge in agricultural development projects in various countries. FAO is also in a unique position to support related research and extension activities. Of the various departments at FAO that are involved in different aspects of work on the replacement of shifting cultivation, the Land and Water Development Division has a vital role to play in bringing together specialists from different disciplines and countries in planning, design, research and sharing of relevant experience and information on the replacement of shifting cultivation with more efficient production systems for sustained yields.

Research Priorities

It has already been emphasized that research in areas of shifting cultivation has so far given highest priorities to technologies and farming systems in vogue in the developed countries of Europe and North America. A drastic change in priorities and strategy is necessary to make research relevant to the needs and environment of small farmers, who produce most of the food consumed in the developing countries of the tropics.

Priority should be given to research in farming systems that involves updating current knowledge of traditional farming systems and experiences in areas of shifting cultivation. This should be followed by identification of gaps in studies of farming systems and designing, testing and evaluating potential alternatives to shifting cultivation. In this process, emphasis should be placed on developing efficient farming systems for sustained yields, with minimum hazard to the environment. Efforts should also be made to develop appropriate technologies adapted to the farmer’s environment and within the means of small-scale farmers to own, use, maintain and repair. High priority should he given to low-input technology, minimization of drudgery in farming and ways of increasing rural employment and achieving multiple land use.

Field Testing and Evaluation

Agricultural production is highly location-specific. Moreover, technology developed in one environment is not easily transferable without adaptation and modifications. Consequently, adaptive research should be carried out to evaluate farming systems designs based on data and experience from various parts of the world. The testing of such designs or improved technology should as early as possible be evaluated at the farm level, to test their adaptability and acceptability to farmers in target areas, ensuring feedback on farmer's reactions to their use and associated problems. The testing of new technology may start in the experiment station but should be evaluated in the field as soon as possible in different environments, followed at various stages by farm level testing. Various agricultural development projects in which FAO is involved provide opportunities for such farm level technology evaluation. During the farm level testing, the farmer should be guided to use the technology and gain first-hand experience of its use, rather than have scientists and technicians carrying out the work.

Extension

This new systems approach will lead to results different from those based on the sequential study of isolated factors. Reorientation and retraining of extension staff is needed to ensure maximum effectiveness in the adoption of improved technology. With emphasis on small farmers, mass adoption of any new technology may require increased numbers of extension staff so as to ensure enough contact hours between farmers and extension workers. Moreover, since production should be diversified and since there is marked division of labour between the sexes in most developing countries, efforts should be made to determine which components of the extension activities should be directed towards the men and which towards women. It may be necessary to determine beforehand the roles of men and women in extension work and relate this to their training. Extension staff in many developing countries are jacks-of-all-trades but the range of alternative farming systems may require extension staff to be specialized.

Recommendations for FAO's Role

In considering the possible role of FAO in projects for research on the replacement of shifting cultivation, the following points have been stressed: first, the multidisciplinary nature of agricultural production systems in general, and in particular the range of possible alternatives to shifting cultivation; second, the impressive diversity of countries and environmental conditions involved, in addition to the differential levels of achievements in providing alternatives to shifting cultivation; third, FAO 's unique involvement in agricultural development activities all over the world, involving several departments and disciplines that could initiate an integrated approach in seeking alternatives to shifting cultivation and related systems. FAO should act as the clearinghouse for data collection and analysis, and should take steps to foster effective cooperation among individuals, institutions, and countries in various regions of the world. The sooner action is taken, the better, since in the race between population growth and food production, time is running out.

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PART II

INVITED PAPERS FOR THE

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held in

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PREFACE

In many developing countries, increases in the population have outstripped the capacity of the land to produce sufficient food and fibre on a sustained basis. Shifting cultivation was suited to the days of fewer people when a piece of land could be used and then abandoned to regenerate because other fertile land was always available for new clearinq. Wlith today's constraints, shifting cultivation does not make the most efficient use of the land; furthermore, if some of its forms continue to be practised reqardless of the consequences, it can exhaust soils and lead to irreversible environmental damage. Therefore, improvements must be made to the more damaqinq methods of shifting cultivation, or more intensive farming systems must be introduced. Measures taken now to improve shiftinq cultivation and to find alternatives can help to ease acute food shortaqes and to increase production in tropical and sub-tropical developinq countries. The success of such measures depends in part on the creative use of appropriate technoloqy, the preservation of sound traditional practices by the small-scale subsistence farmer, a multidisciplinary approach by extension officers, experts and planners, and closer technical cooperation among developing countries.

With this in mind, in February 1983, the Land and Water Development Division of FAO convened an informal, three-day meetinq on Improvements in Shifting Cultivation. Experts from countries with shiftinq cultivation farming systems joined concerned FAO officers from several disciplines to consider a variety of problems caused by damaqinq bush fallowing, and to propose avenues for action. A proqramme of cooperative activities was drawn up by the meeting and is now being implemented by FAO.

This FAO Soils Bulletin contains the papers presented at the meeting, a description of that cooperative programme, and the activities dealing with shifting cultivation being carried out by FAO.

SHIFTING CULTIVATION AND POSSIBILITIES FOR IMPROVING IT IN SIERRA LEONE

by

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Shifting cultivation is a traditional farming system which includes much traditional agriculture in Third World countries. It is used by small farmers who have only the most traditional tools, and who have little or no capital for the work which provides barely enough food for their families.

In Sierra Leone, rotational bush fallow is the most widely used farming system. It follows the slash and burn method of cultivation. Recent agricultural surveys indicate that about 75 percent of the people who earn their living from agriculture use this type of farming, and that each farmer cultivates an average of 1.6 ha. Most shifting cultivation takes place on uplands where rice culture predominates, although mixed cropping of cassava, maize, etc. is also practised. This method of farming is generally practised on soils which are vulnerable to changing climatic conditions and other factors. The essential dilemma of shifting cultivation is that land must be cultivated for relatively long periods, reducing the amoung of time that it can remain fallow. On the other hand, reduction of the fallow period reduces the fertility of the soil and thus lowers crop yields.

Because of population growth, shifting cultivation is using more and more land, exceeding the critical level necessary for a balance between crop land and bush fallow. This relationship must be considered carefully in order to resolve future problems posed by the person/land ratio. Farmers, incidentally, must rely on long natural fallows of between 3 to 30 years, even longer in forest areas. In Sierra Leone the average recorded bush fallow period is approximately 9 years, and varies according to area and other socio-cultural factors.

SOCIO-ECONOMIC PROBLEMS OF SHIFTINIG CULTIVATORS

Although traditional bush fallow practices offer a satisfactory solution to the average Sierra Leonean farmer’s problems of sustaining food production with traditional management, they also pose serious difficulties, which in many cases limit productivity.

In the first place, the social structure of shifting cultivators is based on households of varied sizes whose members are generally closely related. Heads of the households are usually between the ages 30 and 55, and draw most of their labour supply from the household. The land tenure pattern follows the freehold system in which members of the family can use, but not sell, family land. In the case of a community bush, a token fee is usually paid to the chief or tribal head for use of the land.

As a result of recent population increases, the freehold system of shifting cultivation has changed suhstantially. Family size has increased with a conseguent decrease in the amount of land available for hush fallow. Because the growing population has increased the demand for tillahle land, farmers have reduced the fallow period so much that the land has not had sufficient time to replenish its fertility.

In addition to this, traditional livestock producers have had trouble finding suitable grazing areas for their cattle. Consequently, encroachment on crop lands, or the straying of cattle into nearby farms has resulted in litigations and feuds.

Under these conditions, the traditional shifting cultivator in Sierra Leone is faced with problems: how to provide suitable farm land for an ever increasing number of farm families, and how to avoid conflict with livestock-producing neighbours.

Another problem which has weakened the system of shifting cultivation is the shortage of household labour in rural areas. Emigration of young people to the cities has, in recent years, put a tremendous burden on the remaining members of the rural households who must either further reduce the size of their farmland, or shift more of the farm labour to women who are often of child bearing age. The result is a higher incidence of infant mortality due to lack of proper infant care.

With limited access to working capital, the small farmer cannot use appropriate inputs efficiently, and therefore the farm has become relatively less productive. Furthermore, the poor quality of traditional hand tools limits their efficiency.

The rough physical condition of fallow bush sometimes makes cultivation or tillage difficult. Disease and accidents often limit the area that can be cultivated over any one cropping season. In most cases, exhaustion of fallow bush compels shifting cultivators to move to distant locations (i.e. two miles away or more) for farming. Experience shows that successive clearings are further and further away from homesteads. The journeys to and from the farms consume more and more time and cause considerable losses in the transportation of harvests. In certain cases, farms are so far away that shifting cultivators must build new, nearer homesteads.

Discussions about improvements in farm productivity must consider the strict adherence of small farmers to traditional shifting cultivation. A change in attitude would involve not only adoption of new technology, but also changes in cultural practices such as the reservation of forests for specific cults. Another consideration is that shifts are not always made from agricultural necessity. Farmers may move following many deaths in the family, or because they hope to seek new opportunities and therefore do not integrate well in the farming community. Because their beliefs are easily influenced by acts of nature, which . they cannot explain, shifting cultivators, in most cases, act on impulse, moving into areas where the available land can provide them with a livelihood.

IMPROVEMENTS IN SHIFTING CULTIVATION

The need for research

Because of the size of land holdings and because of constraints in yield, shifting cultivation tends to inhibit the productivity of the land and cannot absorb other resources which contribute to productivity. Research is therefore needed to determine the carrying capacity of land, to give a crude estimate of the number of people that a given type of land can support with a given technology. Another area for research is natural resource management including crop and animal husbandry which may be practised in conjunction with shifting cultivation.

While research is needed to investigate land carrying capacity in the tropics, and effective use of resources, another critical area is the determination of appropriate ecological zones where methods of shifting cultivation can be improved. In both the wet forest and relatively dry savanna area of Sierra Leone, shifting cultivation is a way of life that allows few alternatives. The choices of certain crops adaptable to a given ecology are important. For instance, Barrie (1971) suggests a strong case for growing trees or cash crops in forest areas, on the premise that felling trees on an annual basis is arduous and highly labour-intensive.

While shifting cultivation is practised in almost all of the forest and savanna zones of the country, other traditional methods of cultivation are used in other ecologies, such as the Bolis, Mangroves, deep water flooding and inland swamps. There is little variation in crops, since rice, the staple food, is widely grown. In the inland swamp ecology, for example, Sierra Leone farmers and other farming communities in West Africa usually construct small mounds to plant cassava, maize, sweet potatoes or groundnuts or other vegetables after rice harvesting. Thus crop rotation rather than shifting cultivation is practised.

Contemporary farm practices in both the forest and savanna zones suggest that small farmers are gradually using intensive crop rotation as a supplement or partial substitute for shifting cultivation. It is too early to suggest abolishing shifting cultivation in Sierra Leone, especially when lack of capital and other resources compel small farmers to practice it.

Effective resource management

Effective resource management is essential for any farming system. For instance, although crop mechanization in tropical Africa is costly, its introduction, using appropriate labour intensive technology, can increase yields significantly. During ttie process of mechanization, crop rotation may partly replace shifting cultivation. Here land is used more intensively and management is made more efficient. For example, improved water control and land development are essential for effective mechanization.

Managing the farm is often the responsibility of the head of the rural household (usually male). Careful management of family labour is also needed in order to reach targets in shifting cultivation. When family labour is insufficient, hired labour is required at peak periods.

Sustained long-term trends in crop production increases in Sierra Leone are being interrupted by inadequate labour supply. The level of production is also being reduced by inefficient management of farm labour because more experienced workers are moving to urban areas.

Extension and training

The hazards of shifting cultivation can be reduced with adult literacy programmes, which can increase farmers' work performance.

Research and extension work are needed here to provide farmers with more knowledge about shiftinA cultivation. Here it will be necessary Co document the sequential operatinns involved in shifting cultivation, the problems at each stage, and remedial measures to alleviate existing or emerging problems. At the same time the land tenure system in Sierra Leone needs practical and realistic adjustments to suit shifting cultivation, and alternative practices to replace it in the future.

Infrastructure and marketing services

There is a need to re-examine the construction of feeder roads not only to connect people’s cultural life with other more developed areas of the country, but also to link marketing services, which are generally weak, in more remote rural areas. Construction of feeder roads will save farmers tremendous post-harvest losses which now average 15 percent.

There is also a great need to mobilize rural credit for shifting cultivators in order to make capital available for the purchase of packaged inputs.

Organization of small farmers

In order to implement these suggestions for improving shifting cultivation in Sierra Leone, there is a dire need to organize small farmer associations. Such organizations are already in the process of being formed, as an integral part of government policy.

The policies of organizations for obtaining credit vary. Some are based on individual lending and some on collective lending. However, the administration of the credit instruments are based on sound management.

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INSTITUTIONAL ASPECTS OF IMPROVEMENTS IN SHIFTING CULTIVATION

With special reference to transmigration projects

by

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Shifting cultivators and transmigrants are two groups of Indonesian people who are living under less developed conditions and who cannot improve their lives without outside assistance. There are, however, many differences between the two groups. A broad description of each of them will clarify the type of institution appropriate for improving their farming systems. In addition, the attempts made in Indonesia to date to develop institutions which can tackle this major problem are briefly outlined below.

THE TRANSMIGRANTS

Most of the transmigrants are landless peasants of Java, Bali and Lombok, the most densely populated islands of Indonesia. They are already somewhat skilled in soil tilling and crop production. They live in communities already oriented to a market economy. They own little land and have little training in fields other than subsistence farming. The increasing population growth rate results in an even keener competition for land so that a high percentage remains at bare subsistence level. Nevertheless, they have greater agricultural potential.

The landless peasants of Java, Bali and Lombok currently farming could increase their production if only they had enough land. Currently this can be achieved only through transmigration to the less densely populated islands where land for cultivation is still available.

Institutions to implement and service transmigration projects have well defined tasks. They must motivate people to transmigrate, preparing them to leave their places of birth; help them adapt to new conditions; and improve their living standards. Land allocation and clearing in the new areas must be undertaken, houses built, road systems constructed, transportation facilities organized. In addition these institutions must give top priority to provision of the food supply during the first year; in the succeeding four years other programmes must be added, before they are transferred to local government authorities, who would then be responsible for their further development.

The activities of the transmigration programme in Indonesia have high national priority. Consequently, the programme enjoys good support among the people, as well as from all government agencies, and it has achieved considerable success.

Land allocation and clearing are carried out by the Department of Public Works after it has considered the advice of other departments involved (the Department of Home Affairs and the Department of Agriculture) for each location. The Department of Public Works has competence and experience in opening areas for regional development, and has responsibility for engaging contractors to implement large-scale engineering projects. The Department of Home Affairs, especially the Directorate General of Agrarian Affairs, is competent in land use planning, and handles matters concerning customary laws. The Department of Agriculture advises on agriculture extension and development.

To ensure smooth functioning and also to overcome constraints in the various sectors of the transmigration programme, these sectors are responsible to the Office of the President of the Republic of Indonesia. A significant improvement in the slow transportation of the transmigrants by boat has been achieved by involving the Navy and by acquiring a number of air buses.

In well-chosen localities, the transmigrants are gradually increasing their food production and completing construction of their houses. The programme has transformed them from partial or full consumers into self-supporting people who may even produce a surplus.

SHIFTING CULTIVATORS

Unlike transmigrants, shifting cultivators fall into many types. They may be classified according to the various stages of their development. Unfortunately, the problem, as well as the various classes, are not easily understood by most people dealing with the subject, as is shown by the common term for them, “wild shifting cultivators”.

The prevalent interpretation of shifting cultivation is limited to its environmentally destructive and primitive method of food production, its isolated, inaccessible area of operation, the low living standard of the cultivators, their “unwillingness” to follow regulation and their traditional style of life.

It is most unfortunate that many people, policy makers included, believe that these factors are due, above all, to the cultivators’ lack of education. Fven more, some anthropologists urge that the cultivators be allowed to keep their way of life. The anthropologists blame the modern world for destroying the eguilibrium between man and nature through environmental exploitation. Limited medical care coupled with new diseases exacerbate the situation.

Government projects in Indonesia intending to solve the problems of shifting cultivation have assumed that lack of education is the major underlying cause. Shifting cultivators have been resettled near or at the existing centre of development in their particular region. All facilities to help motivate develoment, such as permanent housing, schools, health services, new religious or community hall buildings, community road systems, extension services in agriculture, husbandry, horticulture, cooperatives, social works, etc., are available.

Three Departments in Indonesia are responsible for implementing the resettlement scheme serving shifting cultivators. The Department of Agriculture under the direct personal approval of the President of the Republic of Indonesia finances resettlement schemes from forest areas under “Cutting licences”. The project proposals must be formulated by the provincial planning board concerned, and the President of the Republic of Indonesia gives his sanction, after considering the advice of a small _ad _hoc advisory board. The Department of Home Affairs carries out resettlement projects to reconsolidate scattered shifting cultivators, and the Department of Social Affairs carries out similar projects for isolated nomadic tribes.

There has been considerable criticism recently of the cost of those projects and of the results achieved so far.

Any institution charged with bringing improvement in a shifting cultivation system should be modelled on the key characteristics of the relevant shifting cultivation. These include the motives for shifting cultivation, implications of any improvements within the method, and the ability of the government or society to implement it.

Recent studies on shifting cultivation in Indonesia * propose a method for protecting the utility of improvements, taking into account the communities involved, the available natural resources and the development of appropriate institutions.

These studies suggest that there are several types of shifting cultivation in Indonesia, which are related both horizontally and vertically. The results of these studies were presented in the Eighth World Forestry Congress, 1978, in Jakarta, Indonesia and are summarized in the table.

THREE GROUPS OF SHIFTING CULTIVATORS

The nomadic Sakai people in the forest of Riau, Sumatra, travel from place to place to their cultivated fields. They do not pursue improvements in their way of life. They pay no attention to the abandoned fields, which are sometimes planted with rubber by other groups, mostly Bataks. The Sakais show no interest in maintaining rights on the land they cultivate. They are small in number and the forest is still large enough for them. The fields are far from each other, which prevents the fire used for clearing the land from spreading to other, previously abandoned fields. This type of shifting cultivation does not create permanent open land, since the abandoned fields regenerate easily. Therefore, the characteristics of the shifting cultivation carried out by the Sakai people are related to each other, horizontally, in logical order.

The characteristics of the shifting cultivation of the Dayaks in Central Kalimantan are also logical. The cultivators live in semi-permanent long houses, with several connected units equal to the number of member families. The houses are built from solid materials that can withstand a long period of weathering.

The Dayaks carry out their shifting cultivation on land surrounding their long houses. An abandoned field that has grown into the shrub stage after 10-12 years would be opened up for the next cultivation cycle. Such rotation of 10-12 years is common. After several decades, a declining harvest shows that the soil surrounding the long houses is exhausted. The cultivators then move into virgin or secondary forest and the second major rotation may last 30-50 years or even longer.

While land is being settled for the short, 10-12 year, rotation, territorial rights are established, prohihiting foreigners from settling except under aoreed conditions. These land rights can be defended and recognized by others only as long as the “owners” are still on the spot. When the “owners” move to other locations, another group of people may come to occupy the territory, and this occupation may result in war when the original occupants decide to return. Dayak community organization could have resulted from past experience; it appears that their long house structure may have been part of their defense

*l. Soedarwono Hardjosoediro, Peladangan di Sumatra, 1968
2. Peladangan di natah Biland, Kalimantan Timur, 1979
3. Peladangan di Samarinda-Balikpapan, Kalimantan Timur, 1979
4. Peladangan di Riam Kanan, Kalimantan Selatan, 1980

CHARACTERISTICS OF VARIOUS TYPES OF SHIFTING CULTIVATION IN PARTS OF INDONESIA

Tribe/population group	Socio-structural organization: area occupied (ha)	form of dwellings	rights to land	Time span (years) of impact on environment: cultivation	rotation/fallow	Remarks
The Sakais in Riau Sumatra	10 - 20	temporary huts	none	1 - 2	30 - 50 or more	no permanent open land
The Kayaks in Central Kalimantan	100 - 240 or more	semi-permanent in long houses	temporary	1 - 2	short: 10-12 long: 30-50 or more	no permanent open land
The Bataks and others	one area for one clan: 500 and more	permanent settlement with individual houses	strong communal	1 - 2	5-10	establishes open lands

strategy.

The Bataks have already adopted permanent settlements. They represent all other Indonesian shifting cultivators with permanent settlements. Their houses are built solidly and their social organization is well developed. They practise shifting cultivation close to their homesteads in shortened rotations. Most of their consecutive shifting fields are not far from each other, and as a result, the fire for clearing spreads easily into old fields. Land rehabilitation through regeneration of vegetation is therefore difficult, and open land usually results.

The characteristics of each of the three shifting cultivation groups are related to each other logically. The Dayak's declining mobility is accompanied by the building of houses which are more solid and by the establishment of territorial rights on land. Settlement mobility, their territorial rights on land, their community organization, the rotation of their shifting cultivation develop in a logical progression from the Sakais, to the Dayaks and finally the Bataks.

There is no proof available that the shifting cultivation of the Sakais actually develops into that of the Dayaks. However, there are enough examples with the Dayaks to show that shifting cultivation is a stage in the development of agriculture, and that these stages can also be found within shifting cultivation itself. At favourable locations, the Dayaks demolish their houses, establish permanent compounds, practise shifting cultivation not far from home, in a manner similar to that of the Bataks. Some of them have even developed the technolooy of paddy rice culture. It is not improbable that pioneers among the Dayaks, looking for new fertile soils, practise the same shifting cultivation method as that of the Sakais. This is also true for the Batak groups.

In a survey to identify areas of shifting cultivation, an interesting phenomenon in the Pendopo-Semangus area in South Sumatra (1982) was discovered that supports the above hypothesis.

A compound in Nascendi, Talang Kelapa, is 7 km south of Pendopo. It has five closely related member families: one elderly father and mother, three married sons, and one cousin. Their huts are arranged for convenience and security. The settlement was founded by their late grandparents. They had left their old compound, Babat, 30 km away, 40-50 years ago as pioneers, leaving a garden of fruit trees now owned communally by their descendants. Around the new compound, durian, pete, coconut trees, banana, some rubber seedlings are growing and red pepper is planted between the huts in the new garden. The old orchard may have been formed in the same way. It might have been the pioneers' old settlement.

The small clan of Talang Kelapa does balanced shifting cultivation in the land surrounding the compound, each family for its own benefit, with a rotation cycle of 10-12 years. The oldest son is able to point out his ten consecutive fields. The abandoned fields regenerate in shruh stands, made possible by the fire free belt preparation of the land before the slashed material is burned.

The old father has established a rubber plantation of some 1 500 trees, which are still tapable. The two elder married sons received 500 trees each, while the rest still belong to the father but are tapped by the youngest son. The latter has only recently married. The sons have not yet found it necessary to plant new rubber trees. They are already fully occupied by planting food, tapping the old inherited trees and taking on some paid work in the surrounding area.

A market-oriented economy has been introduced into the community of shiftinq cultivators in the Pendopo-Semangus area. The shrubs on abandoned fields are already privately owned and the produce can be sold in markets in the nearby Kertadewa village, about 12 km from the river Lematang. Some of the plots in this area are planted with pineapples and rubber, along with upland rice in the first year. The area is also famous for producing oranges. Horticulture is shifting cultivation's end result in this area.

Uncontrolled burning to prepare land for shifting cultivation is still widespread in the rest of the Pendopo-Semmangus region, i.e. in the surrounding remote, stable settlements. It is found especially on shrubland bordering on alang-alang (Imperata cylindrica) fields where private ownership of land has not been clearly established, and in the forest where pioneering shifting cultivation is still common. In the "no man's land", pioneering shiftinq cultivators do not feel obliged to prepare a fire free belt to protect neighbouring fields before burning the dry slashed material.

DEPARTMENTAL RESPONSIBILITIES

Improving shifting cultivation is not simple. Its many aspects must be handled by many specialists or qovernment agencies. Each of the various stages of development in shifting cultivation in Indonesia requires special treatment. The Department of Social Affairs concentrates on the problems of the small nomadic isolated tribes like the Sakais, while the Department of Agriculture is responsible for the pioneering shiftinq cultivators.

The Directorate General of Forestry of the Department of Agriculture has to afforest devastated areas and to protect or reforest open forests left by the pioneering shifting cultivators, whom government officials consider wild and secretive.

The Directorate of Reforestation and Rehabilitation of the Directorate General of Forestry could be empowered to improve shifting cultivation throuqh an improved taungya system, already common in the reforestation work in Java. By mechanical ploughing of the bare land not of interest to the shifting cultivators, large tracts of devastated and semi-devastated bare and shredded shrubland couid be made ready for recultivation.

It is first necessary to persuade the pioneering shifting cultivators to settle under conditions agreed upon with the forest service. This peaceful approach should be directed not only to the shifting cultivators, but to the forestry staff as well.

Pioneerinq shifting cultivators leavinq their villages are usually small in number. They could be convinced to settle in small development centres to work in forestry activities in the area and improve their standard of living. Much land could be leased to them for sustained agro-forestry practices . The rest of their labour could paid for and/or incorporated into the taungya system, for their own food production and for planting forest trees.

