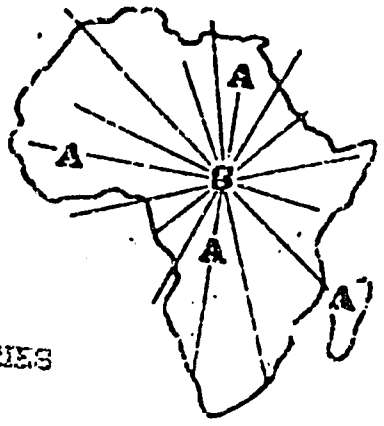

CROPPING SYSTEMS AND RELATED RESEARCH IN AFRICA

By

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Special Issue on the Occasion of the 10th Anniversary of the

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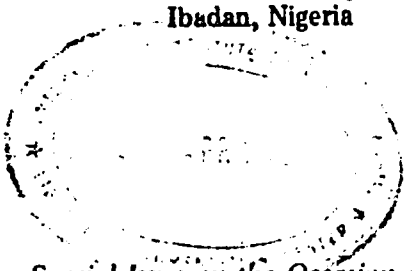

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Contents

PREFACE

During centuries of human biological and social evolution, invasions and migrations by various peoples, diverse farming systems have been developed in different ecological situations in Africa as a result of man's quest for regular and more reliable supplies of food, fibre and other useful products. It is on plants which have the power to trap radiant energy and synthesize various substances that man and animals depend for subsistence.

Cropping systems and associated farming systems which leave their mark on the cultural landscape represent man's attempts to evolve more efficient crop plant and animal production systems for different ecological areas and changing socio-economic conditions. Studies of the farming systems of which they are a part have been documented in numerous journals and different languages by anthropologists, economists, geographers, sociologists, agronomists and specialists in other disciplines. This work represents a humble effort to bring together in one volume published information on cropping systems and related research in Africa.

Much of the material here is based on the *Intercropping Systems in Africa*[1], *Cropping Systems in Africa*[2] presented at the AAASA Symposium on Cropping Systems, Morogoro, 1975 and *Cropping Systems Research*[3] which review, previous research on cropping systems and makes suggestions on strategy for cropping systems research, a paper presented at the symposium on Intercropping in semi-arid Areas, Morogoro, Tanzania in May 10—12, 1976. Definitions on cropping systems approved during the 1975 AAASA Symposium on Cropping Systems at Morogoro are also included.

The author is indebted to those who have carried out the pioneering studies of cropping systems and farming systems of Africa presented here but takes full responsibility for any errors in their presentation, omissions and interpretations that are embodied in this work. Assistance given by Dr. I. O. Akobundu and Mr. J. O. Oyekan in the preparation of the manuscript is acknowledged. Appreciation is also hereby expressed for the encouragement given by Association of Deans of Faculties of Agriculture of African Universities and the financial support given by AAASA through its Executive Secretary, Prof. Bakir A. Oteifa which made possible the publication of this work. It should be noted that this is by no means an exhaustive review of all pertinent literature on the subject. This is an attempt to stimulate interest in the study of traditional and transitibnal cropping systems of Africa and it is hoped that this will be improved upon in the foreseeable future.

[1] *Okigbo, B. N. and Greenland, D. J. (1976). Intercropping Systems in Tropical Africa. In R. I. Papendick, P.A. Sanchez, and G. B. Triplett (ed.) Multiple Cropping. Spec. Pub. No. 27 Am. Soc. of Agron. Madison, Wis.*

[2] *Okigbo, B. N. (1975). Cropping Systems in Africa. Paper presented at the AAASA Symposium on Cropping Systems in Africa, Morogoro, Tanzania, 1975.*

[3] *Okigbo B. N. (1976). Cropping Systems Research. The scope and strategy based on experience of previous and current studies. Symposium on Intercropping in Semi-arid areas. Faculty of Agric. Forestry and Veterinary Science, Morogoro, Tanzania, May 10—12, 1976.*

PHYSICAL BACKGROUND

Africa extends 8000 km from north to south stretching from Cape Ras ben Sakka in Tunisia at latitude 37° 21'N to Cape Aguihas in South Africa at latitude 34° 51'S and from Cape Verde in the West to Cape Ras Hafan in the east. Thus it extends about 4000 km north and over 3000 km south of the equator with a width of about 6,200 km. Its area is about 30.42 x $10^6 km^2$. This land mass which is almost double the area of South America exhibits great diversity in climate (e.g. rainfall intensity, duration and distribution; temperature; radiation intensity; effectiveness and photoperiodicity; evapotranspiration and winds); relief (with respect to altitude which ranges from 0—5,000m or more, slope, roughness of surface, etc.) vegetation and animals (animals, micro-organisms, higher plants in tropical rainforest and other vegetation zones, weeds, pests and disease organisms); geological structure, chemical composition and soils (see Figures 1, 2, 3, 4 and 5). Africa has a population of about 400 million people belonging to many racial cultural and

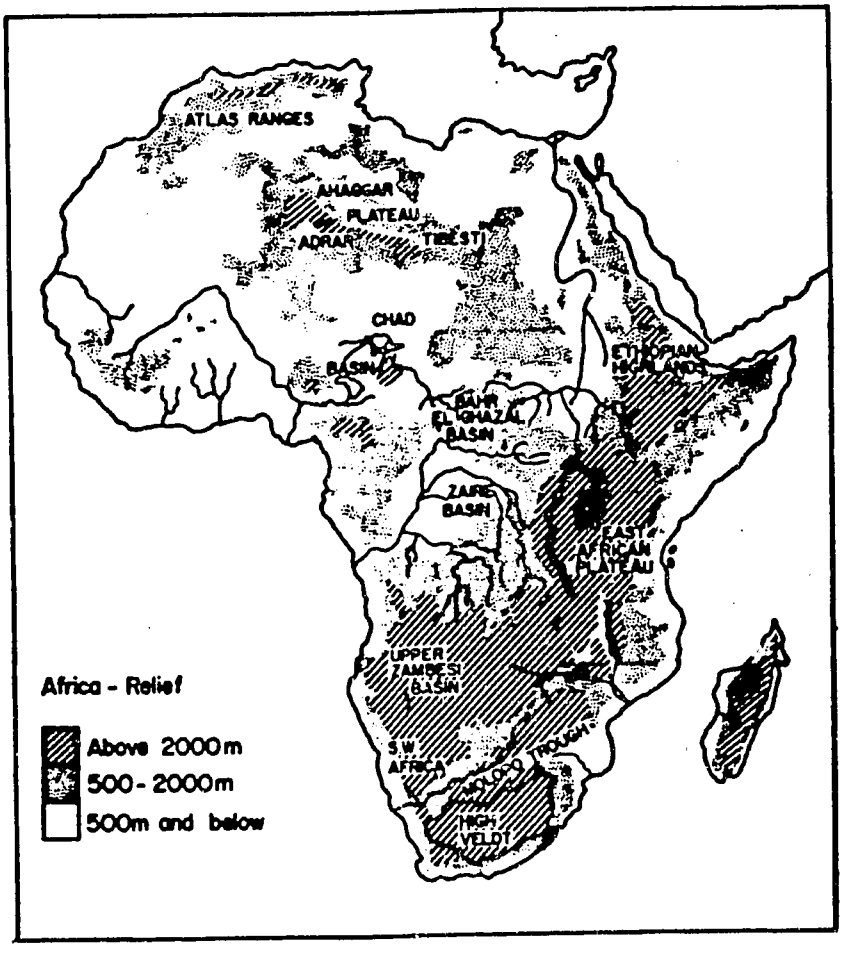


Fig I. Africa-Relief and major physical features (Adapted from Clark, 1965 and Jarrett, 1974)

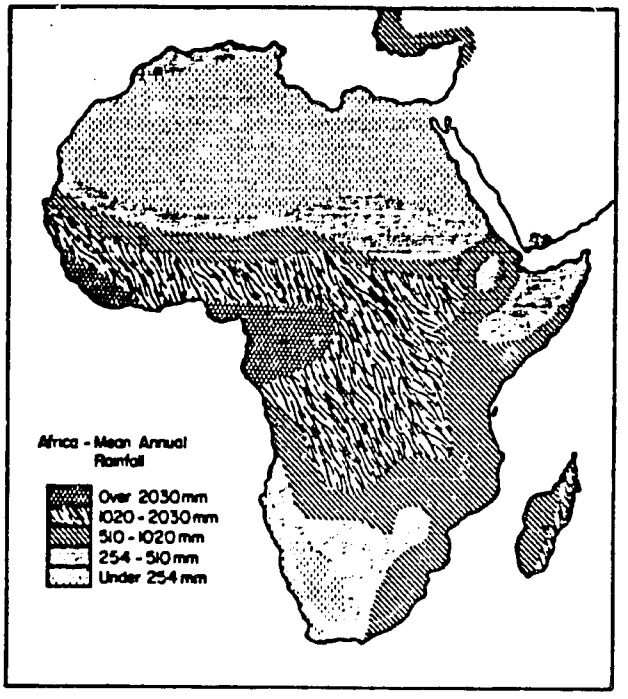


Fig 2. Africa: Mean annual rainfall (Adapted from UNESCO 1975)