No resettlement is needed. Land allocation, technical guidance in balanced shifting cultivation, plant material subsidies, and simple seasonal job opportunities in forest concessions or the forest service would suffice. The cultivators could build themselves huts like those of the pioneering shifting cultivators of Talanq Kelapa during the initial three to four year period. But transmigrants cannot settle unless they are qiven paddy rice fields and the quidance to farm them properly.

A special working team, section, or service under the Directorate of Reforestation and Rehabilitation to handle pioneerinq shifting cultivators is necessary as are extension officials in every province, at every local unit, wherever problems of shifting cultivation exist.

The Pendopo-Semangus area in South Sumatra is one of the best regions for this experiment. It is accessible (thanks to the oil concessions). The terrain is soft and undulating, and is inhabited by a small mixed group of people, both indigenous and spontaneous transmigrants from Blora, Central Java. The people from Blora are accustomed to working hard, and taungya is well known to them. The indigenous people may follow their own pattern (as have the pioneering shifting cultivators of Talang Kelapa) and can be helped to improve their standard of livinq. The Directorate of Reforestation and Rehabilitation has a large-scale rehabilitation project in this area.

The Directorate of Small Holders Farming desiqns nucleus estate projects (NES) to solve some of Indonesia’s shiftinq cultivation problems. The project intends to become a centre for development in commodity farming. Shifting cultivators are beinq persuaded to participate in the nucleus estate as holders of parts of the farms established by the project or to join the development centre by sellinq their produce in a cooperative connected to the centre.

SOCIO-ECONOMIC AND INSTITUTIONAL CONSIDERATIONS IN IMPROVING SHIFTING CULTIVATION IN TROPICAL AFRICA 1/

by

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The practice or adoption of shifting cultivation, like other farming systems, results from a combination of environmental factors. Some of these are socio-economic; others are physical, including land, labour, technology, and all forms of capital; still others are institutional, such as cultural values, land tenure systems, social organization, traditional and new or modern institutions, input and output price policy.

Shifting cultivation is the peasant’s rational response to these forces. The old, superficial observation that natural conditions favoured agricultural production in tropical and sub-tropical Africa has been largely dismissed, as has the prejudiced belief that the tropical African peasant was inefficient, lazy or irrational. Because of marginal, irregular or (more usually) too plentiful rainfall, the agricultural habitat of most of tropical and sub-tropical Africa is rather poor: poor in soil texture, structure, and chemical compostion, elements which determine soil fertility.

The traditional peasant in the tropics has adopted what we call bush fallow or shifting cultivation in response to declining soil fertility and sparse population density, with its implied unlimited land supply. He or she practises the mixed or multiple cropping system to accommodate subsistence production which is linked to several factors: the prevailing closed economy (autarchy), a limited work force, and the low level of technology available. This cropping system ensured that all the food products the family required or wanted were qrown simultaneously on the same plot of land. In addition, this system allowed the family to reduce the size and number of plots needing clearing. This enabled them to save limited labour, for other important household tasks, as well as for leisure. This mixed croppinq system also provided biological disease and pest control.

Several researchers have argued that under the technological, socio-economic and institutional conditions facing most peasants in the tropics, shifting cultivation as a farming system must remain, because it is scientifically sound and economically rational. Even researchers who advocate alternatives to shifting cultivation are discussing changes or modifications of classic shifting cultivation (such as reduction in the fallow period, or an increase in the cultivation period), and not its immediate and complete dismissal or abandonment.

1/ This is a shortened version of a paper presented to the FAO/University of Ibadan Workshop, Ibadan, Niqeria, July 1982.

ECONOMIC DRAWBACKS TO SHIFTING CULTIVATION

In addition to various agronomic disadvantages, shifting cultivation presents a series of economic disadvantages. Some of these are inherent in the system, while others are imposed on it by the rapid socio-economic changes affecting areas under shifting cultivation.

Among the inherent disadvantages are:

i. The low remuneration of shifting cultivation, relative to its labour reguirements and to the shifting cultivator's labour supply. It is also low because shifting cultivators cannot get a good price for their produce, because there are no markets for it.

ii. The massive and systematic destruction of forests and forest products and the degradation of forest soils which accompany shifting cultivation. This destruction constitutes a tremendous loss of valuable resources.

iii. Low investment capabilities characteristic of shifting cultivation. This results from the low remuneration, which makes all investments economically unappealing; this in turn leads to low productivity (thus completing a vicious circle).

The disadvantages imposed on shifting cultivation by various socio-economic and institutional changes relate to two phenomena: growing population and a growing need for cash income.

During the 1970s, the African population (especially in the sub-Sahara) rose by 2.7 percent while per caput food production declined by about 10 percent. Urbanization growth rates have averaged about 6 to 8 percent. Such rapid demographic expansion is making it more and more difficult for the peasant to respect the optimal fallow period, to increase plot size, or to move to different sites. Traditional practices, with their low productivity, cannot produce enough to raise the peasant's consumption above the subsistence level or satisfy new needs which depend on cash.

Shifting cultivators today need more and more cash to buy new goods and services not produced by the family including transistor radios, gas lamps, sugar, schools, medical bills, security, etc. Peasants are finding it more difficult to practise classic shifting cultivation while producing the marketable surplus necessary to meet these new needs.

CONSTRAINTS TO THE IMPROVEMENT OF SHIFTING CULTIVATION

The major constraints to improving shifting cultivation in the African tropics are, by and large, the same constraints that limit agricultural development generally in those regions. The constraints below deal with socio-economic aspects of the problem.

Economic constraints

i. Inadeguate technology. Appropriate technology is now widely accepted as a prerequisite for any real and sustained agricultural development.

ii. Farmers' limited financial resources. The peasant's traditionally low productivity makes it nearly impossible for him or her to save, or to make any productivity-increasing investments from personal resources.

iii. Absence of an appropriate marketing infrastructure, especially for food producers. In order to structure and organize such markets, marketable products must be available. If the peasant is going to produce more for family consumption _and for the increasing urban population, simultaneous adjustments are needed both on the supply and demand sides. On the supply side, the peasant's productivity must increase; this may reguire a considerable degree of product specialization. On the demand side, potential urban consumers must be able to acguire such marketable surpluses at prices favourable to the producers. Where marketing infra-structures are concerned, storage and transportation facilities for inputs and products should receive top priority.

Social constraints

Several social phenomena have also rendered classic shifting cultivation obsolete.

i. The political development and the strengthening of governmment have led to a transfer of powers or authority from traditional leaders to government or political officials, who constitute a new elite.

ii. The appearance of an open economy has contributed to the dislocation of the traditional extended family. This affects the family labour supply, and the organization of family production.

iii. Education and training in the form of new off-farm employment have led to a substantial reduction of active manpower in the rural areas. This migration of the young to cities not only reduces the quantity of labour available to farmers but also its quality, because the average age of peasants is rising.

iv. This rural-urban migration leads automatically to a necessity for hired labour. However, for socio-cultural and historical reasons, many peasants do not want to work for wages, regardless of how much they can earn.

Institutional constraints

Five general types of institutional constraints may affect the performance of shifting cultivation. They are:

i. Constraints related to land tenure systems. As the most central factor in agricultural production systems, land ownership or tenure determines the performance and improvement of any farming system. Commonly found tribal, communal, or collective land tenure systems (with all their variants) in tropical and sub-tropical Africa are not conducive to individual producers' making long-term investments in land, including soil conservation, or practices that supplement or balance fertility. Yet, these are commonly adopted alternatives to classic shifting cultivation.

ii. Institutions for training, research and extension. These institutions are either absent, under-staffed (quantitatively and qualitatively), under-equipped, or not coordinated. Support for and coordination of these institutions is vital.

iii. Local or village structures and organizations. The local organization at the village level is also important for the improvement of farm systems. Shifting cultivation could be improved more or less rapidly depending on whether the villagers can organize themselves freely and readily and on whether there are permanent village level production structures. These structures have to develop within the village and cannot be imposed from the outside.

iv. Institutions for producing, marketing and servicing new agricultural inputs and for marketing farm products. These institutions will give producers incentives by improving their farming systems and cultural practices. Their additional output will have more economic value because of new market opportunities. Unless these institutions are present and operative, the peasant will see no reason to improve farming and cropping systems.

v. Government policies on the balance of income between the agricultural and the non-agricultural sectors (including subsidies, taxes and the pricing of agricultural inputs) have a serious bearing on peasants' efforts to increase their productivity. In most areas of Africa with shifting cultivation, these policies are not yet adequate.

SUGGESTIONS FOR IMPROVEMENT

On the basis of these constraints (and there are many others) the following suggestions about improving shifting cultivation can be made. They are concerned exclusively with socio-economic and institutional aspects of shifting cultivation.

i. Government assistance (financial and otherwise) should be made available to peasants for the tedious, extensive operations of felling and cutting the trees and clearing, rooting and stumping the plots, which are all very costly (in terms of time and energy). This will enable total output, per family and per caput, to increase. The same assistance should be made available for the acquisition of new inputs which reduce the fallow period.

ii. In order to speed up the recovery of initial, costly investments, cleared land could be used simultaneously for tree crops and food crops. In a second stage, the tree crops could be eliminated and replaced when they are no longer economical, or all of the cleared land could be used continuously for growing annual food crops.

iii. Legislation instituting flexible family or individual land ownership with limited transfer or sales rights could encourage shifting cultivators to invest more in land, thus increasing their productivity.

iv. Land settlement schemes used primarily to relax population pressure on over-populated areas could also be used as an indirect means to introduce continuous cropping needing fewer inputs.

v. Governments and research institutions, at both the national and international levels, should give top priority to research in agronomy, agricultural mechanization, animal husbandry, agro-forestry, and socio-agro economics, especially when this research is oriented to the problems and the needs of more intensive exploitation of small-scale farms in tropical forest conditions.

In sum, shifting cultivation is important not only because it destroys forests and degrades soil fertility, but also because its practise affects the life of so many humans.

CROPPING SYSTEMS AND ROTATIONS DEVELOPMENT FOR IMPROVING SHIFTING CULTIVATION AND RELATED INTERMITTENT PRODUCTION SYSTEMS IN TROPICAL AFRICA

by

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Food problems in Sub-Saharan Africa have been a major cause for concern within and outside Africa ever since the Sahelian drought of the early 1970s killed thousands of people and livestock and left others incapacitated. Population growth rates in the region have remained high, between two and three percent annually, and the annual rate of increase of demand for food averages above three percent. But the average annual agricultural production growth rate during 1970-79 was only 1.3%, and for food production in that period it ranged from 0.9% for oils and oil seeds, to 1.8% for root and tuber crops (World Bank, 1981). Oram (1981) noted that traditionally, Africa has not been a major food importer; the food self-sufficiency ratio was much higher in the 1960s (98%) than in 1981 (88%). Meerman and Cochrane (1982) observed that (i) yields per hectare are lower in Sub-Saharan Africa than elsewhere and (ii) whereas yields elsewhere have increased during the last decade, in Africa they have generally either been decreasing or have remained constant. It is, therefore, not surprising that authors of recent studies agree on the poor performance of agriculture and on a gloomy future for food production in Sub-Saharan Africa (World Bank, 1981; IFPRI, 1981; Eicher, 1982; and Meerman and Cochrane, 1982).

In efforts to solve this problem, traditional farming systems have become increasingly outmoded because of such modernization pressures as rapid population growth, high rates of urbanization, rising incomes, and a demand for convenience foods produced outside Africa. High priority must be given to the development of more efficient cropping systems and rotations, in order to improve farming systems.

First, continued reliance on expanding cultivated areas, responsible for about 85% of increases in agricultural production, has not contributed more than an annual growth rate of 1.6%. Then, as Meerman and Cochrane (1982) observed in Sub-Saharan Africa (i) cultivable land is becoming increasingly scarce, (ii) long fallow periods of traditional farming systems have been shortened, thus undermining their contribution to the regenerative power of the land, and (iii) Green Revolution technologies and the associated increases in agricultural production have so far not affected farmers in Africa. Finally, Oram (1981) studied the production potentials of Africa and recommended that the best ways to improve · agricultural production involve appropriate technologies, including: (i) building the base for expanded irrigated agriculture, (ii) increasing the efficiency of seed/fertilizer technology in dryland cropping systems, (iii) managing rainfed systems to conserve soil moisture and fertility, and (iv) integrating more closely range livestock and arable farming. All these emphasize the need to find suitable alternatives to shifting cultivation and related fallow systems.

Improved cropping systems and rotations have a vital role to play in this seemingly intractable problem, because in all crop and animal production systems, it is impossible to establish permanent agricultural production, without developing more efficient cropping systems with improved combinations of crops in terms of timing and space. Improved cropping systems with respect to time involve improved, systematic cropping sequences, which are equivalent to improved rotations. Since crops provide food for people and animals, improved cropping systems are the strongest foundation for increasing agricultural productivity. Moreover, improved, more efficient cropping systems result in a permanent production system giving sustained yields, only when they are carefully integrated with economically viable and ecologically sound land development and soil management practices.

Finally, since the low returns of traditional agriculture, with all its drudgery, has rendered it unattractive and has encouraged massive rural/urban migration, improved cropping systems and associated land development and other soil management must include appropriate technology. This paper considers criteria for selecting suitable farming systems for different ecological zones and suggests more efficient cropping systems and rotations by integrating traditional with new technologies. It also presents examples of improved cropping systems with recommendations for integrating them into planned rational land use supported by research.

SELECTING SUITABLE FARMING AND CROPPING SYSTEMS TO REPLACE SHIFTING CULTIVATION

A farming system is an agricultural enterprise in which the farmer manipulates the environment and organizes inputs in order to establish favourable conditions for producing food, fibre, and other useful products. The products may be consumed or sold for cash and may consist of crop plants or livestock. Farming systems differ from each other in various interacting elements: physico-chemical (soil, climate); biological (crops, livestock, pests); technological (techniques, equipment); socio-economic (labour, markets); and managerial (decision making) (Okigbo, 1981). Each farming system is specific to a given location and may consist of: (i) only one or more crop plants, (ii) one or more species of farm animals, and (iii) integrated crop/livestock (mixed farming) production systems and the associated technologies for their production at varying intensities. All farming systems include these elements.

A procedure for determining the most suitable farming systems to replace shifting cultivation and related outmoded traditional systems should set out criteria for selecting suitable farming systems, and the associated cropping systems, at both macro- and micro-levels. After the specific farming system has been selected, guidelines are needed to design appropriate cropping systems and management technologies.

CRITERIA FOR SELECTION OF FARMING SYSTEMS AT THE MACRO-LEVEL

The range of farming systems which promise high productivity and returns depends on the prevailing climate and, equally importantly, on other environmental, technological, and socio-economic factors. It is usually the climate that determines the vegetation, organisms, and soil types and their inherent fertility: Crops are usually either related to the vegetation found in a given area, or consist of crop plants whose optimum environmental requirements tally with the prevailing climatic conditions. Factors such as rainfall, temperature, and to some extent solar radiation and photoperiod also influence the appropriateness of commodities.

Both the total amount of rainfall per year and its distribution influence the suitability of farming systems. Figure 5 in Part I shows the number of humid months (i.e. months with up to 100 mm of rainfall), the dominant or climatic climax vegetation, and the farming systems most likely to be associated with them. Areas with between two and six humid months are most suitable for ranching. Those with less than nine humid months or from one to nine humid months are suitable for irrigated agriculture, areas of six to nine humid months requiring mainly supplementary irrigation. Where there are seven to twelve humid months, rainfed agricultural production systems prevail. Rainfed aqri- cultural production systems in tropical areas of less than six humid months however, involve growinq of drought tolerant crops adapted to short growth periods such as sorghum, millet, and cowpeas. In areas of nine to twelve humid months, tree and shrub plantations and similar tree crop production systems dominate. Different farming systems overlap somewhat with respect to the number of humid months. In each situation rainfall suitability may have to be considered along with other factors (soil, temperature, local preferences, etc.) in order to decide on farming systems and commodities for production.

Temperature is also important in the selection of a farming system. Crops require certain temperatures which may vary during the crop’s phenological stages. Moreover, temperature indicates the danger of frost which may injure crops.

The soils in an area may determine the crops which can be grown under the given climatic condition. Each of the major soil types can support a different range of farminq systems and requires different technologies and operation in their management. Studies at the International Agricultural Research Centres (IARCS); the AID Supported Benchmark Soils Project, the Soil Management Support Services Project; the Tropical Soils Research Proqram of the University of North Carolina, in addition to various collaborative efforts, are making significant contributions to determining the potentials of various soil qroups, and management practices. They are also investigating problems that arise from using soils for continuous production, solutions to these problems and the extrapolation of results to similar areas worldwide.

Broadly speaking, solar radiation is abundant in tropical regions but within the tropics, humid areas suffer from excessive cloud cover which reduces their hiqher potential for productivity. In subhumid and drier savanna areas there is more solar radiation which enhances productivity where irrigation supplies sufficient water.

A knowledqe of these factors, and suitable phenological data about various crops, can be used to determine the commodities for production in different macro-ecological regions. The FAO Report on the Agro-ecological Zones Project, Volume I Methodology and Results for Africa (Kassam et al, 1978) provides useful information on the suitability of zones for various crops in major ecological zones of Africa.

Once the crops with high potential in different major ecological zones have been identified, it is necessary to relate this information to important estab- lished crops in traditional and transitional farming systems. In determining which crops are grown, consideration should be given to combinations of crops for subsistence and those for sale. Assessment of the alternative farming systems and crop selection during the planning stage (Table 1) should note the possible risks and likely agricultural conditions. Several geoqraphy texts on Africa, for example, give useful data on rainfall variability for different parts of Africa (Brouillette et al, 1974; Best and de Blij, 1977). Similarly, Miracle (1964) and Thomas and Whittington (1969) provide data on prevailinq farming systems and crop dominance zones in Africa.

MICRO-INFORMATION REQUIRED IN FARM AND CROP SYSTEM SELECTION

Even when a specific crop has been selected for a specific major ecological zone, more detailed information is needed about environmental characteristics of smaller regions or areas to help determine how a crop should be grown, including the timing of croppinq sequences and farming operations.

Table 1 GENERAL ENVIRONMENTAL AND AGRICULTURAL CONDITIONS ACCORDING TO LENGTH OF DRY SEASON IN TROPICAL LATITUDES

	six effectively dry months	Two effectively dry months or less
Solar energy	Higher	Lower
Ecosystem stability	Unstable: rainfall variable; biological life cycles fluctuate seasonally	Stable: less fluctuation of biological life; processes continuous
Soil characteristics affecting farming	Toxic salts; drought; high erosion danger; high pH	Inadequate drainage; laterization danger; leaching of nutrients, loss of organic matter; low pH
Pests and diseases	Seasonal explosion of insect and bird populations, migratory populations	Fungus, virus, bacterial diseases; beetles, ants, small mammals are important pests; many interconnections in insect, bird & mammal life
Weeds	Seasonal - not a major problem	Major problem
Cultivation (labour) schedule	Seasonal	Less seasonal
Important subsistence food crops (not grown under irrigation)	High protein grains: millet, sorghum, maize 1/	High carbohydrate tubers & grains: cassava, sweet potato, taro, rice
Important properties of food crops	Drought resistance	Low fertility tolerance (except rice); store well (tubers)
Secondary food sources	Plants: relatively few; domesticated browsing and grazing animals may be important	• Plants: numerous; wild game may be a source of animal protein
Risk of crop loss	High	Low
Likelihood of human overpopulation	Greater	Lesser
Major food supply problems in conditions of overpopulation	Famine	Malnutrition (protein deficiency)

_1/ Maize is one of the few grains that can be grown under a wider range of temperature, rainfall and humidity conditions, but is not a dominant crop in the very humid tropics.

Source: Dasmann et al., 1973

More detailed data is needed on rainfall, soil types, capability classifications or land types in relation to the local topographic features, minor temperature variations with elevation, unimodal or bimodal rainfall characteristics, extent of the erosion hazard, and so on. Harwood (1976) gives detailed information classifying areas according to water availability for various' rice production systems and sequences (Table 2). The data on the monthly distribution of rain is useful for determining timing for planting, harvesting and other farm operations. For example, an area with a bimodal rainfall regime may be suitable for two crops of transplanted or directly seeded rice, sequenced in such a way that each crop of rice matures when there is no rain. In this way, the crop is already dry at harvest and does not require much artificial drying. This would be true of areas of West Africa with an August break. The first crop of rice can be programmed to mature at about the first week of August. Before the first is harvested, a second rice crop is already in the nursery. As soon as the first is harvested the second crop is transplanted. This second crop will be grown on the residual moisture of the second rainfall peak, and it will mature in the dry season with a moisture content suitable for threshing. Harwood also considered various crop management factors such as: (i) soil characteristics and tillage practices and (ii) planting and harvesting requirements in relation to availability of water at planting, and to timing of the crop so that it matures in the field when it can be harvested easily and threshed with a minimum expenditure of energy on drying.

In selecting a cropping system, soil capability and land types in a given topography should be taken into account. One problem with African agriculture is the failure to use relatively fertile valley bottoms and hydromorphic soils. This can be solved through integrated watershed development (see Figure 26, Part I). This would ensure planting the sections or contours in the toposequence with the crops best suited to the soils and slopes thus minimizing erosion. Thus tree crops may occupy the upper parts of the watershed in the humid tropics; midway down where the slopes are not very steep, one might find yam, maize or cassava; while the valley bottom is planted with rice. The rice may consist of one or two crops grown in sequence, or of one rice crop relay-interplanted with sweet potato then followed by dry season vegetables or quick maturing legumes grown on residual moisture after the paddy has been drained (Figure 1).

In all of these systems, priority should be given to ecologically sound and economically viable practices that minimize soil degradation and erosion. Labour and constraints on various inputs facing the farmer should also be given due consideration. Moreover, action should be taken to control any Schistoma parasites infesting streams or swamps on the valley bottom land. Other biological, Technological, and socio-economic factors that merit attention are given in Table 3.

Table 2 RAINFALL AVAILABILITY IN RELATION TO RICE PRODUCTION SYSTEM

Category	Rainfall availability	Rice cultivation system
I	Areas with less than 3 months of 200 mm rainfall	Transplanted rice can be grown provided soil puddles easily to render soil impermeable to water percolation. Production risky
II	Areas with 200 mm of rain for 3-5 months	Prime areas for simple crop of transplanted rice in one year
III	Areas with 200 mm of rain for 5-7 months	Two crops of early maturing rice in paddies possible. Unless rainy season begins abruptly, crop should be direct seeded in unpuddled soil
IV	Area with 7-9 months of 200 mm rainfall	Two crops of transplanted rice possible
V	Area with more than 9 months of 200 mm rainfall	Can support continuous rice production

Note: Problem of artificial drying whenever rice crop matures in the rainy season.

Source: after Harwood, 1976.

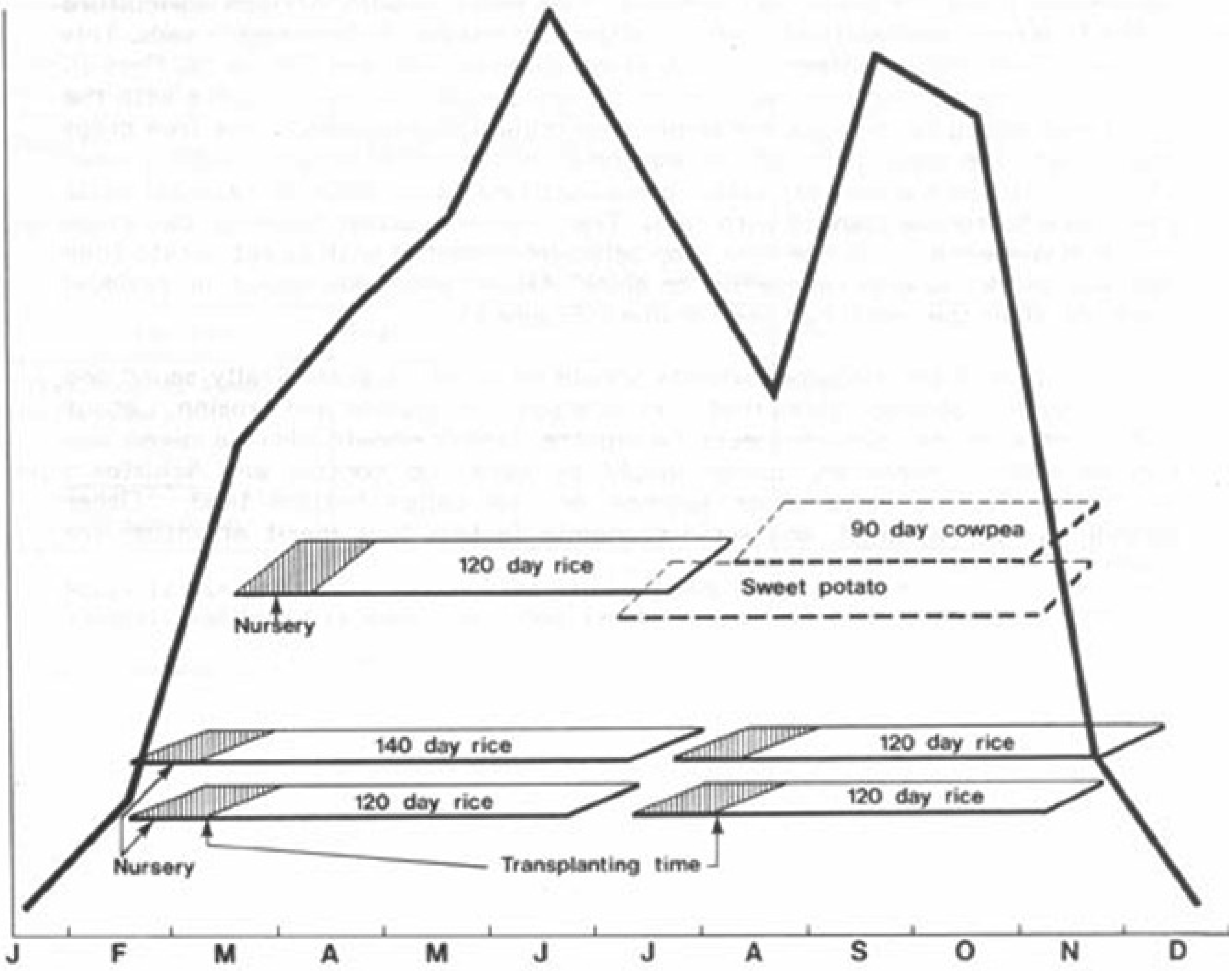

Fig. 1 Cropping calender in a bimodal rainfall area

TABLE 3

BIOLOGICAL CONSIDERATIONS

i. The range of crops available for the different species. This includes improved and traditional varieties and their characteristics in relation to local preferences and their role in the cropping system.
ii. Diseases, weeds, and other pests present, and possible biological, chemical, physical, and cultural ways to control and reduce damage.
iii. Water, nutrient, and other requirements of the crops in relation to prevailing climates and other environmental conditions at different phenological stages of the crop(s).
iv. The possible arrangement of the crops, in combinations and sequences, and the turn-around period required in their production in order to ensure proper timing of operations.

TECHNOLOGICAL CONSIDERATIONS

i. Traditional technologies (practices, equipment, and power source) for the specific crop(s).
ii. Available improved technologies (including equipment and power sources) and arrangements for the farmer to obtain, hire, or use them.
iii. Operations for using the improved technologies and provisions to avoid bottlenecks in stages using traditional technologies. This could include, for example, local manufacture of simple equipment (e.g. simple hand shellers for maize) to eliminate delays.
iv. Overall availability of inputs including quantities and timing.
v. Linkages of farmers with research institutions, extension services and maintenance and servicing facilities that ensure them technical support.

SOCIO-ECONOMIC CONSIDERATIONS

i. Knowledge of traditional or prevailing farming systems to ensure a balance between subsistence and commercial components in the design of alternative farming systems.
ii. Availability of credit, ensuring that priority is not given to large-scale farmers at the expense of smallholders, since the two groups are complementary.
iii. Roles of men and women in crop production, including possible conflict between their work and non-farm activities.
iv. Possible competing farm activities such as export operations and ways of minimizing adverse effects on overall production.
v. Logistical support for moving inputs to farms, and moving produce from farms to stores and markets.
vi. Facilities for postharvest handling and storage of crops.
vii. Pricing and marketing arrangements and cost/benefit analysis necessary for chosing technologies and practices. Consideration must be given to all expenses and possible losses at different stages.

DESIGN OF IMPROVED CROPPING SYSTEMS

The design of new cropping systems should be based on prevailing farming systems, the farmers' objectives, and constraints to increased production. Such designs should embody forecasts of desirable trends and objectives, based on observations of current modernization pressures. Efforts to design viable and acceptable alternatives to shifting cultivation should follow the approach of Hart (1976). His approach maintains that new, improved systems should involve one or more of the following options: (i) modifications of the farmer's prevailing agro-ecosystem, (ii) synthesis of new systems based on agro-ecosystem design and management principles, and (iii) mimicking of analogous natural plant eco-systems.

Figures 2 and 3 are based on Hart's methodologies (1978). A brief consideration of the advantages and disadvantages his approach, based on Okigbo (1982) follows.

Modification of farmer's agro-ecosystems

The advantages of modification include: (i) full use of the farmer's knowledge and the evolutionary adaptability of his or her present management plan and (ii) no drastic changes in the farmer's current farm management practices or technologies.

Disadvantages include: (i) relative specificity to a given site and repetition in different ecological situations which is often expensive and (ii) similarity to what the farmer is doing and hence the likelihood that it will not have a large-scale impact. Of course, a small impact may still significantly increase returns to the farmer and would be more meaningful than a large-scale plan or a system which is not adopted.

Synthesis of new systems-based agro-ecosystems Design and management principles

The main advantage of such a synthesis is that it involves design principles which are continuously being evaluated and refined, as better principles and technologies are developed. This results in more efficient farming systems. Moreover, this approach takes best advantage of an environment and is not limited to something which the farmer is already doing.

The main disadvantages of the approach are the frequent lack of design principles and environmental information; and the major changes in the farmer's management required by the agro-ecosystem management plan. The result is that it is much less likely that a majority of farmers will adopt such a synthesis.

Mimicking of analogous natural ecosystems

Advantages of this mimicking include: (i) minimum emphasis on analysis of ecological factors, since it is assumed that the natural system is already adapted to the prevailing environmental conditions and (ii) in crops, reduction of weed competition because the crops are structurally and functionally similar to the plants considered to be weeds in the agro-ecosystem.

The disadvantages include (i) the relatively closed nature of the natural ecosystem, with little biomass export. Analogous agro-ecosystems may result in very low yields; (ii) there are very few detailed descriptions of tropical ecosystems which have been satisfactorily accomplished.

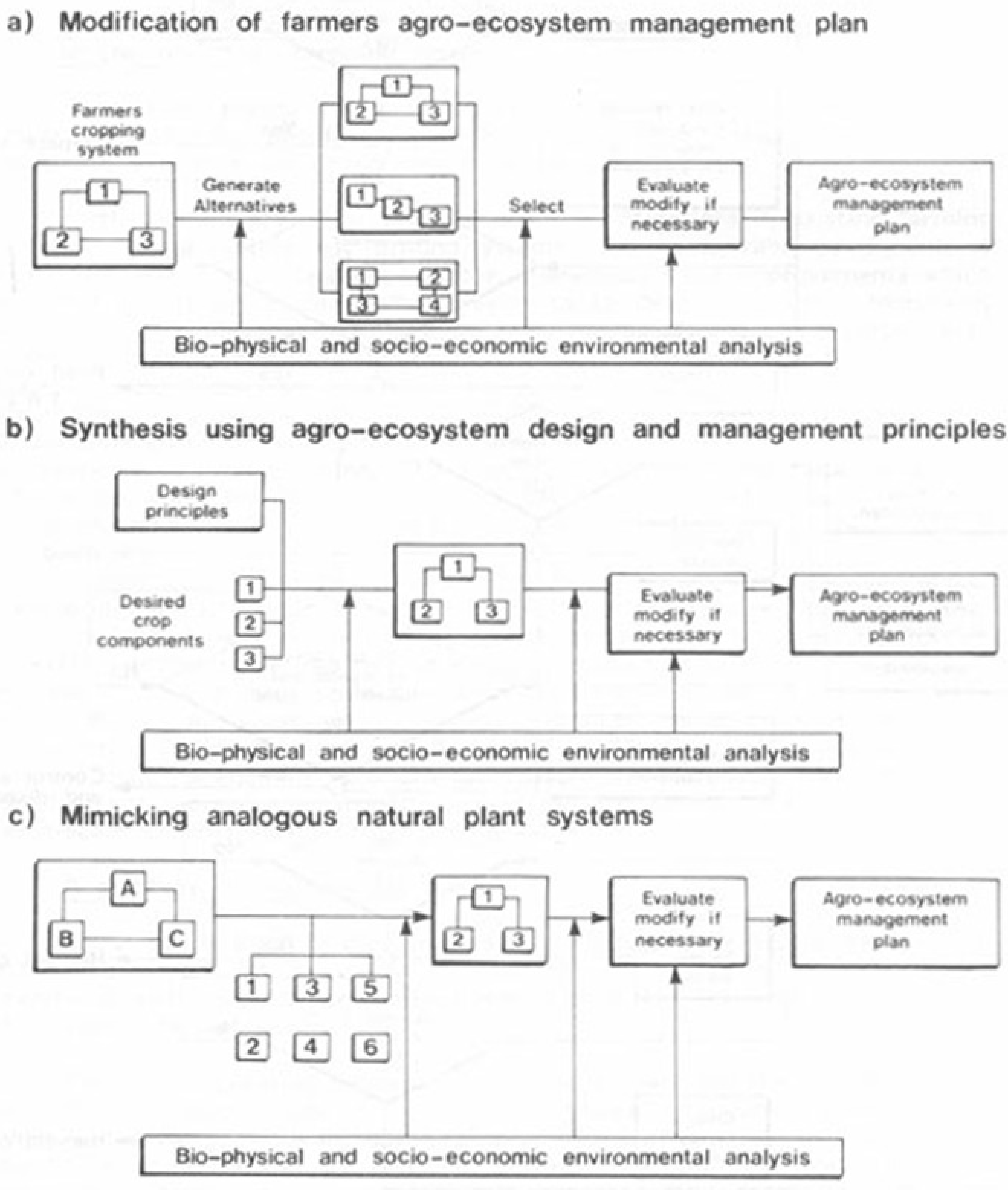

Fig. 2 Three agricultural research methodologies to produce agro-ecosystem management plans

Source: Hart, 1978

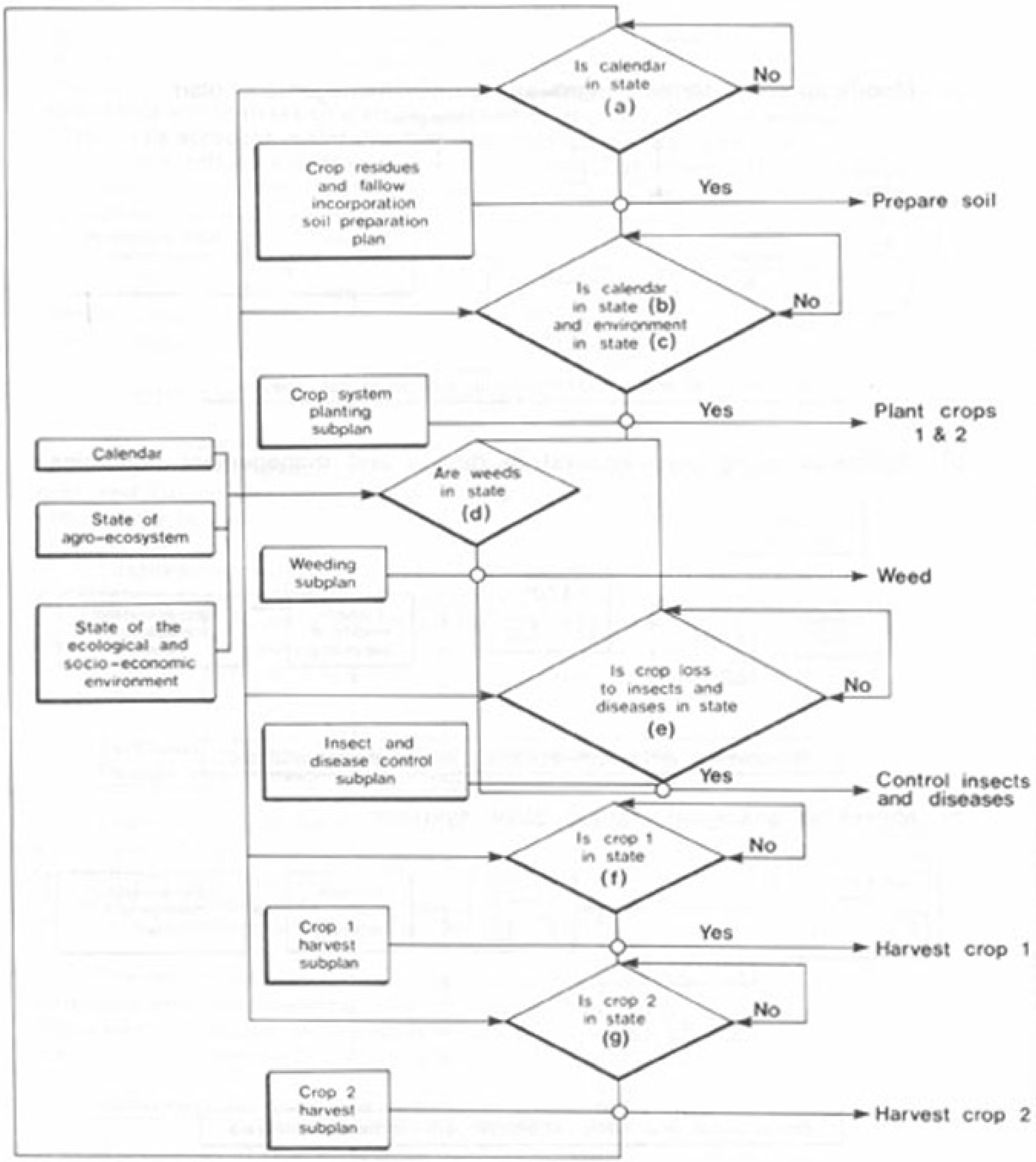

Fig. 3 An agro-ecosystem management plan. The decision to implement a specific management subplan is made by comparing predetermined conditions to actual conditions of the calendar, agro-ecosystem and environment

Source: Hart, 1978

The approach may be useful where a limited number of tree crops, similar in floristic composition and ecosystem structure are grown in polyculture, for example palms, bananas, and perhaps coco-yams.

Integration of traditional and modern technologies in the design of cropping systems

Since time places the greatest constraint on the race between food production and rapid population growth in Sub-Saharan Africa, integration of traditional with emerging or modern technologies has two main advantages.

First, farmers are more likely to adopt modifications in existing farming systems than completely new farming systems. Linking desirable components of traditional and modern farming systems, guarantees some improvements which may not constitute a change so drastic as to deter adoption. Moreover, integration of traditional and emerging technologies affords the opportunity to improve the farming system significantly. Studies and trials of sufficient scope are now being carried out to explore the processes and interacting factors that are necessary to develop designs and management principles for improved, new farming systems. Of course, the new farming systems must not involve changes so drastic as to limit adoption. The modification of prevailing systems, through integration, may considerably narrow the gap between existing and completely new ones, tempering or eliminating the shock of technological changes.

It should also be borne in mind that, while the design and development of completely new alternatives may be more difficult and require more time, there are situations where significant improvements can be made by incorporating new subsystem technologies into new or evolving production systems. For example, failures of various large-scale mechanized crop production projects are well-known in Africa. Considerable progress has been made, however, in finding ecologically sound and economically viable development practices, and subseguent soil management and cropping systems. Moreover, some new land development technologies are either neutral with regard to scale or involve large-scale and small-scale production packages.

A strategy for interation

Since modification of the farmer’s agro-ecosystem appears to be the most attractive current alternative to shifting cultivation, a strategy to integrate traditional and modern technologies is needed urgently. This urgency arises from three recent developments.

First, the increasing concern for the environment and the escalating costs of fuel and other inputs in modern agricultural production systems have identified several disadvantages and deficiencies of modern technology that should be eliminated or at least minimized. Second, new and supposedly improved technologies for increased food crop production have either not been widely adopted or have not significantly increased food production by the majority of small-scale farmers who raise almost all the food in Sub-Saharan Africa. Third, as a result, research approaches to farming systems were developed. These have increased our knowledge of traditional systems, enhancing identification of their scientifically sound and beneficial elements which should be incorporated into any new farming systems in order to improve their suitability. The following desirable features of traditional farming systems, and related undesirable features of modern farming systems should be considered in designing improved systems (Okiabo 1982).

DESIRABLE FEATURES OF TRADITIONAL AFRICAN AGRICULTURE

i, Low energy use: Modern farming systems use far more energy to increase productivity. F3ut the law of diminishing returns has led to increasingly unfavourable energy input/output ratios. In Sub-Saharan Africa increased energy use will certainly be necessary to sustain increases in crop yields and to reduce drudgery in farm work. However, the cost of this energy, relative to the current farmers' lack of adequate credit calls for alternative sources and technologies to minimize energy used per unit increase in crops or livestock.

ii. Low cost inputs: Traditional farming systems are characterized by low cost inputs, and a lack of yield boosting inputs. However, one cannot reap without sowing. New croppinq systems will involve a range of new and more costly inputs. Since many traditional farmers lack credit, new farming systems must use low cost inputs.

iii. The lack of serious hazards to the environment: Relatively speaking, traditional farming systems are free from chemical or pesticidal pollution and the soil erosion and degrading processes associated with mechanized row crop production. Fire in slash-and-burn clearance systems does involve some pollution.

iv. Use of biological processes with obvious benefits: Traditional farming systems take full advantage of nutrient cycling processes and the nitrogen fixing potential of fallow. This may also involve mycorrhizal phosphate nutrition. The cost of production can definitely be reduced if these processes remain part of improved cropping systems.

v. Some built-in soil conservation techniques in traditional farming systems: Such practices as intercropping, relay-intercropping, and aspects of reduced tillage in traditional agriculture minimize erosion and protect the soil. Elements of this conservation technique are essential in new farming systems.

vi. Yield advantages and stability of traditional intercropping systems: Generally intercropping has been shown to result in higher total yields even though yields of components in the mixtures are reduced. Moreover, crop mixtures are desirable in other respects: stability of yields, reduced risk of crop failure, reduced risk of spread of diseases, and so on. These advantages were not appreciated in the past.

vii. Traditional farming systems often integrate crop and animal production for a more efficient use of resources, better manure supply, and economic and nutritional advantages.

viii. Integration of arable crops with tree crops benefits the farmer by supplying various structural, fuelwood and other products, in addition to food.

UNDESIRABLE FEATURES OF MODERN FARMING SYSTEMS

These features are related to problems of: (i) pollution and environmental hazards resulting from pesticides and mechanization, (ii) erosion and increased rate of soil degradation under conventional mechanized tillage and related row crop practices, (iii) the high cost of using inputs and of energy, (iv) the vulnerability to disease and pests of modern cultivars with a narrow genetic base, especially under intensive irrigation systems and where single varieties cover large areas, and (v) the salinity associated with irrigation and inadequate drainage in drier areas.

Beyer (1981) also reviews traditional landscape-altering practices, organizational systems, cooperative management, aversional management, and alternative energy sources.

OBJECTIVES FOR THE DESIGN OF ALTERNATIVES TO SHIFTING CULTIVATION

Whatever strategy is used to design new, improved cropping systems for sustained yields, the following objectives should be met wholly or partly. While they are not exhaustive, they indicate some achievements possible through proper management.

i. Increased commercialization of production. Farmers in many developing countries require more and more cash for school fees, hospital bills, taxes, radios, bicycles, etc in addition to their subsistence needs. This need is often satisfied by export or cash crop production. In plantation agriculture in which the farmer grows only a cash crop, such as cocoa, oil palms or groundnuts, his needs are usually satisfied only if he farms a large area of land of five or more hectares. Most farmers, however, farm two ha or less; a plantation or cash crop of two ha may not give sufficient returns to cover all the farmer's subsistence and other needs. Some cropping systems can, however, be designed to include subsistence and cash elements from local sales or export in which the main cash crops are groundnuts, soybeans, rice, etc. (see Figure 4).

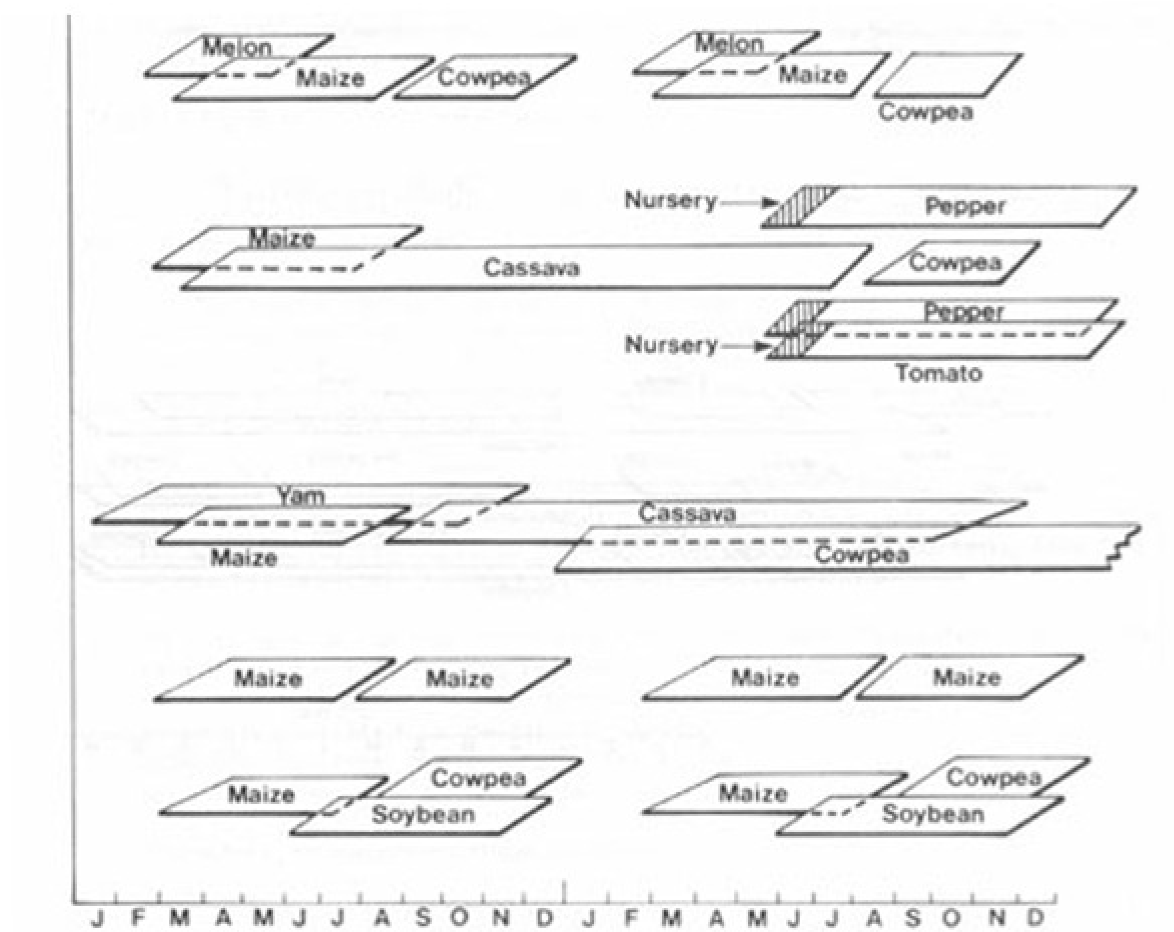

Fig. 4 Cropping calendar involving subsistence and cash crop combinations and sequences with or without intercropping

ii. Minimizing the cost of in uts. Through various environmental manipulations and use of biological nitrogen fixation, nutrient cycling with fallow shrubs could reduce the cost of fertilizer (Figure 5).

iii. Reduction of the fallow period and development of rotations, for sustained yields while maintaining fertility and minimizing pests and diseases. At the same time this provides continuous cover avoiding soil degradation associated with increasingly intensive cultivation (Figure 6).