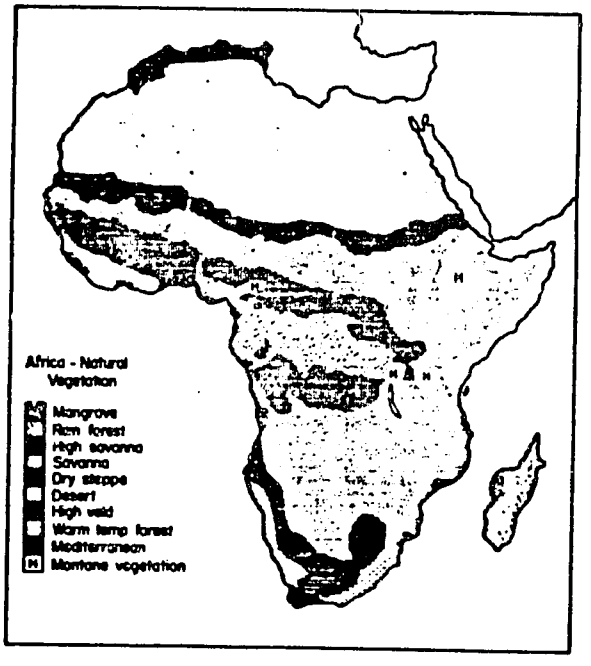


Fig 3 Africa: Natural vegetation (Adapted from Jarrett, 1974)

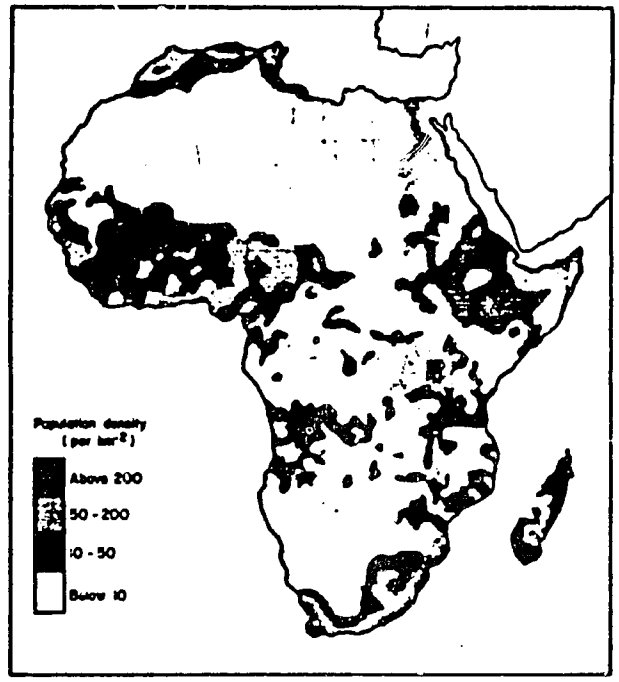


Fig 4. Africa - Population density (After Kimble & Steel, and Jarrett, 1974)

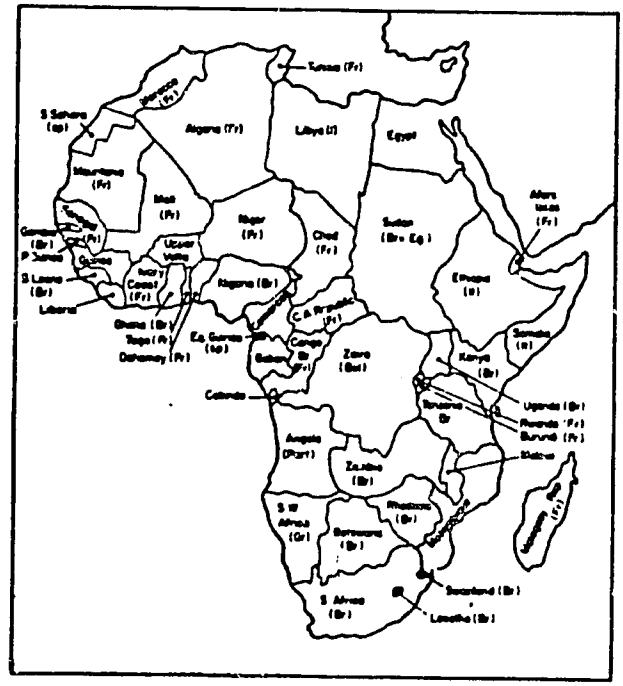


Fig 5 Africa: Political units and colonial background. (Broulfette et al, 1974)

linguistic groups. There are some 50 countries with different colonial experience at various times under 8 European countries and with different political backgrounds. All these features in addition to social (e.g. personal tastes, traditions, religious convictions etc.), economic (e.g. prices, ease of transportation, etc.), political (marketing boards providing marketing channels, stable prices, etc.), environmental factors, and overall level of technological development and resource availability (Norman, 1974) constitute the basis of diversity in number of crops grown and variations in cropping and farming systems that exist in Africa. In this paper the general characteristics of cropping systems in African traditional farming systems are considered in addition to a brief review of research in relevant cropping systems.

Farming Systems in Africa and their Associated Cropping Systems

Whittlesey (1962) published a classification of major agricultural regions of the world and of the thirteen major agricultural regions in this classification only nomadic herding, shifting cultivation, rudimentary sedentary cultivation and aspects of non-rice based intensive agriculture, Mediterranean agriculture, specialized horticulture and plantation agriculture usually occur in Africa. Since then various attempts have been made to develop more functional, practical and widely acceptable classification of the farming systems of the world (Dumont, 1970; Duckham and Masefield, 1971; Laut, 1971; Evenson, Plucknett and Norton, 1972; and Grigg, 1974). Classification of farming systems with emphasis on the agriculture and cropping systems of the tropics which apply to a large section of Africa include those of Allan (1965), Miracle (1967), Morgan and Pugh (1969), Morgan (1959 and 1969), Floyd (1969), Boserup (1970), White (1971), Ruthenberg (1971 and 1974), Benneh (1972), Gleave and White (1972), Greenland (1974) and Grigg (1974). With the exception of Ruthenberg's (1971 and 1974) classification which takes into account the vegetation systems, migration systems, rotation systems, clearance systems, cropping systems and tool systems many of which may overlap in any specific location, most of the systems of classification of farming systems especially for tropical Africa are more or less based on differences in intensity of cropping or cultivation and variations in the duration of periods of fallow used to restore soil fertility after each cropping phase of one or more years (Figures 6 and 7). Distribution of dominant animals and crops in the various farming systems are shown in Figures 8 and 9.

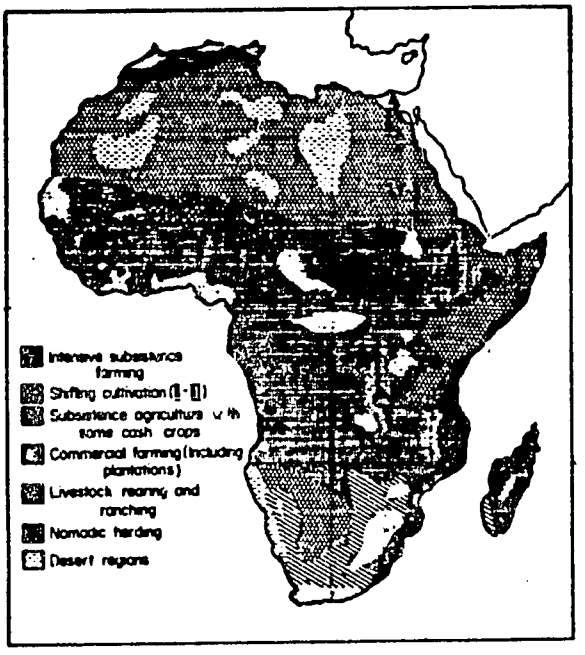


Fig 6 Broad pattern of distribution of agricultural regions of Africa (Brouillette, Grives & Last, 1974)