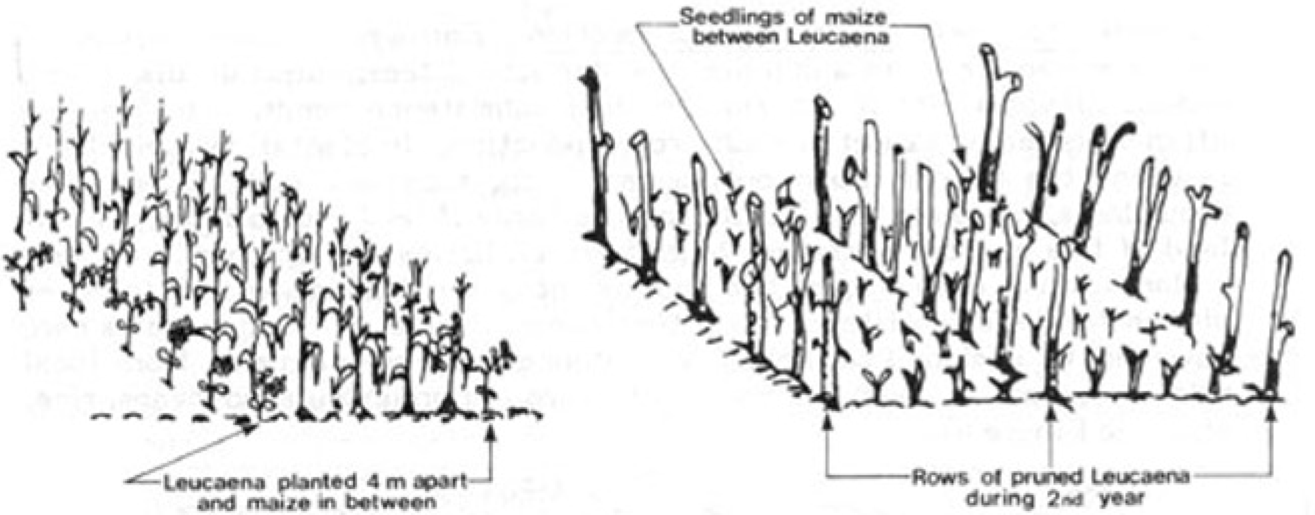

Fig. 5 Leucaena - maize alley cropping (agroforestry system)

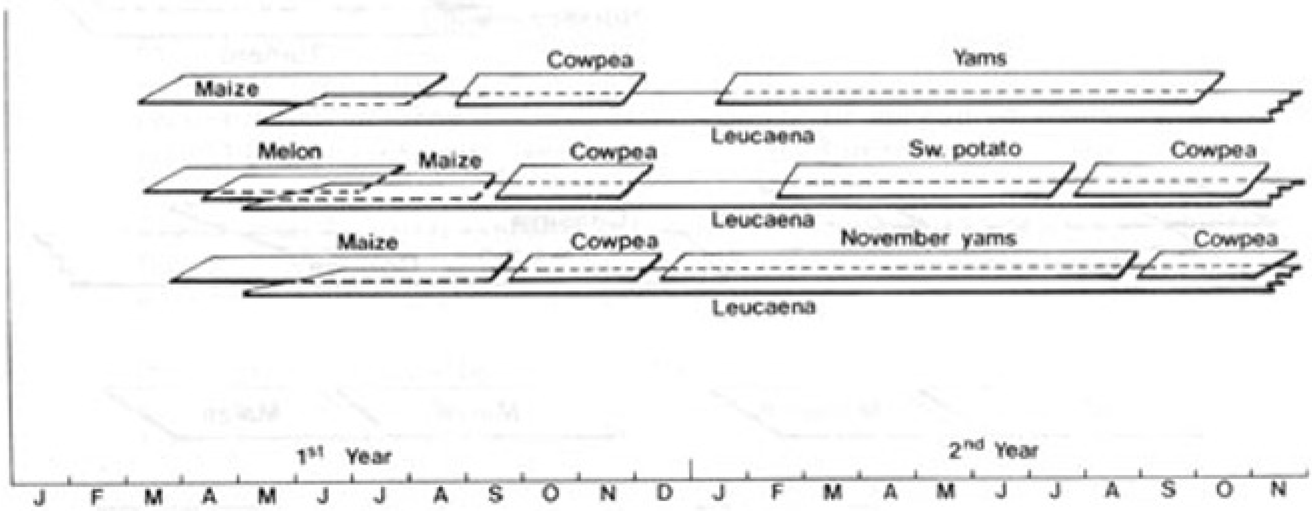

Fig. 6 Leucaena alley cropping rotations

iv. The development of agroforestry systems which, in addition to producing food, satisfy some of the farmer's structural, animal feed, fuelwood and other requirements.

v. Opportunities for rural employment through agroforestry systems that combine, for example, growing of annual food crops with quick maturing trees such as Gmelina which could be used for paper and firewood. The food crop would be grown with Gmelina only during the early stages of plantation establishment while the Gmelina canopy still allows sufficient light to reach the food crop (Figure 7).

vi. Integration of livestock with crops as with coconuts and cattle or small livestock pastured under the coconuts. The animals produce meat, milk, manure, and also power, while the coconuts produce copra, fibre for rural industries, and food. The choice of animals should be related to the prevalance of diseases and parasites and made in such a way as to avoid animals that compete with people for food. An economic analysis of coconut/cattle/food crops enterprises in India reported by Nair (1979) is presented in Tables 4 and 5.

vii. Weed losses, pest and disease damage, soil erosion and so on should be minimized with appropriate choice and arrangement of crops. The tolerance of crops such as coco-yams to shade may be used to advantage. In order to distribute labour more evenly throughout the year, and to obtain nutritional well-being for the farmer, a range of crops should be produced such as cereals, roots and tubers, vegetables, nuts and oil seeds, spices, fruits, and grain legumes. These crops also assure a more balanced diet at lower cost, than if the farmer had to purchase all the family's needs.

CONCLUSIONS AND RECOMMENDATIONS

The development of efficient, permanent agricultural alternatives to replace shifting cultivation has so far appeared more difficult than it should. Remote and immediate causes for this difficulty include:

i. Emphasis was formerly given to plantation and export crops in research, extension, production, marketing, and overall development policies and strategies, because of their benefit to the colonial industries, and later because of their earning power on the foreign exchange, in the case of newly independent African countries.

ii. When attention was belatedly turned to increasing food crop production, the location specificity of agricultural production was overlooked. Efforts to transfer technologies and production systems horizontally from developed to tropical countries proved very disappointing.

iii. So far, Africa has not benefited from the Green Revolution. Even the recent emphasis on making research more relevant to the African farmer of food crops has made only limited progress. The resources and priority currently allocated to developing design and management principles for cropping systems in tropical Africa are not commensurate with the problem's urgency and magnitude.

Therefore, to overcome these problems:

l. The highest priority should be given to cooperative international and regional efforts to help African countries develop their own research especially that seeking alternatives to shifting cultivation and related

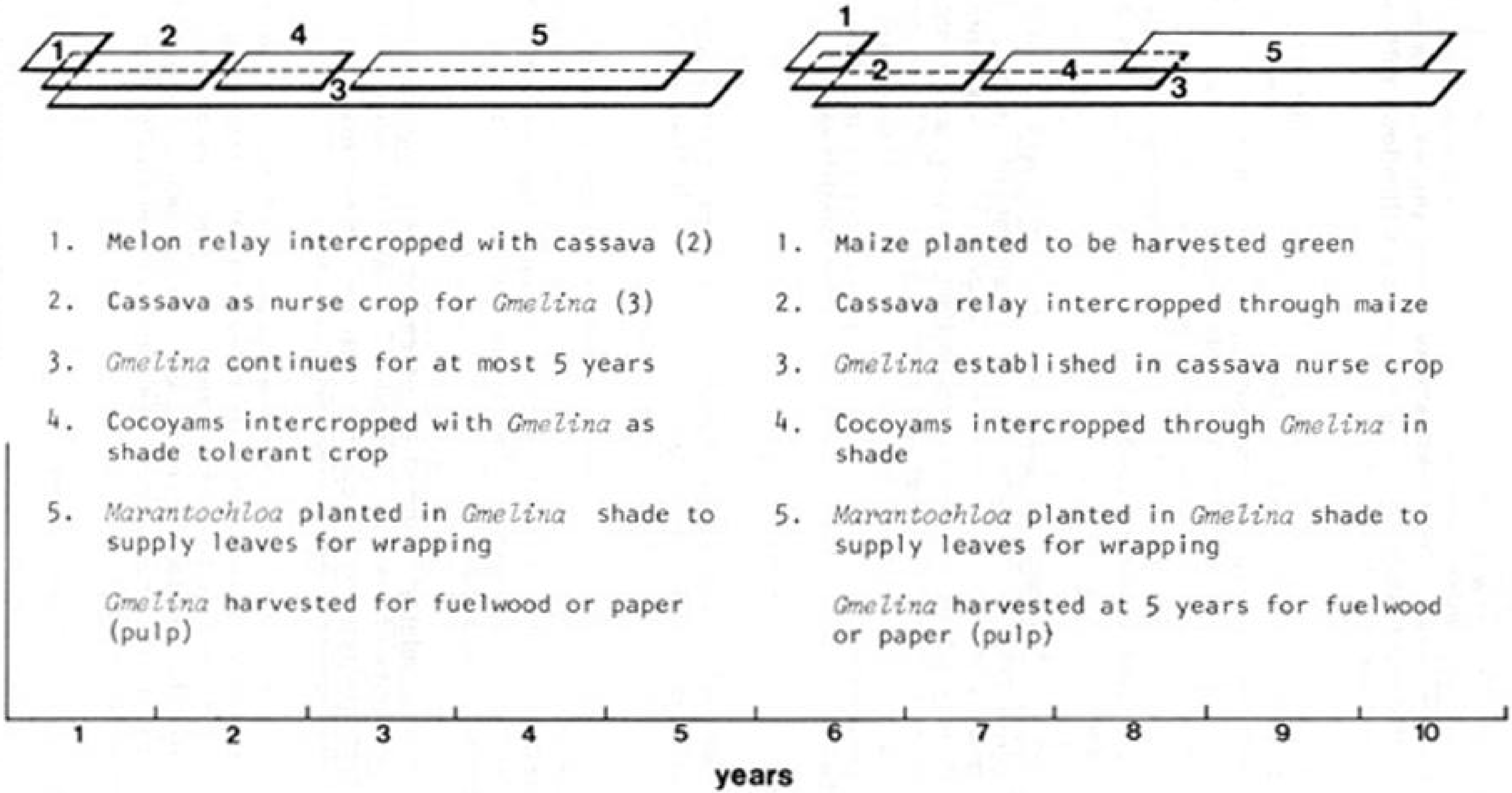

Fig. 7 Agroforestry intercropping calendar in which arable food crops are intercropped with *Gmelina* during the early stages of establishment and phased into shade tolerant crop plants that grow with *Gmelina* until it is harvested

Table 4 SOME FARM PLAN MODELS FOR ONE HECTARE UNITS OF COCONUT AREAS (MONETARY FIGURES IN RUPEES/HA)

	Additional crop				Total net return including coconut	Additional employment days/year	
	Crop	Cost of cultivation	Value	Net return		Men	Women
	A. Cassava in 50% area and other intercrops in the rest						
1.	Elephant yam	2 684	5 314	2 630	6 697	108	10
2.	Sweet potato	2 088	3 770	1 682	5 719	74	19
3.	Greater yam	2 474	5 282	2 808	6 875	79	12
4.	Banana	4 696	7 602	2 905	6 972	132	6
	B. Multistoreyed cropping (Black pepper, cacao & pineapple)						
		3 979	11 800	7 821	15 661	142	21
	C. Mixed cropping with black pepper and pineapple only						
		3 695	6 400	2 705	6 772	189	20
	D. Model B in 50% area and intercrops in the rest						
1.	Cassava	3 051	8 022	4 951	10 905	118	17
2.	Elephant yam	3 470	6 412	2 942	7 009	156	14
3.	Sweet potato	3 875	4 868	1 993	6 060	122	23
4.	Greater yam	3 261	6 380	3 119	7 185	127	16

Source: Nelliat and Krishnaji, 1976

Table 5 INPUT REQUIREMENTS AND ECONOMIC ANALYSIS OF THE MIXED FARMING PROJECT AT CPCRI 1/

		Rupees
1.	**Capital investment**	
	Cost of 4 milch cows	12 000
	Cost of cattle shed	10 000
	Cost of irrigation installations	12 000
	Cost of utensils, equipment, etc.	600
	Total	34 600
2.	**Economic analysis**	
	A. **Receipts**	
	Sale of milk	16 060
	Sale of coconuts	6 120
	Value of subsidiary crops	850
	Total	23 030
	B. **Operating expenses**	
	Cost of cultivation of fodders	1 220
	Labour charges	2 600
	Cost of cattle feed	4 745
	Cost of cultivation of coconuts	1 320
	Miscellaneous	740
	Total	10 625
	Depreciation (cattle and pumpsets)	1 700
	Total operating expenses	12 326
	C. Receipts less operating expenses	10 705
	D. Interest on capital investment	3 460
	E. Net return to farmer 2/	7 245

1/ Area under coconuts in the projects: 1 ha
2/ Labour charges of Rs 2600 to be added to the net income when labour input is by the farmer and his family.
Source: CPCRI, 1976c.

fallow systems.

ii. Land development and soil management benchmark and technology transfer activities of the IARCS, USAID-supported universities, and other international institutional efforts should be strengthened financially and in their national and regional manpower development programmes. Soil management for sustained yields with minimum degradation, reduced erosion and high levels of productivity provides the foundation for permanent agricultural production systems in the tropics.

iii. Although some improvement is being made in the design and development of management principles for cropping systems in drier areas, progress in solving similar problems in the humid and subhumid tropics has been very slow. Crops there include several species not yet affected by the Green Revolution; more serious effort should be devoted to designing cropping systems and developing management principles for the humid tropics.

iv. In countries of tropical Africa which are not producing enough food to meet current demand, high priority should be given to: (a) strategies to increase productivity through more efficient cropping systems and rotations, (b) ways to maximize irrigation benefits including watershed development, especially in the drier areas, and (c) significant increases in the use of valley bottoms and hydromorphic soils especially in rice production for which a possible two million hectares is potentially available in tropical Africa.

v. Most African countries faced with problems in food production are giving priority to achieving self-sufficiency and to producing food commodities that are currently being imported. In all of these efforts, primary emphasis should be placed on those resources, crops, soils, etc. which will give maximum returns per unit input; those of medium potential should be developed secondarily and lastly those with low or marginal potential. In tropical Africa this is not the case, where much effort and many resources are being devoted to production in marginal areas.

vi. FAO can play a major role in coordinating research to find alternatives to shifting cultivation. This requires an integrated multidisciplinary effort at the institutional, national, regional and international levels. The efforts of various divisions in FAO should be coordinated and harmonized to help formulate projects for a network of institutions and countries to find financial support for these projects. FAO could also find ways to advise policy makers in developing countries to allocate more resources to this problem. Time is a major constraint, and foreign assistance alone, without significant complementary efforts by LDC countries, will be unable to solve the problems.

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FROM MIGRATORY TO CONTINUOUS AGRICULTURE IN THE AMAZON BASIN

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INTRODUCTION

Appropriate technologies for changing migratory agriculture to continuous agriculture in some parts of the Amazon Basin have been developed. These agronomically sound, scale-neutral technologies are beginning to be used on some of the Amazon Basin's acid and infertile soils normally subjected to shifting cultivation. They offer an ecologically attractive alternative to the foreboding forecasts for the Amazon Basin, in that their use could lead to not only increased food production for the region's people but also result in a concomitant reduction in deforestation of the Amazon Basin, if wise choices are made by the people and governments of the region.

Nearly one-third of the world's 1 489 million hectares in the humid tropics ecosystem is contained within the Amazon Basin (Figure 1). The paradox due to that area's agricultural potential and the possible adverse ecological consequences of its deforestation is apparent. In a recent study of the humid tropical ecosystems and especially lowland forests, the National Research Council (1982) concluded that these systems "represent a very important, underexploited resource for tropical countries and that, as population pressures increase in these countries, rapid and extensive development will and must take place if even the currently inadequate standard of living in most countries is to be maintained."

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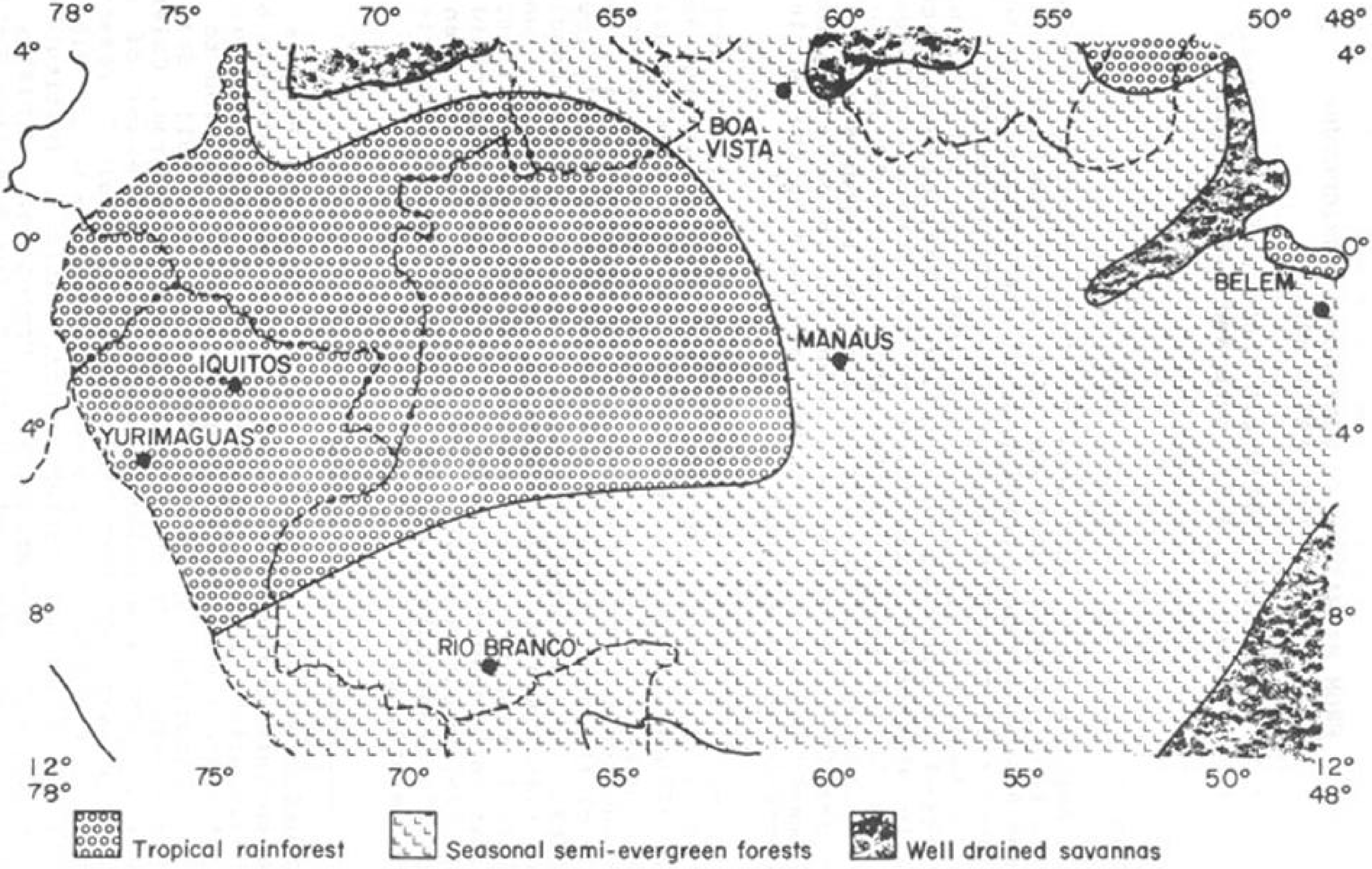

Fig. 1 General map of the three major climatic-vegetative subregions in the Amazon Basin
Source: Nicholaides *et al.*, 1983

Two types of farmers are involved in the clearing of the Amazon Basin. Shifting cultivators are responsible for most of the clearing, in the western part of the Rasin, while ranchers trying to develop pastures are the primary cause for the clearing of the seasonal semi-evergreen forest in most of the Brazilian or eastern portions of the Basin (Myers, 1980; Hecht and Fearnside, 1982.1/ What is needed, therefore, in the areas of the Basin subjected to shifting cultivation is the development and establishment of continuous cropping systems which provide "permanent field cultivation without first going through a sequence of increasingly shorter fallowing and associated environmental deterioration" (Denevan, 1977).

Since 1971, the Tropical Soils Research Program of North Carolina State University (NCSU) under funding from the United .States Agency for International Development (USAID) and in collaboration with the Peruvian Ministry of Agriculture's National Agricultural Research and Promotion Institute (INIPA), has been developig at Yurimaguas, Peru, continuous cropping systems for the acid, infertile soils of the Amazon Basin and other similar agro-ecological areas. The results of these research efforts are felt to offer attractive alternatives for shifting cultivators in the Amazon Basin and in similar soil-crop climatic areas.

AMAZON BASIN ENVIRONMENT

Acid and infertile soils (Oxisols and Ultisols) occupy almost 75% of the Amazon Basin (Table 1). These red or yellow soils are deficient in most nutrients, usually well-drained, and have generally favourable physical properties. Marbut and Manifold's (1926) observation that the soils of the Amazon Basin are strikingly similar to the predominant soils of the southeastern United States of America is substantiated by research presented herein. Other publications (Cochrane and Sanchez, 1982; Nicholaides _et al., 1983) contain detailed descriptions of the climatic conditions and soil resources of the Amazon Basin.

The primary soil constraints to crop production in the Amazon Basin are chemical (Table 2). The crops grown, however, can determine the severity of these chemical deficiencies. Proper management practices can overcome the chemical constraints to crop production in the Amazon Basin just as they have done on like soils in the southeastern United States.

While only 8% of the Amazon Basin soils have been estimated to have a high or severe erosion hazard (Table 2),

_1/ S. Hecht and P. Fearnside, University of California at Berkeley and Instituto Nacional de Pesquisas da Amazonia, Manaus, Rrazil, respectively, personal communication, 1982.

Table 1 GENERAL TOPOGRAPHICAL DISTRIBUTION OF MAJOR SOILS IN THE AMAZON BASIN 1/

Soil grouping	Millions of hectares					
	Poorly drained, level	Well drained			Total	(%)
		Slope 0-8%	Slope 8-30%	Slope >30%		
Acid, infertile soils (Oxisols and Ultisols)	43	207	88	23	361	(75)
Poorly-drained alluvial soils (Aquepts, Aquents)	56	13	1	-	70	(14)
Moderately fertile, well-drained soils (Alfisols, Mollisols, Vertisols, Tropepts, Fluvents)	0	17	13	7	37	(8)
Very infertile, sandy soils (Spodosols, Psamments)	10	5	1	-	16	(3)
Total	109	242	103	30	484	

1/ Source: Sanchez *et al*,. 1982.

it can be noted from the data of Sanchez et al. (1982)that 27% of the soils of the Basin have slopes exceeding 8%. Many of the Oxisols and some Ultisols in the Basin do have favourable structures which permit rapid water infiltration and thereby reduce runoff. However, even those soils with less than 8% slope can be susceptible to erosion if mismanaged. More accurate predictions concerning soil erosion susceptiblity will be possible by a better inventory of soil topography of the region, perhaps dividing the 0-8% slope category into two or even three sub-categories. The senior author estimates that perhaps as much as 40-50% of the soils of the Basin have at least a moderate erosion hazard. Proper management practices will also be the key to controlling erosion in the cropped areas of the Basin.

Table 2 GROSS ESTIMATES OF MAJOR SOIL CONSTRAINTS TO CROP PRODUCTION IN THE AMAZON BASIN 1/

Soil constraint 2/	Million hectares	% of Amazon
Nitrogen deficiency	437	90
Phosphorus deficiency	436	90
Aluminium toxicity	383	79
Potassium deficiency	378	78
Calcium deficiency	302	62
Sulphur deficiency	280	58
Magnesium deficiency	279	58
Zinc deficiency	234	48
Poor drainage and flooding hazard	116	24
Copper deficiency	113	23
High phosphorus fixation	77	16
Low cation exchange capacity	71	15
High erosion hazard	39	8
Steep slopes (>30%)	30	6
Laterization hazard if subsoil exposed	21	4
Shallow soils (<50 cm deep)	3	<1

1/ Source: Nicholaides et al., 1983.

2/ Nutritional deficiences of boron and molybdenum also have been noted in some Amazon Basin soils, but are not quantitatively estimable due to paucity of data.

The old laterization fear that the Amazon Basin soils will turn to brick when cleared (McNeil, 1964; Goodland and Irwin, 1975; Friedman, 1977; Irion, 1978; Posey, 1982) is nothing more than a myth. Only 4% of the Amazon Basin soils possess a laterization hazard (Table 2) and only when the subsoil is exposed. The percentage of soils with similar laterization hazard in the southeastern United States is 7% (Sanchez and Buol, 1975); many of these soils have been farmed continuously for the past 200 years without problems.

Proper management is the key to preventing the soft plinthite in the subsoil from being exposed by erosion and then irreversibly hardened. The erosion necessary for plinthite hardening is unlikely to occur since most of these plinthite soils occur only on the flat, poorly drained landscapes in the Basin (Sanchez et al., 1982). In fact, government leaders in several countries in the 8asin would like to find more plinthite as it is an excellent, low cost material for road beds. Therefore, the laterization hazard is not a constraint to crop production, but rather its limited quantities are constraints to road building in most of the Basin (Sanchez et al., 1982).

Only about 6% of the Amazon Basin soils have no major constraints to crop production (Sanchez et al., 1982). Agricultural efforts should be and are concentrating first on these soils. However, their limited extent, occasional flooding hazard, population pressures, and the fact that migratory agriculture is the main food crop production system in the predominant soils of the 8asin underscore the need for continuous crop production technologies for the acid, infertile soils of the Amazon Basin.

MIGRATORY AGRICULTURE

The term migratory agriculture (or shifting cultivation) includes any system under which the soil remains fallow for a longer period of time than it is cropped and encompasses the many variations practised around the world (Nicholaides _et al., 1984). It has been discussed in various publications, including Moran, 1981; Nicholaides, 1979; Sanchez, 1977a; Ruthenberg, 1976; Sanchez, 1976; Grigg, 1974; Manshard, 1974; Sanchez, 1973; National Academy of Science, 1972; Nye and Greenland, 1960.

Clearing

Most shifting cultivators in the 8asin use the slash and burn technique. In this system, the larger trees and shrubs are cut by axe, machete, or chain saws during periods of low rainfall, are allowed to dry for at least 10-14 days and are then burned either in place or in piles with smaller trees and shrubs. Other shifting cultivators, such as those in the very high rainfall areas of Ecuador’s Amazon Basin, practise “slash and mulch” by broadcasting the crop seed in the forest, cutting the undergrowth and using that vegetation as mulch instead of burning. Still yet another variation of shifting cultivation is in the Xingu River Basin in the centre of Brazil’s Amazon Basin by the Kayopo Indians who plant their root crops in the cleared forest prior to burning (Posey, 1982). Then, with the burn, the root crops lose their greenery, but not the vitality of the underground root system which absorbs nutrients leached from the ash when the rains begin.

As earlier mentioned, not all land clearing in the Amazon Basin is by shifting cultivators. There are large-scale ranchers and farmers with access to capital to employ bulldozers, tree crushers and D-8 tractors to clear their lands. However, the increasing prominence of such mechanized clearing in portions of Brazil's Amazon Basin (Hecht, 1983) is not equated necessarily with increased crop yields.

Cropping and Consequent Fallow

The Basin's shifting cultivators most commonly plant some combination of rice, bean, maize, cassava, sweet potato, and plantain among the ashed debris using a stick to make the hole into which seed or vegetative portions of the crops are planted. Cassava and banana are often planted before rice in many areas of the Basin and it has been reported (Moran, 1981) that cassava is planted to 90% of the Basin's cultivated fields. In the Yurimaguas region of Peru's Amazon Basin, small farmers usually plant rice in monoculture following slash and burn clearing. Then comes an intercrop of maize, cassava, plantain and sometimes pineapple (Bandy and Sanchez, 1981a). This common intercropping practice reduces, but does not eliminate, the need for manually weeding the crops.

However, after only one or two crops, especially on the acid and infertile soils, yields decline so drastically due to soil fertility depletion and consequent greater weed competition that the land is then abandoned to a forest fallow. This fallow usually lasts for 14-21 years during which the fertility of the soil is regenerated by nutrient cycling of the forest growth and litter. The land is cleared once again, cropped and returned to fallow after one or two more crops.

However, although this traditional form of shifting cultivation is ecologically sound (Nye and Greenland, 1960; Moran, 1981) and functional, it has been described by Alvim (1978) as a guarantee of perennial poverty. With the opening of the Trans-Amazon highway and feeder roads, there is consequent increased population pressure, shortening of the forest fallow period and the soil fertility regeneration process, and a subsequent conversion of an ecologically sound cropping system into an unstable, unproductive one which bodes ecological disaster (Sanchez et al., 1982). The effect of this shortened fallow is especially pronounced on the more infertile soils which make up three-quarters of the Basin.

Some alternative cropping systems must be made available to and accepted by the current shifting cultivators on the acid, infertile soils of the Amazon Basin, if there is to be any chance of increasing food production while allowing some of the yet undisturbed Amazon rainforest to be preserved.

CONTINUOUS AGRICULTURE

Included in the possibilities should be the alternate cropping systems developed by NCSU's Tropical Soils Research

Program and Peru's INIPA which determined the agronomic and economic feasibility of continuous cropping of basic food crops in the Amazon Basin near Yurimaguas, Peru.

Yurimaguas is representative in both climate and soil properties of much of the Basin's rainforest subregion. It is the westernmost large fluvial port of the Amazon Headwaters (5o 45' S, 75o 05' W 184 m above sea level). Its annual mean temperature is 26°C and it has a well-distributed mean annual rainfall exceeding 2200 mm with 9 months averaging 200 mm and June, July and August averaging about 100 mm each. The sandy-loam surface soil over a clay-loam subsoil at the Yurimaguas Agricultural Experiment Station reflects a level and well-drained Ultisol. Both the top and subsoil have low cation exchange capacities, are very acid with toxic aluminium (A1) levels and are deficient in most nutrients.

Clearing

The first step and certainly one of the most important affecting cropping productivity of the Basin's infertile soils is the choice of land clearing method. Crop yields on soil cleared by the traditional slash and burn method were found to be superior to those on the same soil cleared by the bulldozer (Table 3). The reasons for this were: 1) fertilizer value of the ash, and 2) no soil compaction nor 3) topsoil displacement as caused by the bulldozer. It was concluded, therefore, that for most farmers of the Amazon Basin's acid, infertile soils the traditional slash and burn clearing system would be the best unless those farmers could afford to add additional fertilizer, lime and tillage operations to compensate for the soil fertility limitations and compaction disadvantages of bulldozed clearing (Alegre et al., 1981). The crucial question then became how to keep these slash and burn clearings continually productive.

Cropping Continuously

Important components of the continuous cropping included determining the most important crops, their nutritional needs, best sequences and changes in soil properties with time of cultivation. Various publications present the details of this research. These include North Carolina State University, 1972-1983; Bandy and Benites, 1977; Sanchez, 1977 a, b, c; Villachica, 1978; Wade, 1978; Valverde et al., 1979; Nicholaides, 1979; Sanchez and Cochrane, 1980; Bandy and Sanchez, 1981a; Sanchez et al., 1982; Valverde and Bandy, 1982; Nicholaides et al., 1982, 1983, 1984. Included in the Yurimaguas research were various rotations and combinations of rice, maize, soybean, groundnut, cassava, cowpea, sweet potato and plantain.1/

_1/ For reasons of conformity with FAO style, the term groundnut is substituted for peanut (except in the Figures).

Table 3 EFFECT OF LAND CLEARING METHOD ON CROP YIELD AT YURIMAGUAS, PERU 1/

Crop (number of harvests)	Fertility Treatment _2/	Crop Yield Clearing Slash & Burn	Bull-dozer	Bulldozer Slash and Burn
		t/ha	t/ha	- % -
Rice, upland (3)	0	1.33	0.70	53
	NPK	3.00	1.47	49
	NPK + Lime	2.90	2.33	80
Maize (1)	O	0.10	0.00	0
	NPK	0.44	0.04	10
	NPK + Lime	3.11	2.36	76
Soybean (2)	O	0.70	0.15	24
	NPK	0.95	0.30	34
	NPK + Lime	2.65	1.80	67
Cassava (2)	O	15.40	6.40	42
	NPK	18.90	14.90	78
	NPK + Lime	25.60	24.80	97
Mean relative yields	O			30
	NPK			43
	NPK + Lime			80

1/ Source: Seubert, Sanchez and Valverde, 1977.

2/ Applied were N, P, K at 50, 172 and 42 kg/ha respectively, and $Ca(OH)_2$ at 4t $CaCO_3$-equivalent/ha.

The climate and rainfall pattern of the Yurimaguas area permit the production of three crops per year without any overlapping relay cropping. The recommended planting dates for the main annual crops in Yurimaguas are shown in Figure . 2. With intercropped combinations, five crops per year were possible (Wade, 1978), but as farmers of the region are now turning to rotational monocultures, only the most promising of those will be presented. Such are the rotations of upland rice-maize-soybean and upland rice-groundnut-soybean. Mono-cultures without rotations did not produce sustained high yields because of a build-up in diseases and insects; this is exhibited in Figure 3 where rice yields after the third consecutive crop began declining and it was only when a rotational system with soybean and groundnut was imposed that yields began to increase.

To date, 25 consecutive crops of the upland rice-maize-soybean and upland rice-groundnut-soybean rotations have been harvested from the same fields since these were slash

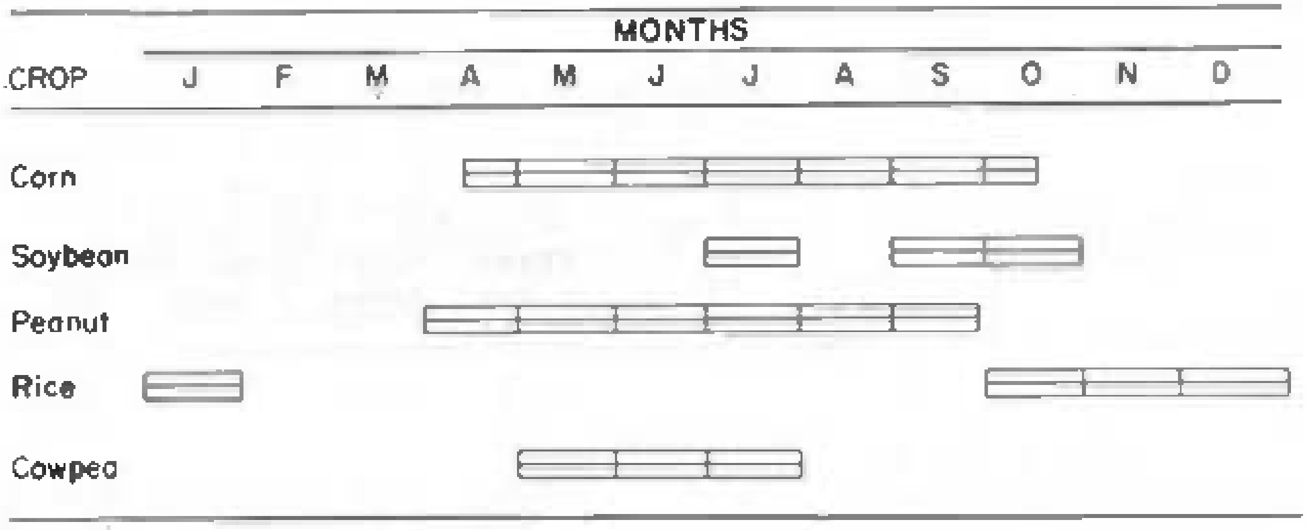

Fig. 2 Recommended planting dates for maize, soybean, peanut (groundnut), rice and cowpea in Yurimaguas, Peru, of the upper Amazon Basin area Source: North Carolina State University, 1978-1979

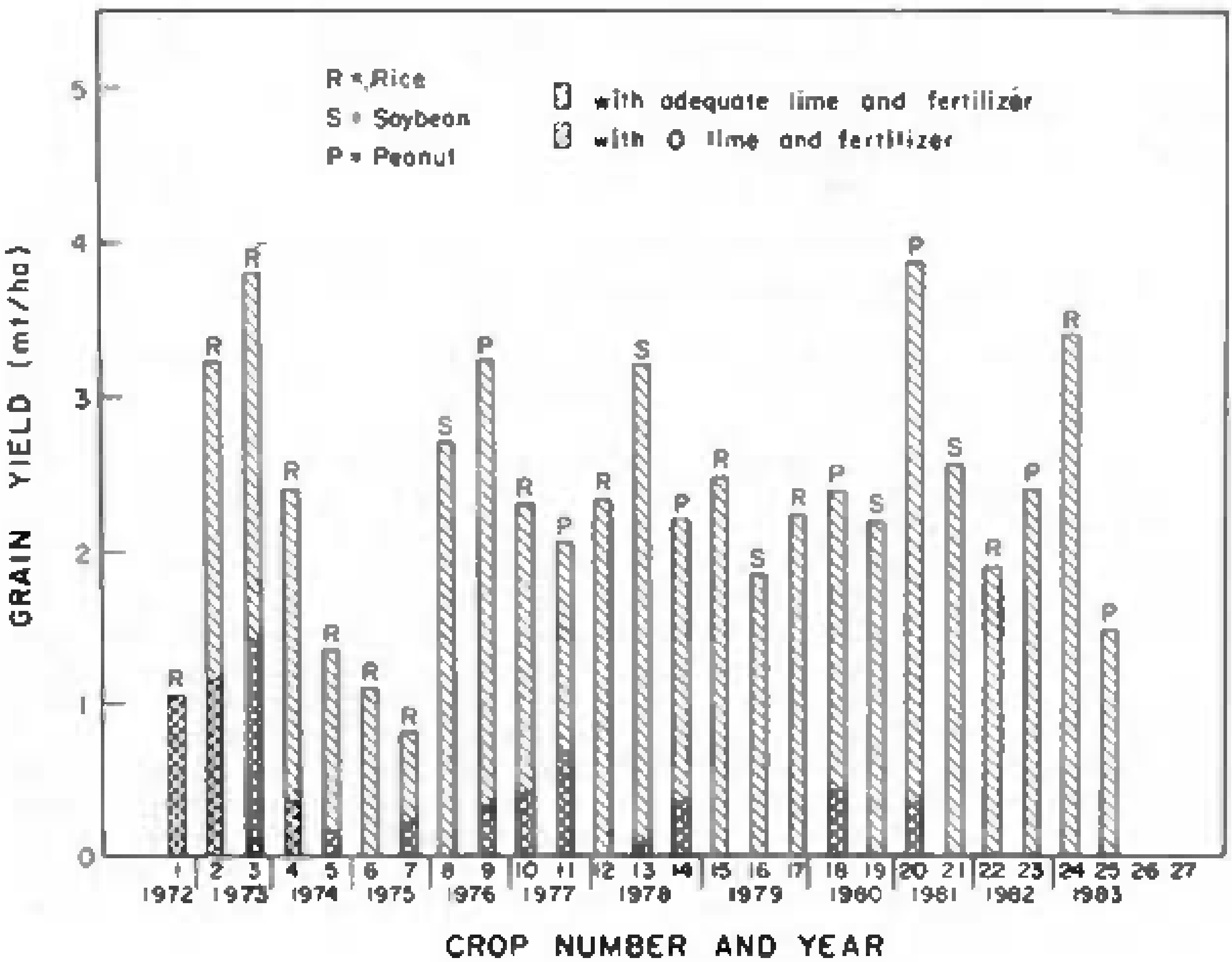

Fig. 3 Yield record of a continuously cutlivated rotation of rice-peanut (groundnut)-soybean in an Ultisol of Yurimaguas, Peru, with and without complete fertilization and lime

and burn cleared in October 1972. Without fertilization and lime, yields declined essentially to zero after the third crop in the rice-maize-soybean rotation (Figure 3). The average annual grain yield of the "complete fertilization treatment" for each three-crop-per-year rotation was 7,5 tons/hectare over the ten years since clearing. These cropping results indicate that applications of adequate lime and fertilizer (Table 4) to some of the Basin's most acid and infertile soils can achieve and sustain moderately high yields of these annual crops. This long-term experiment is being continued to define modifications needed in fertilization practices with time of cropping.

Table 4 LIME AND FERTILIZER REQUIREMENTS FOR CONTINUOUS CROPPING OF A THREE CROP/YEAR ROTATION OR RICE-GROUNDNUT-SOYBEAN ON AN ULTISOG OF YURIMAGUAS, PERU 1/

Input 2/	Rate per hectare	Frequency
Lime	3 tons $CaCO_3$ - equivalent	Once per 3 years
Nitrogen	80-100 kg N	Rice and maize only
Phosphorus	25 kg P	Each crop, split applied
Potassium	165 kg K3/	Each crop, unless dolomitic lime is used
Magnesium	25 kg Mg	Once/year or two years 4/
Copper	1 kg Cu	Once/year or two years 4/
Zinc	1 kg Zn	Once/year or two years 4/
Boron	20 g Mo	Mixed with legume seed during inoculation

1/ Source: Nicholaides et al., 1982.
2/ Calcium and sulphur requirements are satisfied by lime, simple superphosphate and Mg, Cu and Zn carriers.
3/ Potassium application may go to this rate depending on soil test.
4/ Depends on soil test analysis and recommendations.

These systems are also as economically feasible as they are agronomically productive. A net return of US$2.91 per $1.00 invested in fertilizer and lime at the 1977 Yurimaguas prices, which included transportation, was realized for the rice-groundnut-soybean rotation (Bandy, 1977).

SOIL EERTILITY EVALUATION AND IMPROVEMENT

As with crop production anywhere in the world, the nutritional needs and the amendments for crops in the upper Amazon Basin can be determined only by continual soil and plant sampling and testing, and by consequent lime and fertilizer recommendations. The fertility of the soil was monitored by sampling soils after each harvest and analysing for the usual chemical indices. Treatments of special interest were 1) the “check” which never received fertilizer or lime and which was in accord with the traditional shifting cultivation practice, and 2) the “complete” which received the best fertilization and liming practices, according to soil and plant analyses and the accumulated experience of the Program.

The ash from the burn produced a temporary increase in overall soil fertility, as noted by increases in pH, total N, available P, exchangeable potassium (K), calcium (Ca) and magnesium (Mg) and some micronutrients, and a concomitant decrease in exchangeable Al to below toxic levels. It was not surprising, therefore, that the first crop, upland rice, planted in Yurimaguas, did not suffer from Fertility limitations. However, within eight months after clearing, the N and K levels were reduced so much that their deficiency symptoms appeared with occasional others, such as those of sulphur (S), copper (Cu) and boron (B) .

The organic matter (O.M.) content decreased sharply during the first year at an annual decomposition rate of 25% but reached a new equilibrium level beginning the second year. It should be mentioned that this occurs in the traditional slash and burn clearings as well and that continuous crop production after slash and burn clearing maintains the O.M. content approximately at the level to which it had fallen after the initial slash and burn. clearing. The liming effect of the ash was negated by the rapid decomposition of O.M. which is thought to have released hydrogen (H) ions that acidified the soil and increased exchangeable Al to toxic levels (Sanchez et al., 1982).

In the second year, P and Mg became deficient. A half year later, Ca became deficient and then during the fourth year, zinc (Zn). After the eighth year of continuous cropping, manganese (Mn) deficiency was suspected. There have been deficiencies of molybdenum (Mo) occasionally detected in grain legumes. Therefore, after 10 years of continuous cultivation, the crops grown on this Ultisol in the Amazon Basin have exhibited deficiencies of all essential soil nutrients except iron (Fe) and chlorine (C1).

The fertilizer rates (Table 4) for continuous production of maize, soybean and groundnut on Ultisols in the upper Amazon Basin do not differ substantially from those for these crops grown on Ultisols in the southeastern United States. As three crops a year are grown in the Basin, instead of one as in the southeast United States, the total annual amounts are higher in the Basin.

After the First crop on a slash and burn clearing, chemical inputs, whether inorganic or organic, are required to produce and sustain moderately high yields. These lime and fertilizer recommendations are site-specific, as are any sound ones. Recommendations for even similar soil-crop-climatic conditions should be based on local soil analyses and experience. Nevertheless, the fertilizer recommendations developed after 10 years of continuous cropping (shown in Table 4) give an indication of the- inputs required for continuous crop production on these types of Ultisols of the upper Amazon Basin.

The increase in soil degradation with cultivation in the humid tropics is a common concern in the literature (McNeil, 1964; Goodland and Irwin, 1975; Friedman, 1977; Irion, 1978; Sioli, 1980). However, the results reported herein indicate that soil properties improved with intensively managed, appropriately fertilized, continuously cropped rotational systems.

The topsoil pH was increased from a very acid 4.0 prior to clearing to a favourable level of 5.7 after 7 years of properly liming and fertilizing 20 consecutive crops (Table 5). Organic matter contents decreased in that time period by 27%, 93% of which occurred during the first year. Liming also decreased the percent Al saturation from a toxic 82% to a negligible 1% and increased the Ca levels nearly twenty-fold. Although the Mg levels fluctuated over time, they doubled after seven years of fertilizing and cropping from the time of clearing. In spite of the adequate quantities of K fertilizer applied, the exchangeable K levels did not increase, suggesting rapid crop utilization and perhaps leaching to the subsoil.

The effective cation exchange capacity (ECEC), •a measure of the soil’s capability to retain cations against leaching, significantly doubled with the seven-year time, probably as a consequence of the pH-dependent charge characteristics of the kaolinite clay and the iron oxides in the soil. The soil-phosphorus P levels were increased by fertilization from below the critical level of 12 parts per million (ppm) to substantially above it. The same trend occurred with both Zn and Cu as both elements were applied as fertilizers. However, as no Mn fertilizer was applied, available Mn levels decreased to less than the critical level of 5 ppm, suggesting Mn deficiency. Available Fe levels remained considerably above the critical level of 20 ppm. On the whole, these fertility changes are indicative of improvements in the topsoil chemical properties.

Table 5 CHANGES IN TOPSOIL (0-15 cm) CHEMICAL PROPERTIES AFTER 8 YEARS OF CONTINUOUS PRODUCTION OF 20 CROPS OF UPLAND RICE, MAIZE AND SOYBEAN WITH COMPLETE FERTILIZATION IN YURIMAGUAS, PERU 1/

			Exchangeable						Available				
Time	pH	Org. matter	Al	Ca	Mg	K	Eff. CEC	Al Sat'n.	P	Zn	Cu	Mn	Fe
		%	------ meq/100 cc				------	%	-------- g/cc				--------
Before clearing	4.0	2.13	2.27	0.26	0.15	0.10	2.78	82	5	1.5 2/	0.9 2/	5.3 2/	650 2/
90 months after clearing	5.7	1.55	0.06	4.98	0.35	0.11	5.51	1	39	3.5	5.2	1.5	389

1/ Source: Sanchez *et al*., 1982.

2/ 30 months after clearing.

No unfavourable changes in soil physical properties have been detected thus far (North Carolina State University, 1978-1979), primarly because of the protection that three well-fertilized crops per year provide against the impact of rain on the soil. Although crop residues are left in the field until the experimental plots are tilled in preparation for the next planting, soil can be exposed for up to 30 days until the crop canopy is established. Occasionally, prior to complete canopy cover, heavy rains have produced runoff losses on sloping land.

However, a more serious problem is the rampant surface soil compaction in the unfertilized plots which simulate the traditional system. Crops without adequate nutrient supply can never develop a complete canopy. In contrast, healthy fertilized crops do produce a good, complete canopy and the soil, therefore, suffers less surface soil compaction and less potential runoff.

Frequently acting as chemical barriers to root development in the Basin’s Oxisols and Ultisols are the acid subsoils. Crop roots are unable to enter a subsoil with high Al saturation and low exchangeable Ca (Bandy, 1976; Gonzalez et al., 1979; Ritchey et al., 1980). This consequent shallow root system often results in drought-stressed plants during rainless periods in spite of the fact that the subsoil has available water. Deep lime placement compared with normal or shallow lime placement resulted in maize roots being able to grow into the subsoil and utilize the subsoil moisture to reduce plant water stress (North Carolina State University, 1978-1979). However, if Ca movement into the subsoil occurs, deep lime placement is not necessary. Over a period of time, following shallow lime and fertilizer placement in Yurimaguas, the acid subsoil constraints were alleviated by leaching of Ca and Mg which produced in the subsoil increases of Ca and Mg levels and a decrease of percent Al saturation. This more favourable environment for root development than before clearing was produced by several shallow lime incorporations over nearly eight years of continuous cultivation. Therefore, it can be stated that appropriate fertilization, liming and continuous cultivation improved rather than degraded this Ultisol of the upper Amazon Basin.

FARMER ACCEPTANCE

The true test of any improved technology is the acceptance of the utilization by the target group, in this case the shifting cultivators. In 1978, the NCSU/INIPA team felt that research results had sufficient practical application to test and demonstrate at the farm evel. Consequently, a series of demonstration plots were established on the slashed and burned fields of selected shifting cultivators, within an 80 km radius of Yurimaguas. It was the small farmers themselves, with NCSU/INIPA support, who planted and managed the technological systems using various three crop per year rotations (Mesia et al., 1979).

The systems were: 1) the farmer’s traditional system, 2) improved agronomic practices without lime and fertilizer, and 3) improved agronomic practices with moderate rates of lime (1 ton $CaCO_3$-equivalent per hectare per year) and fertilizer (60 kg N/ha for rice and maize only, 35 kg P/ha per crop, 66 kg K/ha per hectare per crop, and 22 kg Mg/ha per crop). System 3 was considered to be equivalent to the “complete” treatments developed at the Yurimaguas Agricultural Experiment Station although the fertilizer rates were lower than those of the complete treatments at the Station; this system will be referred to as the “improved Yurimaguas technology”. The three crop per year rotations were planted on one to ten-year forest fallow, slashed and burned clearings in soils similar to (Typic and Aquic Paleudults and Tropudults) and more fertile (Typic Tropudults and Vertic Eutropepts) than those oE the Yurimaguas Agricultural Experiment Station Agronomic Research.

Agronomic Results

The results of these tests on the farmers’ land under their own management were excellent. The annual cumulative grain yields produced by System 3 ranged from 7.5 to 11.4 tons/ha while those from the traditional System 1 were 3.5 to 5.3 tons/ha (Table 6). These yields are similar to those obtained at the station and are much better than the traditional yields of 1 to 1.5 tons/ha usually produced on shifting cultivator’s land in the Basin (Smith, 1981). Soil fertility depletion in System 1 was due to crop removal and loss of the ash liming effect after three consecutive crops. In that system, soils became more deficient in P, more acidic with exchangeable Al increasing and Ca and Mg decreasing and organic carbon (C) decreasing. The soil fertility depletion was also reflected in declining maize and soybean yields in the respective maize-groundnut-maize and soybean-rice-soybean rotation (Table 6). For those farmers continuing in the second year, yields declined even further in the traditional system as soil fertility depletion became even more severe,

Economic Feasibility

Economic analysis revealed the System 3 maize-ground-· nut-maize rotation to give the highest net revenue per hectare and the highest marginal rate of return, exceeding 600%(North Carolina State University, 1978-1979). The economic analysis was computer conducted using limited capital, limited labour and with even work output limited by nutritional intake of a model seven-member small farm family. The System 3 maize-groundnut-maize rotation on a 1.5 hectare farm, using US$180 (half borrowed at 64% APR) and the farm family as the sole labour pool was revealed by this analysis to provide an annual neet farm income of US$2 797 (North Carolina State University, 1978-1979). That this net income considerably exceeded the family farm net income in the Yurimaguas area of US$750 and the $1 500 annual net income of the top 25% of the families in Lima’s slums (Hernandez and Coutu, 1981) is striking.