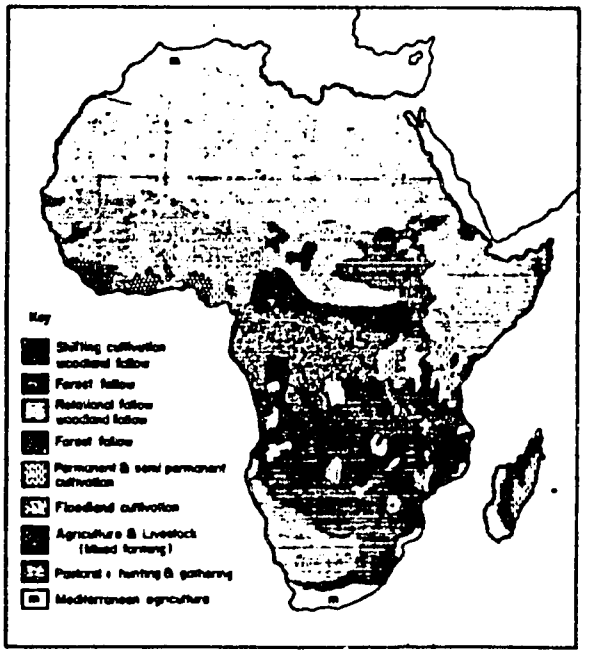


Fig 7. Distribution of agricultural production or farming systems in Africa (After, Morgan, 1969, Jarrett, 1974, Gleave & White 1972)

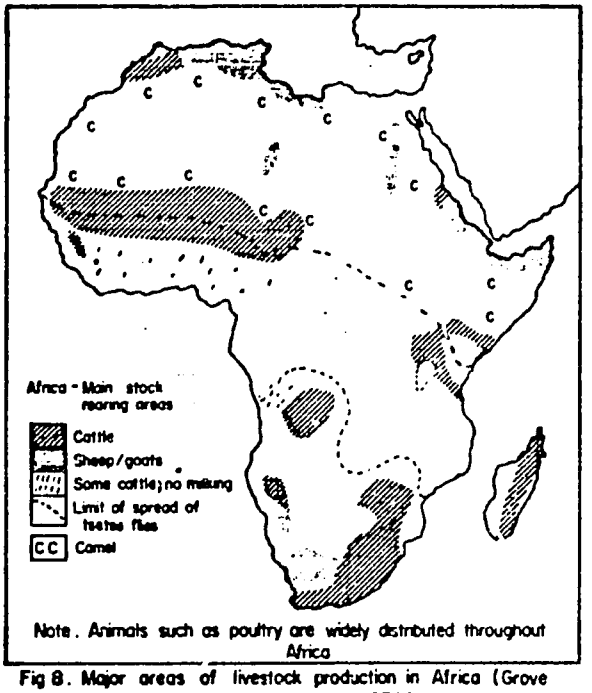


Fig 8. Major areas of livestock production in Africa (Grove 1970, Jarrett, 1974).

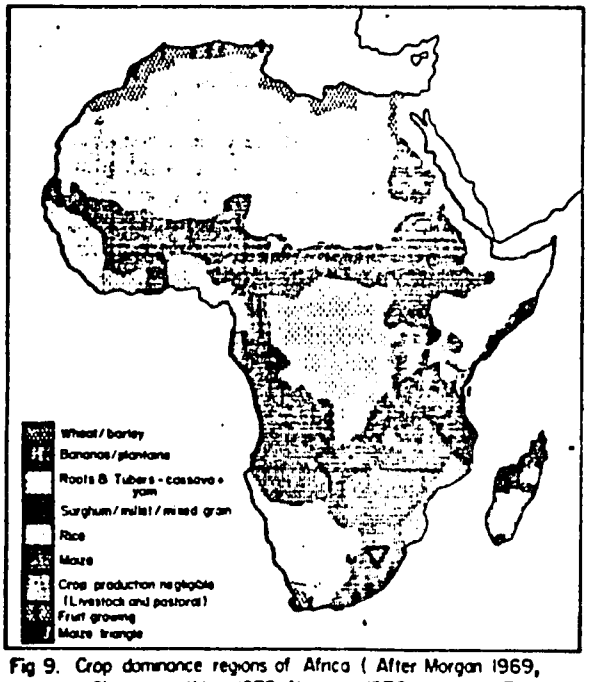


Fig 9. Crop dominance regions of Africa (After Morgan 1969, Gleave and White 1972, Newman, 1976 Jarrett, 1974, Murdock 1960).

Although farming in certain parts of Africa are patterned after the modern farming systems of Europe and plantation agriculture of Southeast Asia, it should be emphasized that the prevailing traditional farming systems at any given time in any specified location represent the culmination of various historical events that are subject to dynamic processes of change. They are, therefore, transitory stages in the evolution of either potentially permanent viable systems under proper management of resources and adjustment to change or degenerating systems that face final collapse under poor management of resources and failure to effectively adjust to change brought about by population pressure, socio-economic changes and other related processes. Consequently, they cannot all be regarded as being in equilibrium with the biological, social and cultural environments of the farmer as they were thought to be in the past under low population pressure and conditions that existed several centuries ago when adjustments to existing conditions came about naturally by providence or after long periods of gradual evolution. A classification which provides a suitable background for the understanding of the developments that led to the existing farming systems, their complexities, similarities and differences is presented below. Originally, two main agricultural complexes were evolved in Africa (Porteres, 1962). These consisted of a *seed agricultural complex* characteristic of open unforested regions analagous to our savannas of today and including those of the Near East and a *vegecultural complex* peculiar to forested regions and involving cultivation of roots, tubers and cuttings in gardens rather than fields. Differences between these two complexes have gradually disappeared as crops and techniques developed elsewhere were adopted within the traditional systems. A recent concept postulated by Harlan (1971) is that of a main center of agricultural origin in the more temperate Middle East (Egypt and the Fertile Crescent) associated with several centers of probably independent origins in West Africa, Central Africa, Ethiopia, etc.

African traditional farming systems as compared to modern farming systems of Europe and North America are less specialized but more complex. Their complexity may be illustrated by the fact that especially, but not exclusively, in the humid tropical areas of Africa, a farmer or farm family usually operates a very much diversified agricultural enterprise which may constitute a combination of different agricultural enterprises and other activities. For example, a farmer whose homestead is located in an upland well drained soil may operate a compound farm or garden close to his homestead, while at the same time maintaining two or more plots under cropping systems of different periods of natural forest, bush or planted fallow at varying distances from the homestead and in the flood plains of a nearby river or stream also practise floodland cultivation. He may also be keeping pigs, goats, sheep and/or poultry for manure, meat, sales and other purposes. The same farmer may be a palm winer tapper, basket maker, musician or priest in the traditional religion, or fisherman. The cropping mixtures on the compound farms and various field types often involve major staples, vegetables and condiment plants grown in multiple, double, relay and patch intercropping patterns of annuals, perennials or both. The compound farm or homestead garden usually carries more species of cultivated plants than bush fallow farms located at various distances from the homestead since on the latter only major staples and a few protected trees may be grown (see Table 5).

Some General Characteristics of Traditional Farming Systems in Africa

A simplistic model of traditional farming systems of Africa consists of a more or less concentric pattern of fields on which are practised various methods of fertility maintenance, fallowing, clearance systems, tillage, production of different numbers

of species and varieties of crops and animals, cropping patterns and sequences, according to the prevailing circumstances and the needs of the farmer. Farming is largely for subsistence but commercialization is increasing and the extent varies considerably from one location to another. Based on this concept, the following generalizations can be made about these farming systems and their associated cropping systems in Africa (see Figures 6 and 7).

1. There is a diversity of farming systems ranging from true nomadic herding and shifting cultivation where settlement is frequently moved to permanent cultivation.

2. True shifting cultivation is rare and is restricted to parts of Rhodesia (Allan, 1965), the Ivory Coast and the Cameroun Republic (Morgan, 1969; Grigg, 1974). Nomadic herding is widespread in the Sahel savannah and adjacent dry regions and East Africa.

3. Permanent cultivation occurs in (i) compound farms, kitchen or homestead gardens, (ii) some soils of high fertility, (iii) confined sites on uplands, islands, etc. (e.g. steep slopes of Maku in the Anambra State of Nigeria where terrace farming is practised and on islands such as the Ukara Island in Lake Victoria), and (iv) overcrowded areas of very high population densities such as in the Ibo and Ibibio areas of the Imo, Anambra and Cross River States of Nigeria, the eastern rice growing slopes of the Malagasy Republic, Kano close-settled zone of northern Nigeria (Morgan, 1969) and on desert oases.