Table 6 AVERAGE YIELDS OF 11 SMALL FARMER-MANAGED CONTINUOUS CROPPING DEMONSTRATION TRIALS FROM JULY 1978-JUNE 1979 IN AN 80 KM RADIUS FROM YURIMAGUAS, PERU 1/

Production system	Crop rotation											
	Maize-groundnut-maize			Total	Groundnut-rice 2/-soybean			Total	Soybean-rice 3/-soybean			Total
	Average grain yields, tons/ha											
I. Traditional	2.44	1.10	1.77	5.31	0.97	1.91	1.34	3.53	1.43	1.91	1.15	4.49
II. Improved, no lime or fertilizer	3.81	1.36	2.73	7.90	1.22	3.56	1.98	6.76	2.09	2.25	1.89	6.23
III. Improved, with lime and fertilizer	5.12	1.62	4.66	11.40	1.49	4.53	2.75	8.77	2.73	2.53	2.22	7.48

1/ Source: North Carolina State University, 1978-1979.

2/ Rice in System I is the traditional Carolina variety; in Systems II and III, it is IR 4-2.

3/ Rice in all systems is the traditional Carolina variety.

Farmer Reaction

After the first year, all initial farmers in the project adopted the use of improved seed and insecticides. Ten adopted the improved plant spacing techniques, six adopted weeding at critical times, five adopted fertilizer use, and none adopted lime use. Since many of the farmers' plots were on higher base status soils, the need for lime was not exhibited as rapidly as it would have been on more acid soils. Due to the fact that the 11 farmers selected to participate in the initial demonstration project are respected community leaders, their neighbours are now learning from them. Although plans were for only three consecutive crops on the initial 11 farmers' lands, three farmers wanted to continue and did so for a second year, and one continued into the third year, stopping only after he had grown seven consecutive crops on soils that could not have produced more than two or three under the traditional system.

These initial 11 farmers are the true salespeople for the workability of at least some of the "improved Yurimaguas technology" on small farms. Several small farmers in the area are now pioneering the continuous cropping technology on areas greater than the recommended 1.5 hectares. One farmer has gone to 3 hectares with hired labour and has increased his net worth considerably in the 1979-1980 and the 1980-1981 growing seasons; five and 19 more small farmers, respectively, entered into the same demonstration arrangement as had the initial 11.

Rural School Project

Also in the 1980-1981 period, a pilot project was initiated with 27 rural schools in the Yurimaguas region in order to reach more small farmers and their families. This collaborative project among INIPA, the Ministry of Education and NCSU set up the same type of demonstration systems with the rural school students, their families and teachers planting and managing the trials. After the first year, over half of the 626 small farm families represented in the project were interested enough to state that they would be willing to use at least some of the Yurimaguas technology on the own lands.1/

Overall Results

The local availability of fertilizer and credit has increased and roads and marketing facilities have improved in the Yurimaguas area due to a favourable Peruvian Government response to the improved Yurimaguas technology. Thus, the small farmers in the region have a continuous cropping alternative to enable them to farm permanently and economically their infertile lands normally subjected to

_1/ Benites, J. 1981. Unpublished report. North Carolina State University, Raleigh, North Carolina.

shifting cultivation. Many other small farmers throughout the Peruvian jungle regions are being taught these technologies by the Peruvian extension service. The “improved Yurimaguas technology” is being tested through adaptive research in other areas of the humid tropics, such as Manaus, Brazil and the transmigration areas of Sumatra, Indonesia. Clearly this is only a beginning, but it is a solid one on which the region and similar areas of the humid tropics can build.

CONTINUED AND NEW RESEARCH

In spite of the importance of the results previously discussed, not all of the answers have been obtained for changing the region’s predominant agricultural practice from shifting to permanent cultivation. Several complementary options for sustained agriculture in the upper Amazon Basin are being investigated by the NCSU/INIPA team and others; these include the following research thrusts.

Low Input Systems for Annual Crops

Special emphasis is being given to developing alternative annual crop systems with lower inputs than those previously described for the region’s small farmers. These systems include:

1) Evaluation of crop species and varieties for tolerance to soil aluminium. Soil acidity (toxic Al) is the main limiting factor to crop production on soils in this region. The determination of tolerant species and varieties could result in lessening the costly, though economical, lime inputs. Promising rice, cowpea and groundnut varieties have been identified by Piha and Nicholaides, (1981). These efforts are continuing.

2) Use of orqanic inputs to supplement the costly, though economical, inorganic fertilizer inputs. This research thrust includes mulching crops with residues from previous crops or from guinea grass (Panicum maximum). Generally, detrimental though non-conclusive results have been found for upland rice, with some positive yield increases in maize, and little or no effect on soybean and groundnut after 20 experiments (Valverde and Bandy, 1982).

3) Use of kudzu (Pueraria phaseoloides) as a green manure. This approach has provided some positive results often giving crop yields similar to those with complete fertilization (Wade, 1978). However, the inordinate amount of labour required to hand harvest, transport and incorporate the kudzu into the soil has made this an unattractive approach to small farmers.

4) Managed kudzu fallow as an intermediate stage between shifting and continuous cultivation. Since kudzu is easily established on the acid, infertile soils

developing a lush green canopy with an abundance of N-fixing nodules on its roots and easily killed by slash and burn after one or two years of fallow, reasonable crop yields have been obtained by rotating one or two crops with 1-2 years of kudzu fallow (Bandy and Sanchez, 1981b). During the second rotation, however, K fertilization was needed to obtain moderate crop yields. There was considerable effect of the residual fertility on the plots on which the kudzu was established.

5) Utilization of compost from crop residues. Only a 20% yield reduction was observed for the first four consecutive crops when complete fertilization was replaced by compost produced from various crop residues and use of the residual fertilizers in the soil (Bandy and Nicholaides, 1979). However, it was necessary to apply K fertilizer with the compost to maintain these yields on the sixth and subsequent crops. The high labour requirements of this practice may also restrict its potential.

6) Increased efficiencies of N and K fertilizers and use of rock phosphate. Cooperative research is being conducted with the International Fertilizer Development Center (IFDC) and the International Center for Tropical Agriculture (CIAT) in these areas. The use of rock phosphate compared with the more costly, though economical, phosphate fertilizers on these acid soils is promising as a new component, but will require more research.

Low Input Legume-Grass Pastures

There is much clearing in the Amazon Basin for pasture development (Myers, 1980) since there is much demand for beef products in the Amazon Basin countries. However, many of these attempts at pasture establishment often fail, with adverse ecological consequences. Therefore, it is appropriate that improved pasture production technologies be developed for this region.

Low input legume-grass pasture production technologies are being developed by the NCSU/INIPA Yurimaguas Program primarily for use on acid, infertile soils on sloping lands. Acid-tolerant legume and grass species selected by CIAT’s Tropical Pasture Program (Toledo and Serrao, 1981) are being utilized. The Program has found promising germplasm adapted to Ultisols with pH values of 4.0 and 80% aluminium saturation. Only 11 kd P as simple superphospate are required per hectare. Included among these adapted species are the legumes Desmodium ovalifolium, Centrosema pubescens, and Pueraria phaseoloides, and the grasses Brachiaria decumbens, Andropogon gayanus and Brachiaria humicola. Combinations of these and other legume grass pastures have been (Ara et al., 1981) and are being tested under grazing pressure, though it is too early for definitive results.

Agroforestry

The use of indigenous and sometimes imported tree species is considered vital to the development efforts of the Amazon Basin and is beginning to receive more international attention. Collaborative research with the International Council for Research on Agroforestry (ICRAF) is being conducted in Yurimaguas and various areas of the Amazon Basin to combine crop production systems at various input levels with promising tree species that can produce food, oil, or pulpwood. Included in these species are peach palm (Guilielma gasipaes), oil palm (Elaeis guineensis), and the pulp producing Gmelina arborea and Pinus caribaea. An apparently very acid-tolerant Parkia spp. is also being investigated as an alternative to Leucaena leucocephala which is not adapted to the acid soil conditions. Other innovative agroforestry systems and approaches for similar soils are being developed by UEPAE/EMBRAPA near Manaus (UEPAE/EMBRAPA, 1979-1981) and by the University of Wisconsin (Denevan et al., 1983).

Paddy Rice on Alluvial Soils

The Amazon Basin's relatively fertile alluvial soils , which are only rarely subject to flooding, have great food production potential. Their inherent fertility and proximity to the natural transportation routes stress their importance. Without eliminating shifting cultivation, farmers have used improved rice varieties and spacing (Sanchez and Nurena, 1972) to double rice yields. Our paddy rice research at Yurimaguas, begun in 1981, is now developing the most suitable production technologies for these alluvial soils. Soon after this research began, a spontaneous cooperative of approximately 35 farm families sprang up across the river from Yurimaguas and began production of paddy rice. Now, several hundred hectares of land on fertile alluvial soils is under cultivation by this cooperative which has large expansion plans.

IMPLICATIONS

Both spontaneous and government-directed colonizations due to increased demand for food within and outside the countries of the Amazon Basin will continue to increase clearing of the region's forest. Development, extension and use of agronomically and economically feasible continuous cropping technologies such as the "improved Yurimaguas technologies", provide an alternative heretofore unavailable for the small shifting cultivators of the Upper Amazon Basin. These small farmers could play a positive role in increasing food production in the region and at the same time in preserving much of the upper Amazon Basin's ecological integrity by continuously cropping their lands. However, the indigenous people, settlers and especially governments of the Amazon Basin countries must make rational; decisions for this increased agricultural production to take place with no adverse ecological consequence.

The improved Yurimaguas technologies provide means by which some of these decisions can be made. Whether or not they will be made yet remains to be seen. However, what is beyond any doubt is that attempts to produce food crops or pastures without the correct technologies for the acid, infertile soils will fail and will cause widespread ecological damage. The development, extension and use of appropriate alternative technologies for these soils for sustained continuous crop pasture or agroforestry production can occur on these cleared lands and is the key to preventing this former scenario.

Although the NCSU/INIPA Yurimaguas Program has developed some of these technologies for continuously cropping the relatively level Ultisols of the upper Amazon Basin, many necessary components of these systems have yet to be found. The value of long-term field research cannot be overemphasized. Second, third, fourth, and fifth generation problems do not appear in the first years of continuous cultivation. Some of the answers to longer term continuous cultivation of annual crops on these soils would not now be available to the farmers if the initial research of the NCSU/INIPA team had been deemed a success and ended after one, two or even five or eight years.

Also needed to be found are technologies for continuously cropping the Amazon Basin’s relatively level Oxisols. Current research is being conducted by several organizations in this area including a cooperative NCSU/EMBRAPA/Rockefeller Foundation programme located at UEPAE in Manaus, Brazil. But, several more years of research will be required before any systems developed are judged to be adequate to extend to that area’s farmers. Lower input technologies, improved pasture production and agroforestry systems must also be developed for the various regions of the Basin to provide alternatives for the people therein. Again, the improved Yurimaguas technologies are only several of many components which will be necessary for increasing food production and minimizing ecological alteration in the Basin.

Limitations

As the NCSU/INIPA research has concentrated on nearly level soils thereby avoiding the erosion hazards of cultivating the undulating lands, it would be incorrect to infer that the continuous cropping technologies described herein are directly applicable to all Ultisols and Oxisols in the Amazon Basin. Adaptation and modification of the improved Yurimaguas technologies to more sloping lands is needed. Perhaps terraces as practised in many areas of humid tropical Asia, perhaps mulching crop residues or even alternating annual crops with pastures will be some ways of addressing these issues. Certainly other options would include continual legume grass pastures and/or agroforestry.

In the opinion of the senior authors, it would be better to leave the forest on the sloping soils pristine, and to concentrate food production on the level, well-drained 17 million hectares of fertile soils and on the level, well-drained 207 million hectares of acid, infertile soils of the Amazon Basin.

Other limitations to the widespread use of the improved Yurimaguas technologies are socio-economic. The Yurimaguas socio-economic conditions described herein do indicate clear economic feasibility for the improved technologies; however, an inelastic demand for products, limited market, different cost:price ratios, government policy changes and many other factors could make the technology unattractive economically. It will be necessary for any region considering adoption of the Yurimaguas technologies to make site-specific economic interpretations based on local and national factors.

Agronomic conditions also differ within and among regions. Prior to other implementation attempts, the improved Yurimaguas technologies must be tested through site-specific adaptive research trials. Certainly modifications in the improved technologies would include crop species, varieties, rotations, planting dates, different fertilizer and lime rates. Some type of soil fertility evaluation and improvement service to assist farmers in changing from shifting to continuous cultivation will be vital to these adaptive research trials and consequent implementation.

Potential

The potential of the improved Yurimaguas technologies is that, once the limitations are realized and addressed successfully, the indigenous people, the settlers, the governments in the Amazon Basin will have available the means to increase food production while sparing many thousands of hectares of forest.

The clearing of the Amazon Basin’s forest is not done because the farmers enjoy it. Anyone who has participated in some of the clearing, learns that slash and burn clearing is excruciatingly hard work. To repeat this system every two years is almost back-breaking. The farmers clear the rainforest because they need to produce food for their families and their livelihood. If they can produce more food, more economically with less work, they will do so without hesitation. If they cannot, then we will see the Amazon Basin’s forest continue to fall under the shifting cultivator’s axes. The improved Yurimaguas technoloqies offer an agronomically, economically and ecologically attractive alternative to that scene for certain areas of the Amazon Basin.

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AGROFORESTRY AS AN ALTERNATIVE TO SHIFTING CULTIVATION

by

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THE SCENARIO OF SHIFTING CULTIVATION

Shifting cultivation has stood the test of time as a land use system. It is still the mainstay of traditional farming systems over vast areas of the tropics. Although it has been criticized for being wasteful and inefficient and for causing soil degradation and declines in soil fertility, it is the most widespread farminq system in the tropics, extending over approximately 30 percent of the exploitable soils of the world (360 million ha) and supporting over 250 million people, about 8 percent of the world's population (FAO/SIDA, 1974). In general, all forms of shifting cultivation (Watters, 1960) follow five stages: site selection, clearinq, burning, cropping and fallowing. The clearing and burning of vegetation release nutrients (Nye and Greenland, 1960; Sanchez and Salinas, 1981) that are used for subsequent food production. The cropping period varies from one to three years. With declining soil fertility, increased weed infestation, etc., crop yields begin to drop, forcing land users to abandon their sites and look for other areas. The abandoned site reqains its productivity over the following crop-free (fallow) period, and the shifting cultivator returns to the site after a wait.

Traditionally, the fallow period was long enough to restore soil fertility, and therefore the resumption of croppinq on a piece of land did not damage soil productivity in any lasting way. Most shifting cultivators had sufficiently clear ideas about requirements for growth of both crop and fallow period vegetation. Furthermore, the mosaic arrangement of cropped and fallow areas allowed fallow areas to act as "sinks" for any soil washed away from the cropped area, and so minimized soil erosion. Shifting cultivation continued as a sustainable system. However, over the years, several factors have increasingly placed a strain on shifting cultivators as well as on the system as a whole. Some factors restricting shifting cultivators' territorial range include: increased population growth; qovernmental restrictions on forest reserves; water catchment areas; changes in land tenure laws leading, in some cases, to increased private land ownership; large-scale migration and resettlement of people due to wars and calamities; introduction of cash crops. Consequently, the length of the fallow period has been reduced so dramatically that the soil is unable to support vegetative regrowth (see for example, Lagemann, 1976). The resulting inadequate vegetative cover, and absence of the traditional mosaic structure of crop and fallow fields accelerate soil erosion. Thus a new system of "shifting agriculture" has emerged that severely impoverishes and degrades the soil (Kundstadter et al., 1978; Hamilton, 1983).

Nevertheless, shifting cultivation is so widespread and so important to the livelihood of so many people that it will be virtually impossible to dispense with it completely. The only alternative seems to be devising land management systems that reduce the fallow period or eliminate it altogether while retaining its beneficial effects. Such systems should allow simultaneous production of food and wood products from the same piece of land, should not depend on high-cost inputs, and should conserve the ecosystem. In addition, the systems should enable the land user to sustain production and should be compatible with the socio-cultural aspirations and economic conditions of the people. Agroforestry is such an approach to land use.

AGROFORESTRY

Agroforestry is the name given to land use systems based on age-old practices of intentionally mixing or retaining trees in crop/animal production fields. It combines agriculture - both crop production and animal production - with forestry, in sustainable production systems, on the same piece of land, either simultaneously or sequentially. Since a modern concept of agroforestry is only now being developed, a universally acceptable ldefinition has not yet been agreed upon although several have been suggested. - One of the more recently coined definitions is "Agroforestry is a collective name for land use systems and practices where woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used on the same land management unit with agricultural crops and/or animals, either in some form of spatial arrangement or temporal sequence. In agroforestry systems there are both ecological and economical interactions between different components."

Whatever the definition or practice, agroforestry is a type of integrated land use particularly suited for marginal areas and low-input systems. The objective and rationale of most agroforestry systems are to optimize the interactions between the woody components with the crop nd/or with the animal component in order to improve the total quantity, diversity and sustainability of production, over what is usually obtained with other forms of land use under prevailing social, ecological and economic conditions.

While the term agroforestry is relatively new, it encompasses principles of some ancient practices including the shifting cultivation and the bush fallow systems. Our knowledge of it is incomplete, however, and quantitative information on its potential, from actual field observations and studies is far from satisfactory. Governments and international aid agencies are showing tremendous enthusiasm for undertaking agroforestry development projects in various parts of the world. They need to identify agroforestry systems and technologies capable of solving land management problems. Since agroforestry emphasizes sustainable production of food and wood products, potential agroforestry technologies will have to be both productive (of basic needs) and protective (of the environment).

PRODUCTIVE ROLE OF AGROFORESTRY

Food production systems

One of the most promising agroforestry technologies, applicable to many situations, is hedgerow planting of woody perennials in crop production fields, growing the crops in spaces or alleys between the hedgerows. The woody species . is pruned periodically during the growing season to prevent shading and to provide green manure. Promising results have been obtained from this type of system in studies conducted at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria (Wilson and Kang, 1981), where the practice is called "alley cropping." The most promising combination based on those trials, is Leucaena Leucocephala/maize.

The main advantage of alley cropping is that it is an organized form of "bush fallow" in which selected species are planted in orderly patterns. The use of Leucaena tops maintained the maize yield at a reasonable level, even with no nitrogen input, on a low-fertility sandy Inceptisol. The nitrogen contribution by Leucaena mulch on maize yield was equivalent to about 100 kg/ha _1/ for every 10 t/ha 1/ of fresh prunings (see Table 1).

1/ For example, see Aqroforestry systerms, vol. l, pp. 7-12, 1982.

Table 1

EFFECT OF APPLICATION OF NITROGEN AND LEUCAENA PRUNINGS ON GRAIN YIELD OF MAIZE VARIETY TZPB GROWN IN ALLEY BETWEEN LEUCAENA HEDGE ROWS (Kang et al., 1981)

Nitrogen rates (kg N/ha)	Leucaena pruninqs added at time of planting (fresh weight, tons/ha)		
	_1/ 0	_2/ 5	_3/ 10
0	2 109	2 732	3 221
50	2 572	3 166	3 256
100	3 377	3 450	3 432
LSD.05	296		

1/ Leucaena tops from two pruninqs carried out during maize growinq seasons were applied as mulch to all treatments.

2/ Prunings were removed from this treatment at planting.

3/ Supplemented with Leucaena prunings from outside the experimental area.

Evaluatinq available data on this type of experiment, Torres (1983) concluded that Leucaena hedqerows planted at rows more than 150 cm apart, 25 cm between plants, and cut at 15-30 cm heiqht at intervals of 8 weeks would yield an averaqe of 45 q N per annum for every metre length of the hedgerow.

The hedqerow cropping system has the advantaqe of incorporating a woody species in an arable farming system without impairing soil productivity and crop yields. Several species of woody legumes might contribute nutrient (N) suggesting many choices for species to integrate into crop production systems. By adjustinq the inter-row spacing of the woody species, mechanized equipment could be used. Moreover, trees can be cut back and kept pruned during the cropping period and leaves and twigs applied to the soil for mulch and nutrients. Bigger branches can be used for stakes or firewood. Research on these aspects of hedgerow cropping is in proqress at various places around the world.

In dry reqions

The traditional farminq system in West African millet and groundnut producing areas includes the integration of trees such as Acacia spp. Althouqh the basic system of bush-fallow remains the same throughout the dry savanna reqions, variations can be found (Seif-el-Din, 1981). Felker (1978) prepared a comprehensive cataloque of farming practices involving Acacia albida in the region. He concluded that in the infertile sandy soils of the Senegalese qroundnut basin, crop yieldslof qroundnuts and millet increased from 500 + 200 kg ha to 900 ± 200 kq ha directly under A. albida foliage. In addition to a 50-100% increase in soil orqanic matter and nitrogen content, soil microbiological activity and water-holdinq capacity also improved. The author further sugqested that ,A. albida on farms could increase land carryinq capacity from 10-20 persons/km to 40-50 allowing farmers to settle more permanently by eliminating the need for fallow periods.

Another notable example is that of Prosopis cineraria, known locally as Khejri in the arid North-Western parts of India, where there is a long tradition of growing pearl millet (Pennisetum glaucum) under Khejri trees. Results of investigations conducted at the Central Arid Zone Research Institute, Jodhpur, India, over the past 20 years on the various aspects of the Khejri tree have been compiled in an excellent monograph (Mann and Saxena, 1981. One of the results, on the nutrient content of soils under the tree and in the open is given in Table 2.

Table 2 NUTRIENT CONTENT OF SOILS UNDER PROSOPIS CINERARIA TREES AND IN THE OPEN IN ARID REGIONS OF INDIA (Singh and Lal, 1969)

Site	Org. C (%)	Total N (%)	Total P (mg/100 g)	Total K (mg/100 g)
0-30 cm			3.82	12.20
under tree	0.37	0.045		
open area	0.25	0.038	1.52	7.52
31-60 cm				
under tree	0.11	0.020	1.95	9.31
open area	0.04	0.010	1.23	6.36

These two cases demonstrate the possibilities for woody perennials in food production systems in two distinct ecological regions. There are several other possibilities for incorporating trees on farmlands (Nair, 1983a) as well as for trees themselves providing basic foods.

Ener (fuelwood) roduction s stems

The seriousness of the fuelwood shortage problem is now well known. As forests and woodlots disappear, people in rural areas must spend more time collecting fuel, often at the cost of less work on the land for food. Another consequence of this is that people burn dung and crop wastes that could better be used as manure and/or mulch. In such areas, agroforestry has a great role to play. Trees incorporated on the farmlands in food production systems or for soil amelioration could also provide much-needed fuelwood. Based on a study on the wood fuel supply from trees outside the forests in the highlands of Kenya, van Gelder and Poulson (1982) emphasized the importance of agroforestry and identified several woody species for the purpose. They calculated that a 2-ha farm, with a tenth of the area under woodlot, one hedgerow protecting the outer boundary and another one surrounding the homestead, and the “usual” spread of farm trees over the remaining area, could provide enough fuelwood to meet the requirements of an average family. Several fast-growing fuelwood crops, suitable for different environmental conditions, have been identified (NAS, 1980), and most of them combine well with conventional agricultural crops.

Livestock production systems

These are the “silvopastoral systems”, which deliberately mix trees and pasture. The woody component in silvopastoral systems could provide either fodder to improve livestock productivity, or another commodity such as fuel , fruit, or timber. Based on this "productivity objective", silvopastoral systems can be grouped into browse grazing and forest/plantation grazing systems.

The browse grazing systems, in which the woody components provide fodder mainly as a protein-rich supplement during the dry season(s), are especially suitable for arid and semi-arid zones. Such systems are found in dry regions throughout the world: India (Muthana and Shankarnaryan, 1978); Africa (Lamprey et al., 1980); America (Elgueta and Calderon, 1971); and Oceania (Moore, 1972). With proper management of the silvopastoral systems any dry season feed gap could be reduced, if not eliminated, and sustainable management systems developed for land which would otherwise be wasted. Two techniques appear particularly promising in these situations:

i. planting multipurpose fodder trees in grazing areas, and as hedgerows in and around crop fields;

ii. a cut-and-carry forage production system to increase pen feeding of livestock. This would improve nutrition in the dry season and increase the amount of collectable manure.

The woody components in the forest/plantation grazing systemms are used mainly for timber (forestry) or other commerical produce (plantation crops). While forest grazing is particularly popular in Australia and New Zealand (Batini, 1978; Borough and Reilly, 1976), plantation grazing is common in most of the coconut-growing areas (Plucknett, 1979; Reynolds, 1980) and to some extent in rubber plantations (Wan Embong and Abraham, 1976). In certain instances, the woody component will also have a "service role", benefitting animals directly (e.g., shelter), or indirectly (e.g., by the effect of the tree canopy on understorey grass growth) (Kennard and Walker, 1973).

PROTECTIVE ROLE OF AGROFORESTRY

The protection given by agroforestry consists of soil improvement and soil conservation provided by the woody components. The avenues through which woody perennials could improve and enrich soil conditions include: fixation of atmospheric nitrogen (mainly by leguminous species); addition of organic matter through litterfall and dead and decaying roots; modification of soil porosity and infiltration rates leading to reduced erodibility of soil and improving the efficiency of nutrient cycling within the soil-plant system (Nair, 1983b). The main protective function of woody perennials, however, rests in physical conservation of the soil.