4. The compound farm system is the most widespread permanent cropping or farming system and often forms the centre from which paths lead to other field systems. The largest numbers of crop species in mixtures are found in compound farms since the crops there are not only grown for food but also for oils and fats, condiments and spices, masticants and stimulants, drugs, fibre, structural materials, animal feed, demarcation of boundaries, firewood, ornamentals, shade, protection and privacy of the homestead, religious and social functions, and various other uses (see Table 5). Its development as a regular feature of the traditional farming systems in most areas of Africa is related to three phenomena—(a) the division of labour between the sexes in which the woman is responsible for cooking and the provision of soups and sauces with which the main starchy staples often produced by men are eaten and for which all-year-round availability of fresh condiment plants, spices and vegetables at close range is necessary and convenient, (b) the fact that with frequent clearing of forests and bushes, useful trees harvested from the wild or protected in fallows are gradually disappearing and their cultivation in compound farms ensures that their products are readily available and that they do not become very scarce or extinct, and (c) the use of the compound farm as an experimental area for trying out interesting plants collected during trips to other areas or from neighbouring compounds (Vermeer, 1976).

5. Semi-permanent long and short bush or planted fallow systems vary in their periods of cultivation as compared to the periods of fallow, in relation to the natural fertility of the land, distances from the homestead, methods of fertility maintenance and population pressure in the area. In semi-permanent fields, major staples are the predominant crops grown with a few subsidiary crops—with the number of species being much less than in compound farms.

6. In a given area, the most important staples and cash crops are usually grown during the first year following clearance of forest, natural bush, planted fallow or grassland. The number of crop species decreases as the number of years of continuous cropping increases.

7. Mixed cropping is widespread in Africa and it attains its highest complexity in the compound gardens especially in the rainforest where annual staples, vegetables and perennial fruit trees are intercropped. Tables 1, 2, 3, 4 and 5 show the extent to which mixed cropping is practised in different ecological zones in Nigeria and Uganda. In farms or fields that are located at varying distances from the homestead, semi-wild, protected and selected wild tree crops but rarely cultivated trees may be found.

8. The growing of more than one crop on a given piece of land in one year in traditional farming systems of tropical Africa more often takes the form of mixed intercropping and relay cropping than double or triple sequences of crops each involving monoculture. Double cropping is more common in those areas of Africa with Mediterranean climate than in tropical Africa. Row intercropping and alternate strip cropping are not very common except under experimental conditions or on farms where animals or tractors are used in cultivation.

9. With the exception of the more temperate subtropical areas of Africa, classical crop rotations involving sequences of crops grown in monoculture are very rare in traditional farming systems of Africa. More common are the so-called "pseudo-rotations" of Allan (1965) in which mixed cultures of different species of crops are followed by a different set of dominant and subsidiary crops in mixed culture, some of which may have been relay intercropped with the preceding crops.

10. Farm sizes are usually very small ranging from less than one hectare to a few (two to five) hectares. There is a tendency for farm sizes to be greater but number of crops in mixtures lower as one moves from the rainforest to savanna, or drier areas.

Table 1: *Areas important crops in Nigeria in relation to the system of production in 1970–1971*

Crops	Hectarage sole	Hectarage mixed	Percentage mixed
	ha X 10^{-3}		%
Yams	503.7	733.2	59.2
Cassava	307.2	112.6	26.8
Cocoyam	27.4	173.9	86.4
Rice	103.9	143.3	58.0
Maize	355.2	1092.8	75.5
Melon	25.9	334.3	92.8
Cowpeas	39.0	3777.1	99.0
Groundnut	19.8	419.7	95.5
Cotton	130.2	524.5	80.1
Guinea corn	1152.0	4557.0	79.8
Soya-bean	48.2	51.8	100.0
Benniseed	36.8	41.3	52.9
Millet	510.9	4411.1	89.6

Table 2: *Areas of land in Nigeria planted to sole and mixed crops by States 1970/71 (in '000 ha)**

States	Yams			Cocoyam			Cassava			Groundnuts			Cowpeas		
	Sole	Mixed	% Mixed	Sole	Mixed	% Mixed	Sole	Mixed	% Mixed	Sole	Mixed	% Mixed	Sole	Mixed	% Mixed
Mostly Tropical Rainforest with some derived Savanna close to the Northern boundaries of some States															
Rivers	1.2	10.1	89.5	3.2	10.1	76.1	17.0	6.1	26.3	—	—	—	—	—	—
Lagos	1.6	0.8	33.7	0.01	0.8	99.9	14.6	2.0	12.2	—	—	—	—	—	—
Mid-west	10.9	101.6	90.3	0.4	5.7	92.9	32.8	33.6	50.6	0.4	2.4	86.7	—	19.0	100.0
South Eastern	2.0	84.2	97.7	0.8	61.9	98.8	49.4	13.4	21.3	3.6	8.9	71.2	0.8	—	—
East Central	58.7	85.0	59.2	12.1	35.2	74.4	54.2	11.7	17.8	3.6	5.3	59.1	—	12.5	100.0
Western	166.3	89.8	35.1	3.3	44.1	92.5	101.2	14.6	12.6	22.3	8.9	28.5	22.3	77.7	77.7
Middle Belt — Derived Savanna & Guinea Savanna															
Kwara	78.9	140.8	64.1	—	0.8	100.0	8.1	0.4	4.7	0.8	7.7	48.7	—	118.6	100.0
Benue-Plateau	169.6	102.8	37.7	0.8	4.0	84.3	4.0	23.5	85.4	23.5	14.6	38.2	—	143.3	100.0
Northern Region of mostly Guinea & Sudan Savanna															
North Western	3.2	53.8	94.4	—	—	—	3.6	1.6	31.1	14.6	61.2	80.8	—	979.7	100.0
North Eastern	—	60.3	100.0	4.9	9.7	66.5	13.8	4.5	24.3	93.9	486.4	83.8	—	1150.6	100.0
North Central	11.3	4.0	26.5	1.6	1.6	50.0	2.0	—	—	19.8	419.7	95.5	15.8	466.6	96.7
Kano	—	—	—	—	—	—	6.5	1.2	15.8	23.9	648.3	96.5	0.1	991.1	100.0
Nigeria	503.7	733.2	59.3	27.4	173.9	86.4	307.2	112.6	26.8	206.7	1663.7	89.0	39.0	3777.1	99.0

Table 2 (contd.): *Areas of land in Nigeria planted to sole and mixed crops by States 1970/71 (In '000 ha)*[*]

States	Cotton			Rice			Maize			Guinea Corn			Millet		
	Sole	Mixed	% Mixed	Sole	Mixed	% Mixed	Sole	Mixed	% Mixed	Sole	Mixed	% Mixed	Sole	Mixed	% Mixed
Mostly Tropical Rainforest with some derived Savanna close to the Northern boundaries of some States															
Rivers	—	—	—	—	—	—	7.7	100.0	—	—	—	—	—	—	—
Lagos	—		—	3.2	6.9	68.1	0.4	13.4	96.8	—	—	—	—	—	—
Mid-west	—	13.4	100.0	—	—	—	12.1	121.4	90.9	4.0	1.2	23.4	—	—	—
South Eastern	—	—	—	0.4	—	—	—	71.6	100.0	—	—	—	—	—	—
East Central	—	—	—	—	—	—	0.8	91.1	99.1	—	—	—	—	—	—
Western	2.8	19.4	87.4	32.4	48.2	59.8	138.8	323.8	70.0	—	78.5	100.0	—	—	—
Middle Belt — Derived Savanna & Guinea Savanna															
Kwara	—	19.8	100.0	—	2.4	100.0	36.8	144.5	79.7	21.4	113.7	84.2	9.0	20.2	69.2
Benue-Plateau	—	—	—	12.5	64.3	83.8	60.2	61.1	79.1	72.4	320.1	81.6	73.3	268.7	78.6
Northern Region of mostly Guinea & Sudan Savanna															
North Western	8.5	131.1	93.9	27.9	1.6	5.5	1.2	84.6	98.6	270.3	953.9	77.9	85.4	950.2	91.3
North Eastern	72.0	66.0	47.8	21.9	4.5	16.9	127.5	68.4	34.9	526.5	1220.6	69.9	265.5	1390.1	84.0
North Central	18.2	200.3	91.0	3.6	8.1	69.2	2.8	72.8	96.4	132.3	865.7	86.7	49.8	794.8	94.1
Kano	28.7	74.5	72.2	2.0	7.3	78.3	18.6	32.4	63.5	125.1	1003.3	88.4	27.9	98.7	97.3
Nigeria	130.2	524.5	80.1	103.9	143.3	58.0	355.2	1092.8	75.5	1152.0	4557.0	79.8	510.9	4411.1	89.6

[*]Federal Office of Statistics (1972) Rural Economic Surveys, Lagos, Nigeria

1. Mostly Tropical Rainforest with some derived Savanna close to the Northern boundaries of some States
2. Middle Belt — Derived Savanna & Guinea Savanna
3. Northern Region of mostly Guinea & Sudan Savanna

1. Mostly Tropical Rainforest with some derived Savanna close to the Northern boundaries of some States
2. Middle Belt — Derived Savanna & Guinea Savanna
3. Northern Region of mostly Guinea & Sudan Savanna

11. Commercial crops are more likely to be grown as sole crops or in association with fewer crops than staples grown mainly for subsistence. Farm sizes for commercial crops not grafted into the traditional systems are usually larger than in traditional farming systems.

Table 3: *Areas of crops in different regions of Uganda according to relative areas and proportions of mixed and sole cropping in 1963–1974*[1]

Crop	Uganda			Western Region[a]			Eastern Region			Northern Region[d]		
	Crop Area (000 Ha)		Percentage of Mixed Cropping	Crop Area (000 Ha)		Percentage of Mixed Cropping	Crop Area (000 Ha)		Percentage of Mixed Cropping	Crop Area (000 Ha)		Percentage of Mixed Cropping
	Pure	Mixed		Pure	Mixed		Pure	Mixed		Pure	Mixed	
1. Beans	6.1	94.7	94.0	28.7	80.0	81.1	13.0	52.6	80.3	10.1	78.3	87.9
2. Cowpeas	–	–	–	–	–	–	18.2	3.2	15.1	10.6	42.1	80.0
3. Cassava	5.3	30.8	85.4	6.9	4.5	39.4	27.1	23.9	46.8	45.7	25.5	35.8
4. Arabica Coffee[c]	–	–	–	–	–	–	6.1	10.5	63.4	–	–	–
5. Robusta Coffee	99.2	122.3	55.2	10.5	22.7	68.3	4.5	29.1	86.8	–	–	–
6. Cotton[b]	40.1	37.7	48.4	5.3	6.5	55.2	209.3	59.1	22.0	113.0	27.1	19.4
7. Groundnut	10.1	22.7	69.1	4.0	4.5	52.4	38.9	32.8	45.8	14.2	26.7	65.4
8. Maize	12.1	61.9	83.6	8.1	13.8	63.0	20.6	114.2	84.6	4.0	42.1	91.2
9. Sorghum	11.7	8.1	40.8	49.8	4.5	8.2	57.9	50.2	46.4	16.2	53.0	76.6
10. Fanges Millet	4.9	8.9	64.7	16.6	4.5	21.2	162.3	72.1	30.7	42.9	120.6	73.8
11. Pigeon Peas	–	–	–	–	–	–	–	–	–	10.5	37.2	78.0
12. Bananas	96.0	115.4	54.6	51.8	24.3	31.9	117.0	52.2	30.9	4.0	3.6	47.4
13. Sweet Potatoes	15.8	4.5	22.0	30.4	1.6	5.1	17.4	2.8	14.0	10.1	2.8	21.9
14. Sesame	1.6	2.0	55.6	–	–	–	3.6	12.6	77.5	45.3	37.7	45.4
15. Peas[e]	–	–	–	15.8	0.4	2.5	–	–	–	–	–	–

1 – Source Jameson (1970)
a – Figures for Western Region exclude Toro
b – Figures relate to Buyoro only
c – Figures relate to Kigezi only
d – Figures exclude Kasamoya
e – Figures relate to Bugisu/Sebei only
– Figures not available

Table 4: *Area of crops grown in almost all of Uganda according to area and percentage of sole or mixed cropping in 1963–1964*[1]

Crop	Area in hectare (000)		Percentage of Crop Grown in			
	Pure	Mixed	Pure	Mixed predominant	Mixed not predominant	Overall % mixed cropping
1. Beans	57.9	250.6	18.7	10.3	71.0	81.3
2. Cowpeas	22.6	47.8	38.2	6.3	55.5	61.8
3. Cassava	85.0	84.6	50.1	10.3	39.6	49.9
4. Robusta coffee	114.6	174.9	39.6	33.0	27.4	60.4
5. Arabica coffee	6.1	10.5	36.6	–	–	63.4
6. Cotton	367.6	130.4	73.8	21.2	5.0	26.2
7. Groundnuts	67.2	86.6	43.7	33.8	22.5	56.3
8. Maize	44.9	232.0	16.3	14.6	69.1	83.7
9. Sorghum	135.6	115.8	54.0	7.4	38.6	46.0
10. Finger millet	226.7	206.1	52.4	41.3	6.3	47.6
11. Peas	17.4	4.0	81.1	–	–	18.9
12. Pigeon peas	12.6	39.7	24.0	7.0	69.0	76.0
13. Bananas	268.8	195.5	57.9	20.9	21.2	42.1
14. Sesame	51.0	53.0	49.0	19.1	31.9	51.0
15. Sweet potatoes	73,7	11.7	86.3	4.7	9.0	13.7

1 – Source: Jameson 1970.
– Figures not available for these categories.

Table 5: *Observation on Food Crops and Other Useful Plants Found in Crop Mixtures In Compound and Outlying Farms In Parts of Southeastern Nigeria*

Plant group	Area Of Sample										Mean Percentage Frequency
	A 0.003–045ha		B 0.04ha		C 0.04–0.4ha		D 0.04–0.5ha		E 0.04–0.5ha		
	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	
1. Roots & Tubers	1–12	5	4–6	5	5–8	7	1–8	4	7–9	8	47
2. Cereals & other Starchy Staples	0–3	1	1–2	1	2–3	2	0–4	2	2–3	2	38
3. Leaf Vegetables	3–7	4	0–4	2	4–8	6	10–11	6	2–8	5	27
4. Fruit Vegetables	4–6	4	1–3	2	5–6	5	0–6	2	3	3	44
5. Legumes	1–5	3	0–4	2	2–4	2	0–3	1	0–3	2	33
6. Fruits, Nuts & Oil Plants	1–14	5	0–1	1	10–11	10	2–15	7	5–12	9	20
7. Spices & Beverages	0–3	1	0–1	1	2–6	4	0–9	4	1–7	4	18
8. Miscellaneous	0–7	2	0–1	0	10–14	13	1–29	11	4–18	12	11
Range in total number of species or cultivars	6–52		4–19		40–48		6–62		25–52		

A = Transition Zone – Derived Savanna/Oil Palm Bush
B = Transition Zone – Derived Savanna/Oil Palm Bush
C = Oil Palm Bush – High Population Density
D = Oil Palm Bush – Medium/High Population Density
E = Oil Palm Bush – High Population Density

12. Farming involves simple tools and a lot of human labour and only in the more temperate and tse-tse fly free regions are animal power and mechanical power used.
13. The most widespread clearance systems involves the use of fire.
14. With the exception of some irrigation projects in a few locations in semi-arid and arid areas, most cropping systems rely heavily on the prevailing rainfall with the cropping patterns and mixtures of crop species related to some aspects of the uncertainties in rainfall distribution and intensity (Fig. 10).

Historical developments and Factors which have contributed to continuing changes in cropping systems and adaptations to prevailing conditions

1. Variations and changes in cropping systems have arisen from the introduction of Asian crops (taro, *Colocasia esculenta;* water yam *Dioscorea alata;* banana *Musa* spp; rice *Oryza sativa;* etc.) starting from the first three centuries A.D. (Shaw, 1972) and American crops (maize, *Zea mays;* cassava, *Manihot esculenta,* sweet potatoes, *Ipomoea batatas,* etc.) in the sixteenth century A.D. and later.
2. Development of sedentary culture and population growth probably following the introduction of Asian and American crops and modern advances in medicine, sanitation and public health which have resulted in increasing pressure on the land.
3. The development of markets for perennial crops (Morgan, 1959a).
4. Expansion of cassava production due to its adaptation to shorter periods of fallow resulting in lower soil fertility and demands for cheaper staple food in urban centres (Morgan, 1959b). Moreover, in the tropical areas of Africa