Soil conservation

Tree planting along contours is widely recommended, to reduce runoff and to protect terraces, wherever physical soil conservation measures are adopted (for example, see Wenner, 1980). The soil conservation benefit of woody perennials can be conveniently exploited in agroforestry if the species provides additional benefits and outputs such as fodder, fuel, wood, food, etc. For example, in Southeast Asia, especially Indonesia, there is a long tradition of planting Leucaena leucocephala in contour hedges for erosion control and soil improvement. Indirect terraces are also formed when the washed-off soil collects behind hedges (see Figure 1). These contour rows of Leucaena survive the long dry season because their long taproots reach water deep in the ground. Loppings and prunings from such hedgerow species could also provide mulch to help prevent sheet erosion between trees. An example of this in practice is found in the GTZ (Germany) - sponsored project in Nyabisindu, Rwanda (Zeuner ,

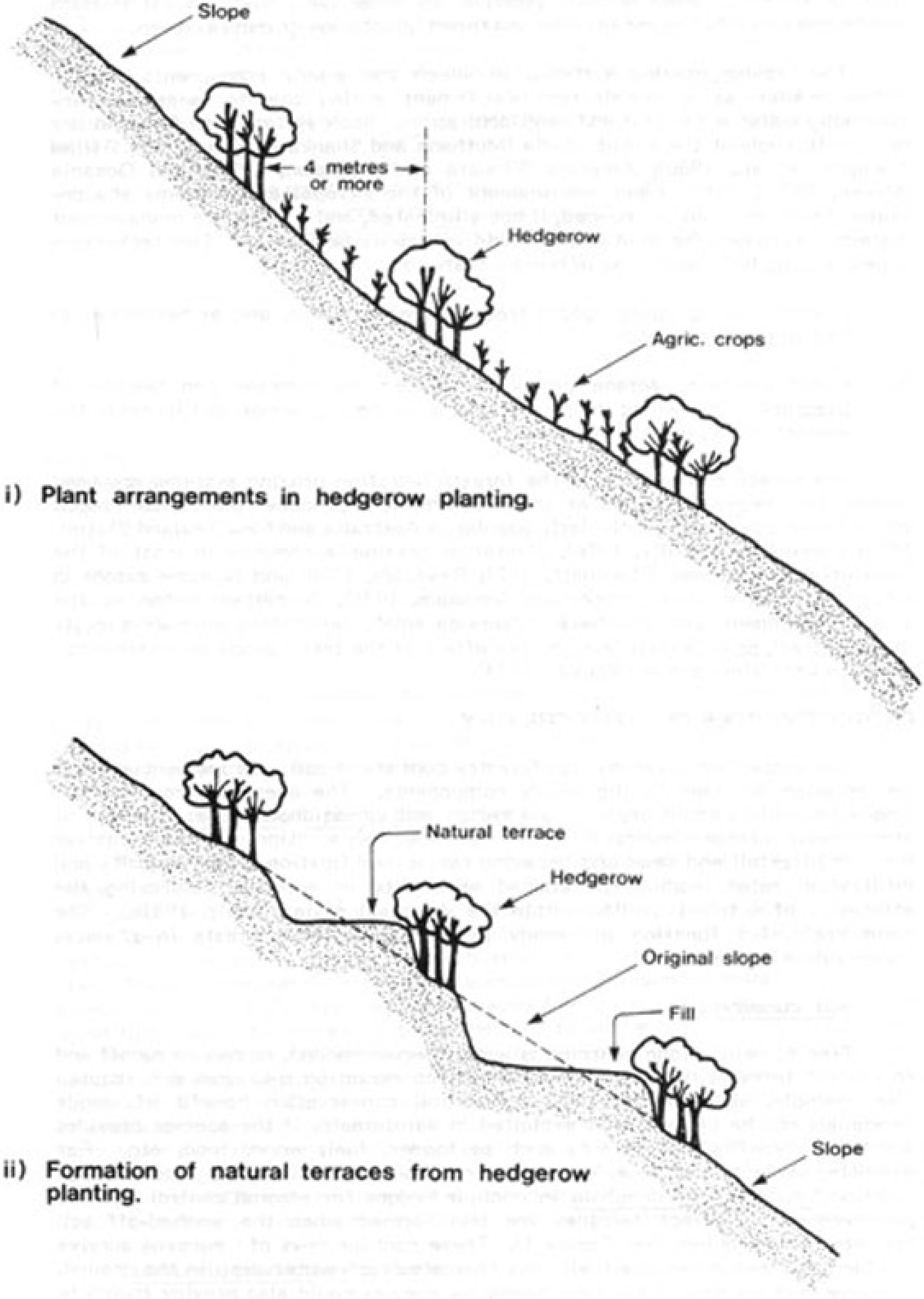

Fig. 1 Hedgerow planting for soil conservation (adapted from Vergara, 1982)

1981; Neumann, 1983). More plant cover on the soil, either live or as mulch, also reduces the impact of raindrops on the soil and thus minimizes splash and sheet erosion. Therefore, as pointed out by Lundgren and Nair (1983), agroforestry conserves the soil not only when woody perennials block erosion, but also by providing mulch and/or fodder and fuelwood at the same time.

Shelterbelt and windbreaks

Continuously blowing moderate to strong winds, as found in coastal areas, high plateaus and mountain tops, can directly and indirectly harm plants. Direct effects are often obvious in the physical deformation of plant parts and in their growth patterns. Indirect effects deal mainly with the water balance of plants and moisture content, erodibility and other properties of the soil. Use of trees and other woody perennials to protect agricultural fields from these effects of wind is widespread in many agricultural systems. The principle can be of considerable value in developing sound agroforestry technologies for areas prone to wind damage. Here again, it is important to select appropriate species of woody perennials and manage them suitably in order to obtain other outputs from them, in addition to the windbreak/shelterbelt effects. Very encouraging results in this area have been obtained from studies conducted at the Pakistan Forestry Research Institute, Peshawar (Sheikh and Chima, 1976; Sheikh and Khalique, 1982). Darnhofer (1982) examined physical, ecological and biological considerations in the design of agroforestry shelterbelts, and felt that design has to be site-specific, depending on a large number of factors including the components of the farming systems (crops/livestock), desired pattern of windbreak (simple, multiple or successive, network system, i.e. with or without secondary hedgerows). The choice of woody perennial species for windbreak is also very important. As in other agroforestry systems, it will depend upon the species' phenology, growth habits, adaptability to multiple purposes, and compatibility with other species.

WOODY PERENNIAL SPECIES FOR AGROFORESTRY

Plants, especially woody species, that have been infrequently studied until now may prove themselves to be very valuable for agroforestry. Prime candidates will be those that grow well with other species, that can thrive in environments too harsh for most other species, that simultaneously yield several products (food, fuel, fodder), that improve the environment (e.q. through soil conservation), and that enrich the micro-site, for example by nitrogen fixation, efficient nutrient cycling or addition of organic matter to the soil through litterfall and root exudates and decay. Growth habits of both the above and below-ground parts of the species are also significant. WWith this long list of attributes, it would be possible to prepare a check-list of characteristics, or to suggest some types of woody plants for agroforestry. Although such approaches are certainly useful to the long-term selection process, expediency demands that we look for some of these characteristics in trees commonly existing in agricultural lands - either mixed with agricultural crops or otherwise deliberately retained. Such studies have recently been made for the humid and semi-arid areas of Kenya (G. Poulson, personal communication, 1981; A. Getahun, personal communication, 1982), and essential attributes and ecological requirements of about 100 woody species potentially suitable for agroforestry have been compiled. Okigbo (1977) has described the significant role, until now neglected, played by various plants, in traditional farming systems in the humid lowland tropics of Wlest Africa. The U.S. National Academy of Science publications on underexploited tropical plants (1975) and firewood crops (1980), and some other puhlications (e.g. Kaul, 1970; Ritchie, 1979) describe several such species possihly valuable in agroforestry.

TABLE 3: SOME CHARACTERISTICS OF A FEW MULTIPURPOSE WOODY PERENNIALS WITH A POTENTIAL AGROFORESTRY ROLE IN VARIOUS ECOLOGICAL ZONES

MAJOR ECOLOGICAL ZONE	SPECIES	ECOLOGICAL ADAPTABILITY				MANAGEMENT ASPECTS			
		ALTITUDE (m.a.s.l.)	RAINFALL RANGE (mm/yr)	MAXIMUM DRY PERIOD (months per year)	SOIL CONDITIONS	ESTABLISHMENT	SEED TREATMENT	CARE	COPPICING ABILITY
ARID/SEMI-ARID	*Acacia albida*	up to 1200 m	300 - 800	6-8	Sandy/silty well drained soils; good tolerance to salinity	Seedlings	Hot water (80°C) & soak for 24 hours	Weeding	poor
	A. senegal	up to 1700 m	200 - 800	8-11	Sandy or well drained soils. Poor tolerance to waterlogging.	Seedlings	Hot water (80°C) & soaking 24 hours	Weeding	good
	Balanites aegyptiaca	up to 1500 m	200 - 1000	6-8	Most sandy/stony soils including black cotton soil.	Seedlings	Stone must be cracked		good
	Parkinsonia aculeata	up to 1300 m	300 - 1000	9	Sandy/gravelly soils. Good tolerance to high alkalinity and salinity. Poor tolerance to waterlogging.	Seedlings, shoot or root cuttings	Scarified & soaked in water 24 hours		
	Prosopis cineraria	up to 1000 m	75 - 850	8-10	Grows on sandy/rocky soils. Tolerates pH 9.0 and good tolerance to waterlogging and salinity.	Seedlings or root suckers	Scarified & boiling water & soak	Good tolerance to weeds	good
	Ziziphus mauritiana	up to 600 m	300 - 2000	8-10	Wide variety of soils. Good tolerance to high alkalinity.	Direct seeding	Seed should be cracked		good
HUMID/SUB-HUMID	*Acacia auriculiformis*	up to 600 m	1000-1600	4-6	Wide range of soils including Uranium and tin mining spoils pH range 3.0-9.5	Direct seeding or seedlings	Boiling water & soak 24 hours	Weeding	poor
	Calliandra calothyrsus	up to 1500 m	1000-2000	3-4	Wide range of soils. Good tolerance to flooding.	Direct seeding or seedlings	Boiling water soak 24 hours	Good tolerance to weeds	excellent
	Gliricidia sepium	up to 1600	2300	2-3	Does well in moist or dry soils even when very alkaline.	Seedlings or large cuttings	Hot water (80°C) & soak 24 hours		good
	Leucaena leucocephala	best below 500m	250-1700	5-6	Wide range of soils pH range 5.0-8.0 but poor growth on acid soils. Poor tolerance to flooding.	Direct seeding or seedlings	Hot water (80°C) & soak 48-72 hours	Weeding	good
	Albizia lebbek	up to 1600 m	500 - 2000	2-3	Grows best on well drained soils. Good tolerance to salinity and salt spray.	Direct seeding/ seedlings/cuttings	Boiling water & soak 24 hours	Weeding	good
	Sesbania grandiflora	up to 800 m	1000-2000	2-3	Wide range of soils. Good tolerance to flooding.	Direct seeding/ seedlings/cuttings	none	little maintenance	good
TROPICAL HIGHLANDS	*Acacia mearnsii*	up to 1100 m	500 - 1000		Cannot tolerate calcareous soils	Direct seeding	Boiling water & soak 24 hours		
	[illegible]	up to 2000 m	350-600	8	Most soils - acid or alkaline. Exceptional tolerance to flooding or drought.	Seeds/seedlings/ root cutting		Good tolerance to weeds	
	Alnus acuminata	up to 3200 m	1000 - 3000		Best on well drained alluvial soils but grows on gravels/ sands/clays.	Seedlings	None. Short seed viability	Weeding	good
	Grevillea robusta	up to 2300 m	400 - 2300	6-8	Grows well in most soils. Prefers deep soils. Does not tolerate waterlogging.	Direct seeding or seedlings	none	Good tolerance to weeds	poor
	Prosopis chilensis	up to 2900 m	200 - 700	8-11	Sandy/gravel and even shallow soils. Good tolerance to salinity.	Direct seeding or seedlings	Scarify & soak 24 hours		
	Trema orientalis	up to 2000 m	2000 - 2500		Most soil types. Colonize denuded, fallow or poor soils.	Direct seeding/ cuttings	Refrigerate 2°C for 3-4 months	Good tolerance to weeds	good

* *A reference list for the above species is available from the authors.*

TABLE 3 (CONTD.)

* FAIR
** GOOD
*** EXCELLENT

MAJOR ECOLOGICAL ZONE	SPECIES	FOOD: Fruits/Pods	FOOD: Nuts/Seeds	FOOD: Vegetable	FOOD: Oils/Fats	FOOD: Starch	FOOD: Spices (S)/ Condiment (C)	FODDER: Leaves	FODDER: Fruits/Pods/Seeds	FODDER: Shoots	FODDER: Bee Forage	WOOD: Fuel Wood	WOOD: Charcoal	WOOD: Building Material	WOOD: Wood for Utensils & Tools	WOOD: Sawn Timber	WOOD: Others	SERVICES: Windbreak	SERVICES: Live Fences	SERVICES: Soil Conservation	SERVICES: Dune Fixing	SERVICES: N Fixing	SERVICES: Organic Manure	SERVICES: Mulch	SERVICES: Other	OTHER: Waxes	OTHER: Essential Oils	OTHER: Tannins (T) Dyes (D)	OTHER: Gums	OTHER: Fibres	OTHER: Medicinal/Drugs	OTHER: Cultural, Ritual Social	OTHER: Ornamental	OTHER: Other	REMARKS
ARID/SEMI-ARID	*Acacia albida*							*	*	*	*	*	*	*	*					**	*	*	*					*					*		
	A. senegal							*	*	*	*	**	**	*	*					*	*	*						*	**						Gum Arabic
	Balanites aegyptiaca	*		*	*			*	*	*		*		*	*																*				
	Parkinsonia aculeata	*						*	*	*		*	*						*	*													*		Sericulture, Shellac
	Prosopis cineraria							**		*		***	**	*	*					*	**														
	Zizyphus mauritiana	*						*	*			*	*		**				*	*		*					*				*				
HUMID/SUB-HUMID	*Acacia auriculiformis*											**	**	*			pulp											*					*		
	Calliandra calothyrsus							*				*								**		*	*										*		
	Gliricidia sepium							*			**	*		*	*	*			**			**											*		Toxic to Horses
	Leucaena leucocephala		*	*				*	*	*	*	*	*	*				*	*	**		*	**	*											
	Albizia lebbeck							**		*	**	*		*		*				*													*		
	Sesbania grandiflora	*		*				*	*			*					pulp	*	*	*			**					*	*						
TROPICAL HIGHLANDS	*Acacia mearnsii*											*	*				pulp			*			**					*** (T)							
	Ailanthus altissima											*	*	*	*			*		**													**		
	Alnus acuminata											*		*	*	*				**		*													Shade over tea + coffee
	Grevillea robusta										**	*		*		*																	*		
	Prosopis chilensis	*						*	*	*		*			*							*													
	Trema orientalis							*	*			*	*	*			pulp			*		*													Shade over tea + cocoa

A promising group of woody perennials of tremendous value in agroforestry are the fast growing nitrogen fixing trees, mostly legumes. The greatest advantage of these species is their ability to “fix” rather substantial guantities of atmospheric nitrogen. For example, Leucaena leucocephala has been observed to yield from 70 to 500 kg nitrogen per hectare annually under various conditions (Vergara, 1982). In addition, some non-leguminous tree species are capable of fixing nitrogen giving them tremendous potential in agroforestry; examples are Casuarina, Alnus, and Parasponia.

A summary of characteristics and descriptions of a few woody species with a potential role in agroforestry in different ecological regions is given in Table 3. Undoubtedly, one of agroforestry’s most important opportunities lies in tapping the hitherto unexploited potentials of these numerous types of multipurpose trees and shrubs. A number of steps are being taken. At the recently established (1980) ICRAF Field Station at Machakos in Kenya (semi-arid, 700 mm rainfall per annum, 1 500 m above sea level, good but erodible soils), over 30 species of multipurpose trees have been planted so far, with plans for more. Similar initiatives are also being undertaken by several other agencies. And, in order to initiate systematic studies on such species, a consultative meeting on multipurpose tree germplasm collection and evaluation was held by ICRAF and the US National Academy of Sciences in Washington, D.C., in June 1983.

AGROFORESTRY INTERVENTIONS FOR IMPROVING SHIFTING CULTIVATION

The foregoing analysis of the productive and protective role of agroforestry leads to some general conclusions about agroforestry options for different ecological regions. These are summarized in Table 4. Basically, there are two approaches: incorporating trees on farmlands according to different tree/crop proportions; and integrating crop/animal components with monocultural stand of trees as in forests and plantations. For any of these systems or practices, a wide variety of woody perennials (see Table 3) could be combined with appropriate crop and/or animal components. Special mention is not made of such agricultural (crop/animal) components, however, because farmers will generally use the species with which they are familiar. This should minimize the farmers’ and shifting cultivators’ usual resistance to and doubts about, unfamiliar technologies.

It is probable that these agroforestry technologies, which place very little emphasis on costly resources are likely to be socially usable and environmentally acceptable. However, expectations about the outcome and output levels of agroforestry should not be too high. Since the technologies are very location-specific and appropriate choices depend on a number of local factors, the degree of success varies. Since these systems encompass elements of shifting cultivation, however, and at the same time strive to reduce its drawbacks and alleviate its disadvantages, they could be viable and feasible alternatives to shifting cultivation in certain situations.

TABLE 4. GENERAL INDICATIONS ON AGROFORESTRY ALTERNATIVES TO SHIFTING CULTIVATION

Agroforestry		General indications on the feasibility in		
Systems	Practices/Technologies	Semi-arid regions	Humid and sub-humid areas	Tropical highlands
Agro-silviculture	a) Hedgerow planting (alley cropping) with fast growing woody perennials	Depends on rainfall pattern: to be careful about termites	Very good	Very good, especially when combined with or as soil conservation measure
	b) Multipurpose trees on farm-lands	Good possibility for extensively managed systems	Good possibility for intensively managed systems	Good
	c) Livefences/shelterbelts/windbreaks	Very good	Good	Site specific
	d) Cut-and-carry mulch production (zonal agroforestry)	Desirable	Site-specific	d & e: Depends on slope; areas unsuitable for crop production could be used for wood-lots for mulch/fodder production
	e) Agroforestry fuelwood production	Good	Highly desirable	
	f) Various forms of multispecies plant associations around dwellings (home gardens)	Highly desirable	Highly desirable	Highly desirable
	g) Overstorey shade for shade-tolerant commercial crops	Limited	Feasible	Highly desirable
Silvopastoral	a) Grazing in forest/plantations	Good	Good	Very good
	b) Commercial/shade/fruit trees in pasture	Limited	Very good	Very good
	c) Multipurpose fodder trees	Good	Good	Good
	d) Cut-and-carry fodder production	Desirable	Site-specific	Same as cut-and-carry mulch production
Agro-silvo-pastoral	a) Crops and grazing in plantation	Site-specific	Very good	Site-specific
	b) Multipurpose trees with crops/animals	Good	Site-specific	Good
	c) Woody hedgerows with perennial grasses for mulch production and soil conservation	Site-specific	Good	Very good
	d) Crop/tree/livestock mix around homesteads (home gardens)	Very good	Very good	Very good

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THE TAUNGYA SYSTEM IN SOUTH-WEST GHANA

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The taungya system, as it was developed in Burma, involves peasant farmers in afforestation or reforestation. This system interplants trees with agricultural crops, particularly the local population's staple foods, and so serves to satisfy the farmer's quest for arable land.

The taungya system was introduced in Ghana about fifty years ago, and it has since been modified. The usefulness of taungya depends upon two conditions: a degraded forest or one that is poorly stocked in economically valuable species (in Ghana mainly the Meliaceae); and a scarcity of arable land.

This study uses a rather narrow definition of intercropping agricultural and forestry crops without regard to who owns the agricultural crop, so as to bring out variations. It also sees the Tropical High Forest Zone in the country as covering South-West Ghana.

THE EXTENT OF THE ZONE AND LOCALITY FACTORS

The Tropical High Forest extends approximately 83 000 km2, a third of the country. This is the total area in which the climatic and edaphic factors can support a Tropical High Forest; the actual area of forested land has been estimated at about 20 000 km^2 , or approximately 24% of the zone in 1975. It is composed of 21% reserved forest, and 3% unreserved.

This type of forest exists largely south of latitude 7°45'N. It reaches the coastline for approximately a quarter of its length and thereafter is separated from it by a belt of mangrove, scrub and coastal savanna formations, which fan out from west to east.

The zone is characterized by uniformly high temperatures, a rainfall regime with two peaks, mean annual precipitation ranging from 2135 - 3 000 mm in the southwest to 1 250 -1 375 mm in the northeast, and a high relative humidity. The humid environment maintained by the forest cover enables the cultivation of such cash crops as cocoa, oil palm, rubber and kola nuts. Cocoa and timber are the two major export commodities.

FOREST TYPES AND TIMBER PRODUCTION

The zone has been divided into four ecological associations (Taylor, 1960), the Rain Forest or the Cynometra-Tarrietia Association in the south western corner and the Moist Semi-Deciduous Forest, with three associations, the Lophira-Triplochiton, the Celtis-Triplochiton and the Antiaris-Chlorophora Associations, arranged in that order from southwest to northeast.

The Celtis-Triplochiton Association is the richest in economic timber species, and its reserved forest will be managed as natural forests for the production of such species. Efforts are being made to convert poorly stocked reserves, particularly in the Rain Forest and the dry end of the Moist Semi-Deciduous Forest, into plantations of fast-growing timber species.

POPULATION DEMANDS ON THE LAND

The population density in the Tropical High Forest is relatively high (62.1/km^2) compared with that of the Savanna Zone (32.1/km). It is predominantly an agricultural community, practising both shifting cultivation for the production of its food crops and a more permanent type of agriculture for crops such as cocoa, oil palm, citrus, rubber and kola nuts. In addition to the land reserved as the nation’s permanent forest estate, a sizeable area available to agriculture is being used for these cash crops. Thus land available to the peasant farmer for subsistence agriculture is rather limited.

THE TAUNGYA SYSTEM

The taungya system was introduced in 1928, with two objectives: to establish plantations of fast-growing, useful timber species and, second, to meet the peasant farmer’s demands for arable land, using forest reserves where land was genuinely needed.

The size of the forest land allocated annually depended on the demand and the ability of the Forestry Department to cope with it. The latter was largely determined by the stock available. On a few occasions, farmers were asked to raise seedlings themselves.

In exchange for this privilege farmers were asked to assist in establishing the plantation by preparing the site. They provided pegs, tended the planted tree crop alongside other food crops and also were governed by restrictions as to choice of species and spacing imposed by the Forestry Department. Farmers continued to receive allocations only if they adhered to these conditions.

FARMERS’ ATTITUDES

Peasant farmers were generally pleased. These allocations gave them the opportunity to raise crops on relatively fertile forest land, increasing crop yields and improving the standard of living. Preparing sites in the Tropical High Forest is the most expensive operation in plantation establishment. The farmer did not reap the full benefit of this investment, but this did not concern him unduly. He had no opportunity cost for his labour and in so far as he could handle the work, involving his family, all his produce was profit. He expressed his gratitude to the forester by adhering to the rules, and generally becoming increasingly cooperative. Some 5 000 hectares were planted under this system.

THE DEPARTMENTAL TAUNGYA .

The Forestry Departmment stepped up its plantation programme in 1969. It scheduled an area of 13 km for planting in five forest reserves, intending that tree crops be interplanted with agricultural crops.

This meant too much land for the farmer under the traditional taungya system. It was therefore decided that the department should play the role of traditional farmer, selling the food to offset part of the initial cost of establishing the trees.

The success of the system and the benefits accruing to the rural community were never assessed quantitatively. Nevertheless, it created an opportunity for concurrent production of wood and food crops on a large scale and in compact blocks; furthermore, it opened possibilities for continuous, regularly paid employment in the rural areas.

It must be emphasized that the coming of the departmental taungya system did not end the traditional system of taungya. The peasant continued to have his allocation if he desired and deserved it. Some peasant farmers were absorbed into the forestry labour force, and the enterprising among them took advantage of both opportunities, tending to their private plots during off duty hours. They thus enjoyed fuller employment, higher earnings and a more meaningful life.

THE COMMERCIAL FARMER

The large-scale reforestation scheme gave rise to yet another type of farmer, the big time city dweller, who used hired labour to cultivate food crops on the plantation sites.

The Forestry Department felled big trees and allocated plots to these “entrepreneur farmers” for a fee. The system resulted in a number of powerful farmers too difficult to control and consequently it failed. The poor peasant farmer was excluded from these areas.

ADVANTAGES OF THE TAUNGYA SYSTEM

In this system the forester may be able to raise a tree crop at a lower cost, and at the same time increase food production. The farmer always has the advantage of being able to use land which has been kept fertile under a forest cover.

If this is true, then could the system not be modified to solve some of the problems inherent in shifting cultivation? Could the farmer substitute a planned, short rotation tree crop for the bush fallow and earn additional income? Could a carefully selected tree crop, the leguminaceous nitrogen fixing soil improvers, be used to shorten fallow periods and could the system be extended to include animal husbandry? In short, could Agroforestry solve some of the problems of shifting cultivation?

The answer appears to be yes, but only when the constraints of the system, some of which may also be constraints to successful shifting agriculture, have been removed. These relate to land tenure and size of farm, cash and other inputs, technology and choice of species.