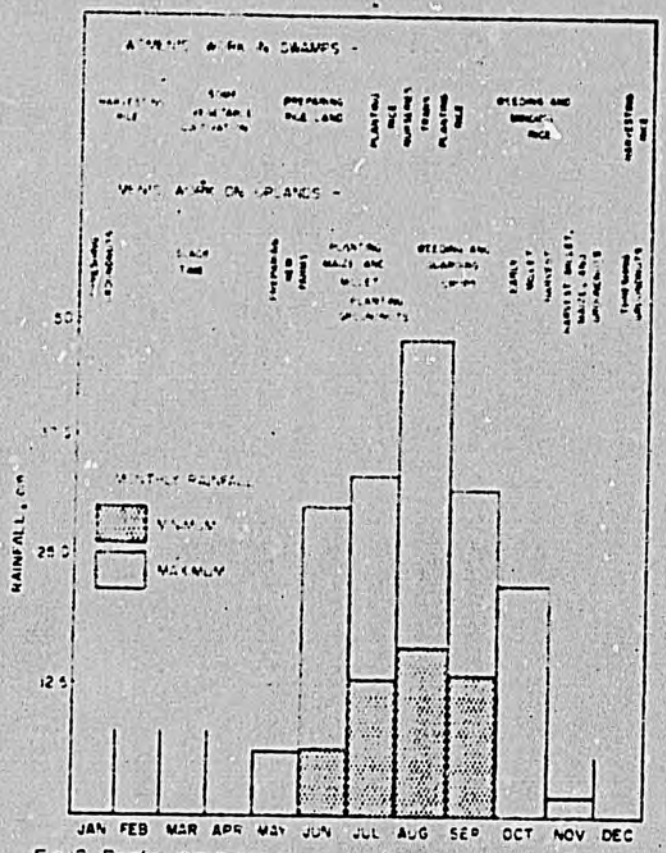


Fig 10 Rainfall distribution, crops and farming activities in Gambia (After Jarrett, 1974)

where the dry season ranges from one to five months, cassava is the only crop that can thrive without irrigation.

5. Development of commercial production of food crops and market gardening especially close to urban centres.
6. Development of railways, road systems and markets and the growth of settlements and farms along roads and railways and close to markets (Morgan, 1959b).
7. Increased fruit and vegetable production for sale and in support of local canning industries.
8. Reduction of period of cultivation, and sizes of holdings and farms.
9. Development of irrigation schemes in semi-arid and arid areas.
10. Land reform (e.g. in Egypt and Kenya).
11. European settlement and farming activities in certain parts of African and more recently the various agricultural, industrial and infrastructural developments which have followed independence of most countries in Africa.
12. Increasing mechanization of agriculture and use of pesticides and fertilizers.
13. Changes in division of labour between the sexes and status of women in the society. Related to this is the rapidly increasing shortage of labour on farms as a result of rural migration to urban areas.

Crop Diversity and Spatial Arrangements

A common feature of traditional farming systems is the production of several crop plants and numerous varieties of each species on each farm or by each farmer. Hailey (1968) observed that in addition to the major staples, subsidiary crops are numerous and in a survey of a comparatively limited area in Northern Rhodesia (Zambia) over 100 crop varieties were identified. Hailey also reported that in several farms in southern Nigeria where yams (*Dioscorea* spp.) is the staple food crop, it was found that 93% of them also carried maize, (*Zea mays*) 99% pumpkins (*Cucurbita maxima*), 24% cassava (*Manihot esculenta*), 92% groundnut (*Arachis hypogaea*), 80% various grain legumes, and 90% peppers (*Capsicum* spp.). In Zaire, Miracle (1967) reported various numbers of species of crop plants and varieties associated with different fallow systems. For example, he noted that the Medje grew as many as 80 varieties of the 30 species of food crops they cultivated in 1911. Of these, there were 27 varieties of bananas and plantains (*Musa* sp.) and 22 varieties of yams and related crops. The various varieties of each crop exhibit different characteristics, mature at different times, and may be adapted to different ecological situations and cultural practices. While crops are apparently established haphazardly in mixed culture, a close study of planting patterns indicates that both on the macro and micro level of a given landscape, the pattern of land use or planting used in traditional cropping systems usually involves location and spacing of plants in such a way as to:

1. take advantage of local topographic features, toposequences, microrelief and other related peculiarities (Figure 11),
2. disperse individual plant species at such wide spacing as to allow other crops to be grown in between without unnecessary overlapping of their canopies,
3. ensure that crop cover is adequate to effectively control soil erosion and weeds, and
4. ensure that heliophytes are grown more in open spaces while shade tolerant species such as cocoyams (*Colocasia esculenta* and *Xanthosoma sagittifolium*) are located under trees and along hedgerows.

Where annual staples are uniformly planted among tree crops in compound farms, heavy pruning of the tree crops is usually carried out to ensure that light reaches the ground level. Whether crops are grown on mounds, beds, ridges, or on the flat, their spatial arrangements and frequencies in mixtures are usually related to their importance in the diet and sometimes to their uses. Vegetable crops such as cucurbits (*Cucurbita* spp.), cowpeas (*Vigna* sp.), bitter leaf (*Vernonia amygdalina*), and peppers (*Capsicum* sp.) which are harvested for household use are usually planted along the edges of the garden or along fences surrounding gardens close to the homestead. The ingenuity involved in the utilization of various parts of the

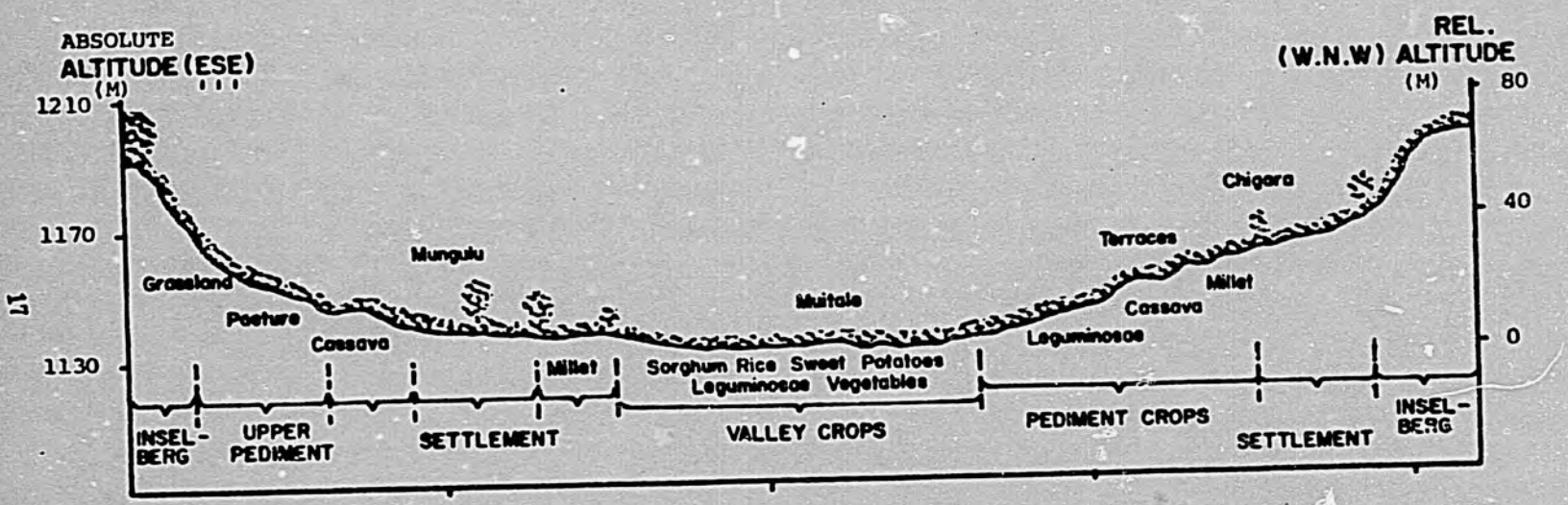


Fig 11. Profile of a typical valley showing land use in Ukara Island (After Ludwig, 1968 + Berry 1976).

large mounds on which different crops are grown in a hydromorphic soil of the Abakaliki area of the Anambra State of Nigeria is illustrated in Figure 12. The crops are located on the mounds according to their root systems and in relation to to their tolerance to high water table.