PART III

COOPERATIVE PROGRAMME FOR IMPROVING SHIFTING CULTIVATION SYSTEMS

Introduction

In some regions of the tropics, particularly in Africa, shifting cultivation and related fallow systems, are the most widespread agricultural systems. These systems have evolved, through centuries of trial and error, into scientifically and ecologically sound ways of managing agricultural resources. Now, however, population growth in tropical Africa and in other parts of the developing world, has placed considerable pressure on this system, forcing a drastic shortening of the fallow period.

In some areas of West Africa's humid tropics, at least five years of fallow are required before crops can be successfully cultivated again (Nye and Greenland, 1959). This varies, of course, according to soil type and ecological zone. There are even areas where fallow periods have been reduced to less than two years. Under such conditions, farmers face problems of soil degradation, loss of fertility, reduced yields, rampant weed growth, infestation by pests, and more.

As a result, many parts of the world urgently need to improve or develop new efficient systems for sustained yields which are scientifically sound, economically viable, and culturally acceptable. It is especially important to improve the farming systems used by the small-scale farmers who grow most of the food in developing countries. At the same time, large-scale mechanized farms should not be forgotten, although they have received considerable support in the past, with disappointing results in regions where there is shifting cultivation.

These problems cannot be tackled piecemeal. Recognizing this, participants at the February 1983 Informal Meeting on Improvements in Shifting Cultivation (held at FAO) decided that an international programme involving various types of institutions would be the most promising approach. This Cooperative Programme is the result of their deliberations.

Programme Goals

There are three overall goals for a programme to develop' more efficient, continuous production systems that could replace shifting cultivation. However, such continuous production systems are superior to the more traditional methods only if they receive the higher levels of inputs they require to make them work.

1. Systems should improve on the capacity of shifting cultivation, and related systems of intermittent production to accommodate population growth and modernization.

2. Systems should be suitable for farmers in developing countries, especially small-scale farmers. A multidisciplinary research approach helps ensure that this is so.

3. Systems should be environmentally sound, and at the same time supply farmers with their requirements for food and for cash, which they need to pay for other goods and services.

Short-term objectives

In the humid and sub-humid tropics, a few workable continuous production systems already exist which could replace shifting cultivation. In addition, research at several institutions has produced some viable alternatives. Given the urgent need, the programme should initially concentrate on collecting information on such alternatives.

The systems identified by such a search should be assessed, refined where necessary, and tested on farmers' land. Such participation from the initial stages encourages adoption and promotes widespread popularization through extension services. However, implementation of this approach should not preclude attention to longer-term solutions, because, while it promises good results for certain commodities, the production systems identified are likely to be highly location specific and therefore limited in their impact on overall food production in developing countries.

Long-term objectives

An approach with a longer-term and more widespread impact would consist of a collaborative worldwide programme to fund improvements in and alternatives to shifting cultivation. Priority should be placed on areas where the situation is already critical. This long-term programme's components are:

- research
- training and extension
  publications.

Consideration must also be given to policy issues which cannot be solved directly through research.

Research

The research strategy should be to use traditional technologies wherever possible, integrating them or their components into modern technologies. The farming systems research approach facilitates this, because it is based on a thorough understanding of existing systems and of the environment. Systems which are based on a blending of modern and traditional technologies or which modify the existing systems, are more attractive to farmers and therefore are more likely to be adopted than completely new systems.

The initial phase of programme and site identification consists of studies, based on information already available, supplemented by special surveys when. necessary. Data should be collected on:

- the farmer's environment, including agroclimatology, soil, vegetation, pests;
- existing farming and production systems;
- commodities produced, including trees, crops and livestock;
- resources management;
- input/output ratio;
- infrastructure, including: roads, transportation facilities, marketing and pricing systems;
- credit availability and other constraints to production increases.

All of this data is necessary in order to identify priorities and to determine strategies for research. Care should be taken in selecting treatments for each type of production system, subsystem, and component technology (see table 1).

Table 1

A. Baseline Data Collection

1. Environmental Assessment
   - Agroclimatic data
   - Socio-economic and geographical data
   - Traditional farming systems
   - Input/output relations
   - Infrastructure
   - Identification of policy issues, etc.

2. Productions S stems and Arrangements
   - (a) Systems
     - Cropping systems
     - Animal production systems
     - Mixed farming (crop/livestock) systems
     - Agroforestry
     - Agrisilvopastoral systemms
     - Forestry production systems

   - (b) Systems Arran ements
     - Combinations of commodities
     - Sequences and rotations of subsystems, including fallow

B. Subs stem components within which selected treatments can be compared with traditional practices subsequent to environmental assessment as necessary .

3. Subsystem and System Components	Treatment Options: Traditional	Treatment Options: Others
(a) Land or site development		
(i) Clearing		
(ii) Other		
(b) Tillage		
(c) Soil amendments		
Liming		
Fertilizer		
(d) Planting		.
(i) Manual		
(ii) Other		
(e) Pest control or management		
Weeds		
Insects		
Diseases		
(f) Harvesting		
(i) Manual		
(ii) Other		
(g) Marketing		

Includes use of resistant or tolerant varieties

Table 2

Observations and evaluation for treatments used in experiments for farming systems component technology development

Factor		Observations or evaluation criteria
(1) Soil and other ecological components	(a)	Effects on physical properties of soil
	(b)	Effects on fertility of soil
	(c)	Extent of erosion
	(d)	Biological effects
	(e)	Ecological interactions
(2) Commodities (agriculture, forestry and livestock)	(a)	Effects on growth and development including tops and roots
	(b)	Effects on weeds, pests and diseases in advance yields of dry matter and economic products
	(c)	Quality and market value assessment
	(d)	Post-harvest technology and sundry problems
	(e)	Inter-species interactions
(3) Socio-economic factors	(a)	Labour intensiveness and drudgery
	(b)	Cultural acceptability including preferences for varieties, including dietary preferences
	(c)	Economic viability in relation to extent of technology being within means of farmer to own, hire, use and repair
	(d)	Relevance of technology and system components to men and women in relation to possible division of labour, income generation and income distribution ‘
	(e)	General availability of inputs in relation to government policy and infrastructure
	(f)	Employment generation opportunity

Criteria are listed in Table 2 for assessing observations and data from the experiment.

Training and extension

The collaborative programme needs to familiarize farmers with the results of its research and to help them develop the new skills they will require. Some of this can be accomplished by the involvement of farmers in the experimental projects described above. The farmers can also acquire new knowledge and skills through involvement in the evaluation of the alternative production systems.

In addition, a range of conventional extension methods will be used.

Extension work usually involves interaction between farmers and extension workers, which improves the feedback to researchers. That process is strengthened when extension workers share the same experiences as the farmers. Therefore, personnel of the existing extension and training programmes will need orientation to the principles and processes involved in alternative production systems and in systems to improve shifting cultivation.

Publications

Publications can also give farmers, extension workers, and policy makers greater familiarity with alternatives to and improvements in shifting cultivation. As literacy in foreign and local languages increases, the use of publications becomes even more important, especially in disseminating and popularizing results. The news media can also be used in campaigns which make people aware of common practices that cause soil erosion and environmental deterioration.

Through such publications, the programme plans to reach out to many constituents: technical personnel, farmers, policy makers, politicians, and the general public.

It will be especially important to disseminate results of the programme to policy makers for several reasons. First of all, unless policy makers are aware of the issues and committed to taking appropriate action, it is unlikely that the needed resources will be available or that policies will be supportive of the programme directions. Secondly, policy makers and politicians are usually particularly interested in dramatic changes in farming, without regard to environmental hazards. It is therefore important to keep them informed about practices that harm the environment or that do not lead to sustained productivity. Legislative and regulatory measures may also be required. .

In addition to puhlications, other measures should be taken to keep politicians and policy makers aware of developments in the programme, including demonstrations at the experimental stations and in the farmers’ fields.

Policy issues

Effective policies are essential in ensuring that necessary and adequate support, infrastructure and services are available to farmers. While this applies universally, it is especially true for developing nations. For instance, infrastructures such as roads, post-harvest handling and storage facilities, and marketing services that are supported by an adequate pricing structure are ways to ensure that farmers receive maximum returns from their labour. They motivate farmers to adopt new technologies which can improve their lot significantly.

Equitable pricing policies and appropriate marketing structures

New farming systems based on continuous cultivation will succeed only if some of the staple, and most of the commercial, products are sold at prices that cover costs. Equitable agricultural pricing policies and appropriate marketing structures are needed, therefore, to provide rural families with income earning opportunities. The magnitude of returns to labour determines the extent of the positive incentive for increased farm productivity.

Women's role in agricultural production

New systems of continuous cultivation affect women and men differently, in terms of the tasks performed and the income-earning opportunities which become available.

Rural women contribute greatly to the work in many regions where shifting cultivation is practised. With the introduction of new systems of continuous cultivation, women and men will take on new tasks. As this will affect women's workload which includes multiple responsibilities, in food production, income earning, food preparation, housekeeping and child care, the new systems should be tailored to women's needs and problems.

The programme's organization

The programme's organizational structure should facilitate inter-disciplinary and interinstitutional collaboration. The top level of organization will be regional, in order to identify programmes that can grapple with the regional peculiarities of the developing countries of Africa, Southeast Asia, and Central and South America. (There will also be cross-regional communication to consider issues which are more widespread.) While within each region there are similarities in agricultural production systems, it is nevertheless necessary to identify sub-regions, which are more homogeneous. Extrapolation of results would therefore be most useful within these subregions; however, this does not preclude extrapolation of results, with modifications, if any variations and differences are carefully defined.

Projects will then be replicated within their own region. Standardized procedures in environmental description, monitoring, data collection, etc., will enhance the transfer of technologies across the regions and worldwide.

Since such a programme, being collaborative, is expensive, existing national and international institutions should be involved as much as possible. This will reduce the funding needed and will minimize duplication. Mechanisms should be developed for linking research, training, extension, and the farmer. In addition, interdisciplinary collaboration in research and development requires involvement of experts from various disciplines from the very beginning stages, in planning and subsequently. This ensures that all involved are attuned to their individual responsibilities, professional career opportunities, and possible complementary services they might provide for the advantage of all concerned.

Role of FAO

FAO has played a unique role in the past, and is in a position to make particularly important contributions:

- it includes countries with areas under shifting cultivation;
- it has direct contact with many regional and international institutions

involved in agricultural research and development. It is also acquainted with individual experts from many disciplines, and is uniquely placed to use all facilities at its disposal to foster greater international collaboration. In many cases it is also able to provide direct support to such programmes;

- it can promote an exchange of expertise and experience among countries with critical problems in shifting cultivation, particularly through Technical Cooperation among Developing Countries (TCDC);

- it can inform policy makers, through the FAO statutory bodies and other fora, about the issues and actions needed to introduce improvements in and alternatives to shifting cultivation;

- it can attract donors to support specific areas of research, training, transfer of technology, and dissemination of information, within the programme's priority areas;

- it can develop projects at the national level to demonstrate improvements in shifting cultivation;

- it includes a wide, multidisciplinary group of experts who can contribute to greater awareness of the issue: land development specialists, agronomists, animal husbandry and grazing specialists, foresters, sociologists, farm management specialists, etc;

- it works with national agencies responsible for rural development - which means that its work has the potential for tremendous impact.

Appendix 1

ACTIVITIES FOR THE IMPROVEMENT OF SHIFTING CULTIVATION BEING UNDERTAKEN BY FAO DIVISIONS

Animal Production and Health Division, Agriculture Department (AGA)

Regular programme

- Publication on the Development of Integrated Crop /Livestock Farming Systems in West Africa. This deals mainly with humid and subhumid zones of West Africa where population pressures are rapidly increasing, more and more fuelwood is being removed, tsetse flies are retreating, and spontaneous colonization of previously underpopulated land is accelerating. Much of this land has high potential for production.

  The publication includes comments from ILCA and IITA. It brings together existing knowledge and indicates promising approaches for integrating systems beginning from three starting points, i.e. (i) extensive pastoralism (ii) shifting cultivation and (iii) plantation cropping.

- Draught animal power programme. The transition from long-fallow shifting cultivation to more continuous cropping systems requires more energy inputs for cultivation, weeding, etc. Where suitable animals are readily available, this need may be met by animal traction. The AGA/DAP Programme was initiated as a result of the UN Conference of New and Renewable Sources of Energy (Nairobi 1981). It includes the following assistance to member nations:

  - promotion of international networks for research development and training;
  - organizing practical workshops;
  - consultancies in support of national programmes

- Workshop on Appropriate Livestock Production Technology for Small Farmers in Latin America which identified technically and economically sound technologies for improving livestock production on small farms in Latin America and discussed a TCDC regional project to promote their use.

- Utilization of crop residues and agro-industrial by-products in animal feeding. Farmer’s successes in integrating livestock into cropping systems is determined largely by use of animal feed of adequate quality. AGA’s Feed Resources Programme has been promoting a research network for use of crop residues and agro-industrial by-products in animal feeding in West Africa. In collaboration with ILCA this activity is now being extended to other parts of Africa.

- Promotion of small farmer milk production. Shifting cultivators seldom have the land-titles needed to qualify for credit in order to acquire new seeds, fertilizers and pesticides. Milk production in these circumstances can provide the income for investment in these essential inputs. The AGA International Scheme for Coordination of Dairy Development focuses on development of milk production by small farmers.

Field activities

- The Small Ruminant Programme. AGA is developing the integration of haired sheep breeds into cropping systems through a number of field projects in West Africa (Togo and Ivory Coast). In East Africa (Kenya) it is helping to develop intensive goat production for meat and milk based on cultivated fodders as well as encouraging sheep production.

- Development of integrated crop/livestock farming systems in Africa. AGA is involved in projects in Africa to integrate crop and livestock production. On the island of Zanzibar, this involves the introduction of dairy cattle into local cropping systems. In Nigeria, it focuses on intensifying livestock production along with increases in fodder and crop production by traditional pastoralists. This can lead to more efficient land use and alternatives to shifting cultivation on the one hand, and shifting livestock production on the other.

Land and Water Development Division, Agriculture Department (AGL)

Rationale

Continuous cultivation of annual food crops under low-input farming systems is only successful on soils of high intrinsic natural fertility such as Andosols, Phaeozems (Mollisols), and Luvisols (Alfisols). On soils of lower intrinsic fertility, a rest period, or fallow period, is essential between cropping periods to restore soil fertility. The poorer the soil's natural fertility, the longer the fallow period required to restore productivity.

At a global level, the distribution of soil units of high, intermediate and low intrinsic fertility is known, with some approximation, through FAO/Unesco's Soil Map of the World with a scale of 1:5 000 000. Shifting cultivation is predominantly found on Acrisols (Ultisols) and Ferralsols (Oxisols) on all continents; these are soils which lack natural fertility.

In many soils, natural fertility accumulates in the topsoil. After clearing of the land and slashing and burning, nutrients which have accumulated in the soil's organic matter are used by the growing crop and are leached or carried away by erosion. Restoration of soil fertility depends on the presence of a mineral reserve. It is insufficiency, or unavailability of this reserve that forces farmers using low inputs to rest their soils for a somewhat prolonged period.

Fertilizers, lime and other inputs can restore the soil's fertility quickly, but for most areas of shifting cultivation the cost of these inputs exceeds the benefit. In addition, in remote areas of developing countries, the right chemical fertilizers must be available, before it is possible to apply other inputs . successfully.

Programme

- Improved Soil Tillage Methods. The introduction and extension of simple improved tillage techniques to conserve soil moisture and organic matter in soils may help to reduce somewhat the need for prolonged fallows between cropping periods.

- Research contracts to improve shifting cultivation with Cameroon, Malawi and Nigeria, and forthcoming contracts with Indonesia, the Congo and Sierra Leone. The results of these cooperative research programmes with national institutions will help to indicate what improvements can be made in shifting cultivation. Contacts are also maintained with the project at Yurimagnuas (Peru) financed by US-AID/University of North Carolina.

- Training courses for agricultural extension officers to encourage the use of improved shifting cultivation techniques are conducted in several countries. In 1982-83, such courses were organized in Cameroon, Indonesia, Madagascar and Ecuador.

The Land and Water Development Division is also deeply involved in the diffusion of organic recycling techniques, which can accelerate the build-up of normal soil fertility. The extension of simple organic recycling techniques (mulching, composting, use of biogas digester effluents and residues, manuring, etc.) can greatly help to improve shifting cultivation and to reduce the need for a prolonged fallow period.

_Publications programme. The service's publications include Soils Bulletin 27 on Shifting Cultivation and Soil Conservation in Africa; and a report on Shifting Cultivation and Soil Conservation in Latin America (in press, in Spanish with English summaries). Other publications include the paper on "Improved Permanent Production Systems as an Alternative to Shifting Intermitten Cultivation" written in cooperation with IITA. This paper , which forms Part I of this Bulletin, reviews shifting cultivation in Africa and includes proposals for improvements to achieve sustainable production systems, which may eventually become permanent.

An informal meeting on improvements in shifting cultivation was held in February 1983. The papers from this meeting form Part II of this Soils Bulletin No. 53.

Farm Management and Production Economics Service
Agriculture Department, AGSP

- The Service has supported the preparation of papers on shifting cultivation with emphasis on its economic aspects. Two are available, prepared by Ruthenberg and Dabasi-Schweng (FAO Soils Bulletin No. 24).

Numerous experts have been assigned as farm management economists to field projects to improve the productivity of specific crops within an area of shifting cultivation.

- AGSP is initiating a "farming systems development approach" to shifting cultivation in cooperation with other services throughout FAO. Activities will include identifying cooperating institutions in selected developing countries and sub-contracting with that organization and/or its staff to:

  - Select 5-10 representative landholders in shifting cultivation areas and surveying their present farming activities. This data will serve as both a benchmark for later evaluation and for identifying constraints to improving production.

  - Use existing national research findings, the experience of successful farmers, and the expert knowledge of experienced agriculturists, to prepare improved crop and livestock systems for each enterprise being undertaken by the selected farmers.

  - Use these improved sub-systems to plan a total improved farming system for each farm, implementing this improved system over a three to four year period, adjusting the system annually.

  - Use the coefficients from this activity to encourage local preparation of an investment proposal for a larger number of farms within the area, submitting it for financing.

Plant Production and Protection Division Agriculture Department (AGP)

While AGP is not directly involved with shifting cultivation, many of its activities are indirectly related. Its three main spheres of activity are:

A. General Agronomy

l. Variety trials: organization of country and inter-country cooperative trials to identify high yielding varieties.
2. Crop management: development of suitable agro-techniques including better crop management and improved pre-and post-harvest technology.
3. Cropping systems: promotion of intensive cropping such as intercropping and multiple cropping which lead to better utilization of land and water resources, increasing per unit area income of the farmer.
4. Seed production: to determine the quantitative needs for various crop seeds and identify corresponding investment requirements.

B. Research and Training

l. Breeding: promotion of intensive plant breeding programmes leading to the identification of high yielding, high quality varieties.
2. Research: strengthening and giving support to national research institutes for their programmes, technical manpower and facilities.
3. Genetic Resources: cooperation in collection, conservation, utilization and exchange of seed, plant material and genetic resources.
4. Manpower development: organization of suitable training programmes, workshops and seminars in the improvement of agricultural methods for crop production, with the ultimate aim of developing national competence in solving production problems at the farm level.

C. Liaison and Information

l. Regional networks: development of suitable regional cooperation in research and development of crops.
2. Collection, processing and dissemination of information on the most effective technology of crop growing and improvement.
3. Liaison and cooperation: development of linkages between various relevant regional and international centres and institutes and programmes.

Forestry Department

Rationale

In most tropical countries, shifting cultivation and its variations are familiar to foresters and forestry institutions. It takes place in forested land, or even in legally gazetted forest reserves; it involves forestry communities, and natural or man-made forest re-growth during the fallow period assists soil regeneration. Agroforestry and more generally agrosilvopastoral systems figure among the most viable and useful alternatives to shifting cultivation.

Shifting agriculture accounts for 45 percent of total deforestation in the tropics, according to the findings of the recently completed FAO/UNEP Tropical Forest Resources Assessment Project. Shifting cultivation and secondary forest fallow formations increase worldwide every year by 5.1 million ha, of which 3.4 million ha is in humid closed forests and 1.7 million ha in the drier woodlands and mixed forest-grassland formations. In tropical Africa, the proportion of deforestation due to shifting cultivation amounts to 65 percent: every year shifting cultivation involves about 0.95 million more ha in the closed forests and about 1.45 million more ha in the open forests or a total of 2.4 million ha annually, for a total annual deforestation of 3.7 million ha (1.35 million ha in closed forests and 2.35 million ha in open forests).

FAO's Forestry Department has therefore actively dealt with this problem, both in its regular programme activities carried out mostly from Headquarters and the Regional Offices, and in its field programmes in the countries concerned.

Regular programme

- National and regional studies published between the late 50's and early 70's: "L'Agriculture nomade" concerning the Ivory Coast and Zaire in 1956 , Hanunoo Agriculture in the Philippines" by sociologist-anthropologist Conklin, published in 1957, revised 1975; and "Shifting Cultivation in Latin America" by Watters in 1971.

- Papers and questionnaire on shifting cultivation discussed at the first, second and fourth sessions of the Committee on Forest Development in the Tropics, a statutory body of FAO established "to study technical, economic and social problems relating to the development of tropical forests".

- Preparation of special sessions on shifting cultivation and agroforestry at the 8th World Forestry Congress organized in Indonesia in 1978.

- Implementation of the FAO/UNFPA project on "Population/Environment Planning for Asian Forestry Communities Practising Shifting Cultivation" in Bangladesh, India, Indonesia, the Philippines and Thailand from 1978 to 1980.

- Activities on shifting cultivation and agroforestry within the framework of two of the most socially oriented programmes of the Forestry Department, viz. the Forestry for Local Community Development Programme and the Forestry and Rural Energy Programme.

- Production of filmstrips on several aspects of social forestry including one on agroforestry in the Philippines.

Presently the Forestry Department is engaged in a major study on alternatives and modifications to shifting cultivation in the use of forest land in Africa, with particular reference to their acceptability by small farmers and to forestry aspects. A sociologist is working in the Forestry Department on this study, using as part of her background documentation seven case studies carried out by outside institutions and consultants (in Ghana, the Ivory Coast, Madagascar, Senegal, Sierra Leone, and two in Tanzania). An ad-hoc advisory task force includes representatives of the Forestry Department and of interested divisions from the Agriculture, and Economic and Social Policy Departments. The study also takes into account related work from FAO Divisions, including one done in ESH, "Economic, Social and Institutional Aspects of Shifting Cultivation in Humid and Semi-Humid Africa".

Field activities

Numerous projects supported through the Forestry Department deal with shifting cultivation. A list and descriptions of these project is available upon request.

Appendix 2

Programme

Informal Meeting on Improvements in Shifting Cultivation

22-25 February 1983

Tuesday 22 Feb. morning	Chairman: N. R. Carpenter, AGS Opening address: F. W. Hauck, AGL Brief presentation of FAO activities in shifting cultivation: AGLS, FO, ESHI, AGA, AGPC, AGSP
(afternoon)	Chairman: R. J. Clark, ESH Technical session 1. Socio-economic and institutional aspects of improvement in shifting cultivation 2. Organizational aspects (Indonesian experience)
Wednesday 23 Feb. morning	Chairman: J. P. Lanly, FO 3. Agroforestry as an alternative to shifting cultivation. 4. Shifting cultivation, its extent, problems and proposed action programme in Sierra Leone. 5. Taungya system in southwest Ghana. 6. Prospects for the development of integrated crop/livestock systems. Discussion
(afternoon)	Chairman: A. Bozzini, AGP 7. Improvements in soil management in shifting cultivation 8. Cropping systems development for improvement in shifting cultivation in Africa. Discussion
Thursday 24 Feb. morning	Chairman: B. N. Okigbo, IITA Discussions on approaches to field programme development in improving shifting cultivation systems.
(afternoon)	Continuation of discussion
Friday 25 Feb. morning	Chairman: F. W. Hauck, AGL Plenary: Recommendations. Winding up session and conclusions.

Appendix 3

Participants

Informal Meeting on Improvements in Shifting Cultivation

22-25 February 1983

J. Brookman-Amissah - Forest Products Research Institute, Kumasi, Ghana
S. Hardjosoediro - Gajah Mada University, Indonesia
F. Kamajou - Dschang University, Cameroon
P.K.R. Nair - International Council for Research in Agroforestry, Nairobi, Kenya
J. J. Nicholaides, III - Tropical Soils Research Program, North Carolina State University, Raleigh, N.C., (USA)
B. N. Okigbo - International Institute of Tropical Agriculture, Ibadan, Nigeria
Joseph L. Tommy - Njala University, Sierra Leone

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Agriculture Department

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P. L. Arens - Land and Water Development Division
H. Braun - Land and Water Development Division
N. R. Carpenter - Agricultural Services Division
W. Ferguson - Animal Production and Health Division
F. W. Hauck - Land and Water Development Division
H. Kunert - Agricultural Services Division
J. H. Monyo - Research Development Centre
C. S. Ofori - Land and Water Development Division
E. N. W. Oppong - Consultant, Animal Production and Health Division
E. Reynaert - Former Project Manager, Bolivia, Land and Water Development Division
D. W. Sanders - Land and Water Development Division
R. Van Vaerenbergh - Animal Production and Health Division

Economic and Social Policy Department

R. J. Clark, Human Resources, Institutions and Agrarian Reform Division .

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M. Biagini - UNASYLVA
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M. E. Chipota
J. P. Lanly - Forest Resources Division
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