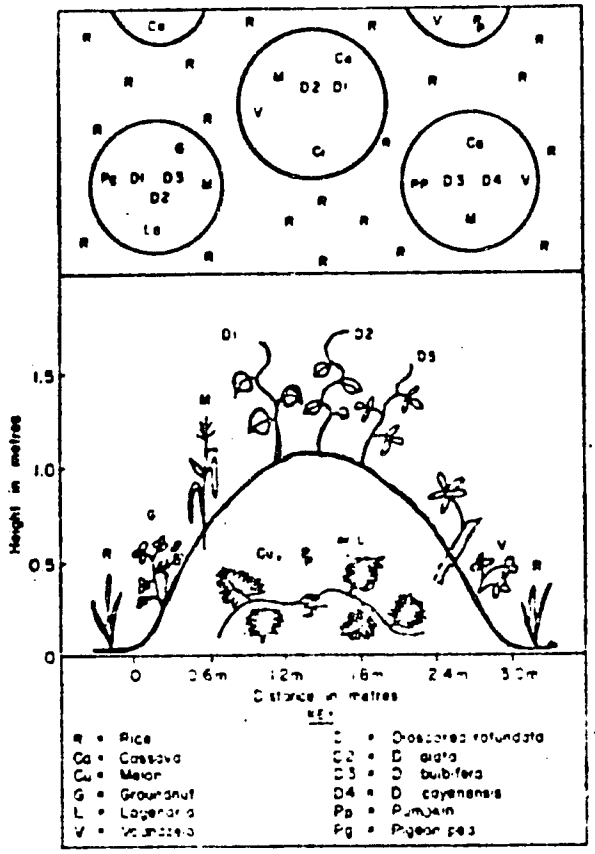


Fig 12 Spatial distribution of crops on mounds in Abakaliki, Anambra State, Nigeria

Various methods of utilizing special topographic and other features include: the concentration of sugarcane *(Saccharum officinarum* L.), rice and off-season vegetable crops in depressions and valley bottoms, the location of pineapples *(Ananas comosus)* and fruit trees along pathways in compound gardens, the growing of climbing crop plants such as lima beans *(Phaseolus lunatus)*, climbing cowpeas and yams close to trees, shrubs, fences, hedges and other structures which act as supports or stakes. Related to this is the location of condiment plants, fruit trees, and vegetables where they can be protected, watered, and harvested with ease. Various compound farm land use and cropping arrangements in parts of tropical Africa have been reported by Allan (1965), de Schlippe (1956) and Miracle (1967).

In addition to these intercropping patterns, small patches of pure stands of certain crops in adjacent plots are prevalent in many areas. Similarly in smallholder market gardens close to urban centers, vegetables are grown either in pure stands or in mixtures on small adjacent beds.

Regional and country survey of cropping systems and practices

WEST AFRICA

Nigeria

Nigeria stretches from latitude 5°N to latitude 15°N and longitudes 2.5°E to almost 15°E. It has physical and climatic features which have resulted in more or less parallel vegetation zones and ecological zones ranging fr n mangrove swamps in coastal areas with almost no pronounced dry season in the extreme south to the Sahel savanna zone with over 5 dry months in the extreme north. The altitude varies from zero to over 1,000m. Thus a diversity of crops can be grown including roots and tubers of the tropical rainforest, crops of the semi-arid areas such as sorghum and millet and subtropical crops such as potatoes and vegetables. Unlike the countries of East, Central and South Africa, there has been no European settlement. Consequently, with the exception of a few tree crop plantations and some large scale irrigation projects which are now being developed, the agricultural and cropping systems have been restricted to traditional smallholdings. Thus about 55 percent of the farms in Nigeria are below one hectare and about 90 percent are below four hectares (FOS, 1972). Farm sizes are lowest in the southern states where over 86 percent of the farms are below one hectare. In the Middle Belt and northern states of Nigeria, 71 percent and 49 percent, respectively, of the farms are below one hectare.

Mixed cropping as indicated above (Tables 1 and 2) is the predominant practice for both major staples and cash crops. The number of crops involved in the mixtures may exceed 50 species (Table 5) and consequently many more varieties since several strains of a given crop species may be grown in any one field. The practice of intercropping is a long standing tradition to the extent that it sometimes militates against adoption of improved crop varieties. In certain parts of Nigeria, farmers could not be persuaded to grow an improved introduced and superior American cotton variety because it did not perform as well when intercropped as did the local variety (Faulkner and Mackie, 1936).

The predominant practice of maintaining soil fertility is bush fallowing involving consecutive cropping periods of one to five years alternating with fallow periods of from two to over 15 years depending on the population pressure on the land. In the densely populated areas of Anambra, Imo and Cross River States of Nigeria, planted fallows of *Acioa barteri* and *Anthonotha macrophylla*, respectively, are used. Similarly, *Gliricidia sepium* may be grown for the same purpose in Oyo, Ogun and Ondo States of western Nigeria. Permanent cultivation with no fallow or very short fallow periods is practiced in the compound farms on floodland terraces of Eastern Nigeria and the Kano close-settled area (Morgan, 1969). Shifting cultivation

proper (Phase I shifting cultivation of Greenland, 1974) is restricted to some parts of Ogoja province very close to United Republic of the Cameroun.

The most widespread 'multiple' cropping systems consist of mixed intercropping and relay intercropping. Double cropping is limited to the growing of two crops of maize. In market gardens and in certain aspects of vegetable crops production double cropping, triple cropping and alternate strip cropping systems are sometimes practised. These are not uniformly or systematically adhered to over large areas of the country. In the southeastern states of Nigeria the dominant staples are yams, cassava, cocoyams, bananas and plantains and to some extent maize. They are usually grown with a range of subsidiary crops such as groundnuts (*Arachis hypogaea*), okra (*Hibiscus esculentus*) pumpkins (*Cucurbita maxima*) melons (*Colocynthis vulgaris* and *Cucumeropsis* spp.) leaf vegetables *maranthus hybridus, Celosia argentia, Corchorus olitorus, Telfairia occidentalis Solan*, etc.). The above root crops are also grown in Western Nigeria but the bananas, plantains and cocoyams are not as important as in the eastern parts of the country. Tree crops grow in association with the annual and biennual staples. For example, in much of southeastern and midwestern Nigeria oil palms constitute part of the climax vegetation and an important cash crop. Semi-wild groves and plantations of oil palms exist in monocuoture but many palms are found in compound farms or scattered in outlying fields where they are protected. Similarly, rubber in Bendel State and cocoa and kola in Oyo and are also found in association with annual staples. The 'Middle Belt' of Nigeria which consists of much of the Benue, Plateau, Kwara and Niger States grows some of the important crops of the tropical rainforest such as yams in the southern half of the area and sorghum and millet in the northern half.

Clearance systems involve slash and burn techniques. Planting on mounds or heaps and sometimes ridges is a general practice except in areas with deep alluvial or sandy soils where planting on the flat is not uncommon. The mounds attain their most impressive development in the hydromorphic soils of Abakaliki Division of the Anambra State of Nigeria (Figure 12, Tables 6 and 7). Here mounds up to 2.5m in height and over 3m in basal diameter are found. Examples of rudimentary rotations and various kinds of mixed cropping are presented below.

Eastern Nigeria

Traditional cropping systems range from shifting cultivation in isolated areas near the Camerouns border to intensive sedentary cultivation (Floyd, 1969; Uzozie, (1971). Figure 13 shows the key to cropping schedules and combinations used in this discussion.

Rotations

No 'systematized' rotations are in regular use. Crops that are grown are sequenced according to the number of compatible species in the mixture that can produce reasonable yields at the soil fertility level prevalent at each stage of cropping cycle. Examples of crop rotations used in bush fallow and rudimentary sedentary cultivation fields at Nnewi in Onitsha province reported by Floyd (1969) consist of the following (see also Figure 14):

Table 8: *Crop Combinations in different locations observed in 100²m Sample Plots in Relation to Seed Bed Preparation.*

Crop	Ogidi (Mounds)	Abagana (Mounds)	Umuleri (Mounds)	Awka (Mounds)	Ezillo (Mounds)	Abalaliki (Mounds)	Ikom (Mounds)	Oron Flat	Ikam Ekpe Flat	Onne 1 Flat	Onne 2 Flat	Percentage Freques
Dioscorea rotundata	X	X	X		X	X	X	X	X	X		82
D. rotundata (Abi)		X		X								18
D. dumetorum						X		X	X	X		36
D. bulbifera					X	X						18
D. alata			X		X	X						36
D. cayenensos								X				9
Cassava (Maniot sp)		X		X	X	X		X	X	X	X	64
Cocoyam *(Xanthosoma)*			X	X				X	X			45
Cocoyam*C(Colocasia)*			X		X			X	X			36
Sweet potato			X									9
Musa sp				X			X		X			27
Maize (Zea sp)	X	X	X	X	X	X	X	X	X	X	X	100
Cowpeas (Vigna sp)			X		X							18
Groundnuts *(Arachis sp)*					X	X	X					27
Voandzeia sp					X							9
Sphenostylis sp								X				9
Solanum sp	X		X									9
Capsicum sp												18
Okra (Hibiscus sp)	X	X	X		X	X	X	X	X			73
Pumpkin (Cucurbita sp)	X	X						X				27
Melon (Colocynthis sp)	X	X	X	X		X	X					55
Telfairia sp					X				X			18
Lagenaria sp					X	X						18
Amaranthus sp	X		X	X								27
Corchorus sp			X	X			X		X			45
Bitter leaf (Vernonia sp)									X			9
Talinum triangulare							X	X				18
Castor beans (Ricinus sp)	X		X	X	X							36
Sugar cane (Saccharum sp)								X				9
No. of Species per sample	9	7	13	9	13	10	9	13	12	4	2	

Table 7: *Crop Combinations on Mounds of various sizes* observed in Abakaliki and Ikom Divisions in Nigeria in 1975*

Crop	Locations and Mound Sizes															Percentage Frequency
	Emene Mound Size 0.8x1.3m			Nkalagu Junction Mound Size 1x3m			Ezillo Mound Size 0.9x2m			Abakaliki Mound Size 1.3x3m			Ikom Mound Size 0.1x1.5m			
	No 1	No 2	No 3	No 1	No 2	No 3	No 1	No 2	No 3	No 1	No 2	No 3	No 1	No 2	No 3	
1. *Dioscorea rotundata*	X		X	X	X			X	X	X	X	X	X	X	X	80
2. *D. alata*	X	X	X	X	X		X		X			X				53
3. *D. bulbifera*	X	X	X	X			X	X								40
4. *D. cayenensis*		X					X	X								20
5. *D. dumetorum*										X	X	X				20
6. Cassava (*Manihot* sp)	X	X	X	X	X		X	X	X	X	X	X				73
7. Cocoyam (*Xanthosoma* sp)							X							X		13
8. " (*Colocasia* sp)		X	X	X	X				X							33
9. Maize (*Zea mays*)	X	X	X	X	X	X	X	X	X				X	X	X	80
10. Cowpeas (*Vigna* sp)	X			X	X											33
11. Pigeonpeas (*Cajanus* sp)	X	X														13
12. Bambara groundnuts (*Voandzeia* sp)										X		X				13
13. Groundnuts (*Arachis* sp)						X	X	X	X	X	X	X	X	X	X	67
14. Okra (*Hibiscus* sp)	X			X	X		X	X	X			X			X	53
15. *Solanum* sp			X					X								7
16. Pumpkin (*Cucurbita* sp)								X	X							33
17. Melon (*Colocynthis* sp)		X							X	X	X		X	X	X	40
18. *Telfairia* sp														X		7
19. *Talinum triangulare*	X		X	X	X					X	X					7
20. *Lagenaria* sp							X	X	X							40
21. *Capsicum* spp.																33
No. of Species per sample	9	8	8	9	8	2	9	9	11	7	6	7	4	6	5	

* First figure indicate the height of mound, second figure is basal diameter

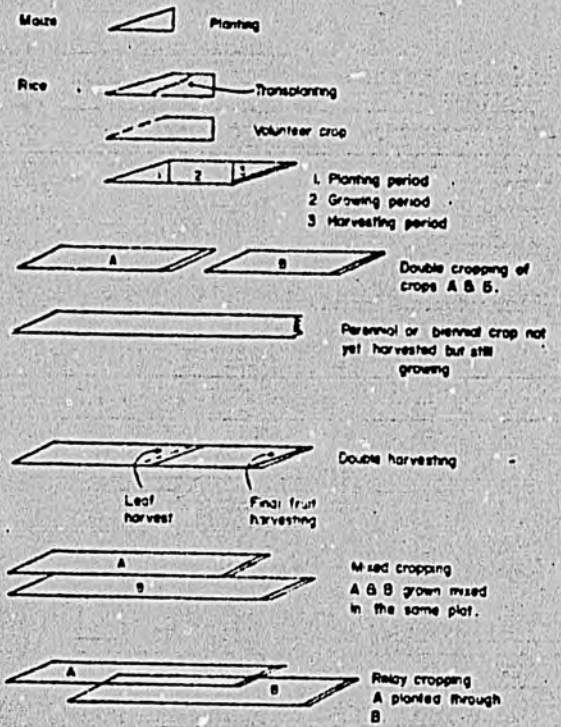


Fig 13 Key to cropping schedules and combinations

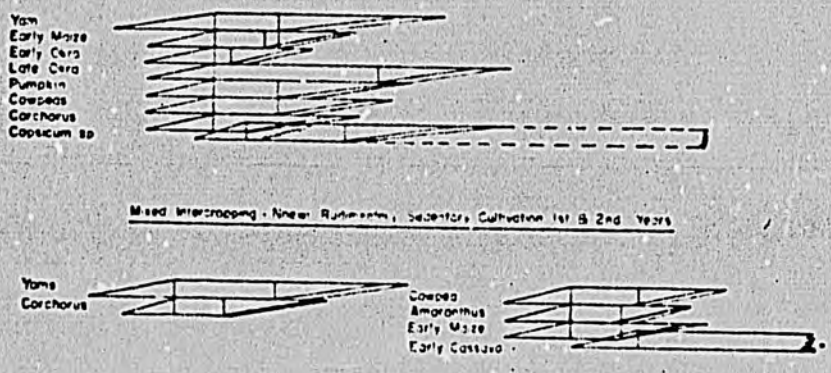


Fig 14 Mixed and relay intercropping - Nnewi 1st year bush fallow

Bush Fallow Rotation (Fig. 13)

1st Year	*2nd Year*	*3rd Year*	*4th Year*	*5–8th Years*
Yams	Cocoyam	Yam	Early cassava	Late cassava
Maize	Maize	Maize	Cowpea	Bush fallow
Cowpea	Cowpea	Cowpea	Vegetables	
Pepper	Pepper	Cocoyam		
Okra	Okra	Vegetables		
Vegetables	Vegetables			

Rudimentary Sedentary Cultivation Rotation (Fig. 14)

1st Year	*2nd Year*	*3rd Year*
Yams	Maize or cocoyam	Late cassava
Cowpea	Cowpea	Pigeon pea
	Vegetables	Cucurbits
	Early cassava	Crotolaria fallow

Cropping sequences observed in the vicinity of Ibadan (Faulkner and Mackie, 1933) and in Bendel State (Akumazi) and parts of the former Western State (Alade) by Upton (1967) are presented below:

Rotations at Akurnazi (2 years cropping, 4 years fallow)

1st Year	*2nd Year*	*3rd Year*
Yams	Cassava	Cassava +
Maize		Fallow
Cocoyams		
Cowpeas		
Cucurbits		
Peppers		
Okra		
Leaf vegetables		

Rotations at Alade, Western Nigeria (Figure 16)

1st Year	*2nd Year*	*3rd Year*	*4th Year*
Yams	Early maize	Cassava	Cassava +
Maize	Cocoyam		Fallow
Cowpea	Cassava		
Okra	*OR*		
Peppers	Early maize		
Vegetables	Late maize		
	Late cassava		

Compound Farm Rotations

1st Year	*2nd Year*	*3rd Year*
Yams	Cocoyam	Repeat 1st year
Maize	Maize	Crop combinations
Vegetables	Vegetables	

Crop Combinations

Uzozie (1971) on the basis of six selected primary food crops identified the following dominant crop combination regions in southeastern Nigeria (Figure 15).

(a) Imperfectly developed monoculture based on yams
(b) Imperfectly developed monoculture based on cassava
(c) Yam/maize
(d) Cassava/yam
(e) Yam/cassava/maize
(f) Plantain/cocoyam/cassava
(g) Cocoyam/plantain/cassava/yam
(h) Cassava/yam/cocoyam/maize
(i) Yam/cassava/cocoyam/maize/pigeon pea

Western and Midwestern Nigeria

The dominant food crops in the Midwest and the Western States are yams, cassava, maize, cocoyam, plantains and bananas, and subsidiary vegetables and other minor crops. The most important cash crops in the Midwestern State are rubber and oilpalm while in the Western State cocoa and kola are the important tree crops. There are subsidiary fruit trees and perennials, nuts and oil plants which include the African pear *(Dacryodes edulis)* in the Bendel State and conophor *(Tetracarpedium cocophorum)*, coconuts, avocado pears, citrus fruits, pineapple, castor beans, guava, etc. in both states.

Rotations in Ibadan Area (Faulkner and Mackie, 1933) (Figure 16)

1st Year	*2nd Year*	*3rd Year*	*4th Year*
Late maize (flat)	Yams (continued)	Early maize	Cassava +
Early yams (mounds)	Early maize	Late cassava	Fallow
	Late cotton		
	Cucurbits		
	Cowpea		
	OR		
Early Maize	Cassava	Cassava +	
Okra			
Melon			
Late Maize			
Late cowpea			

(Figure 16)

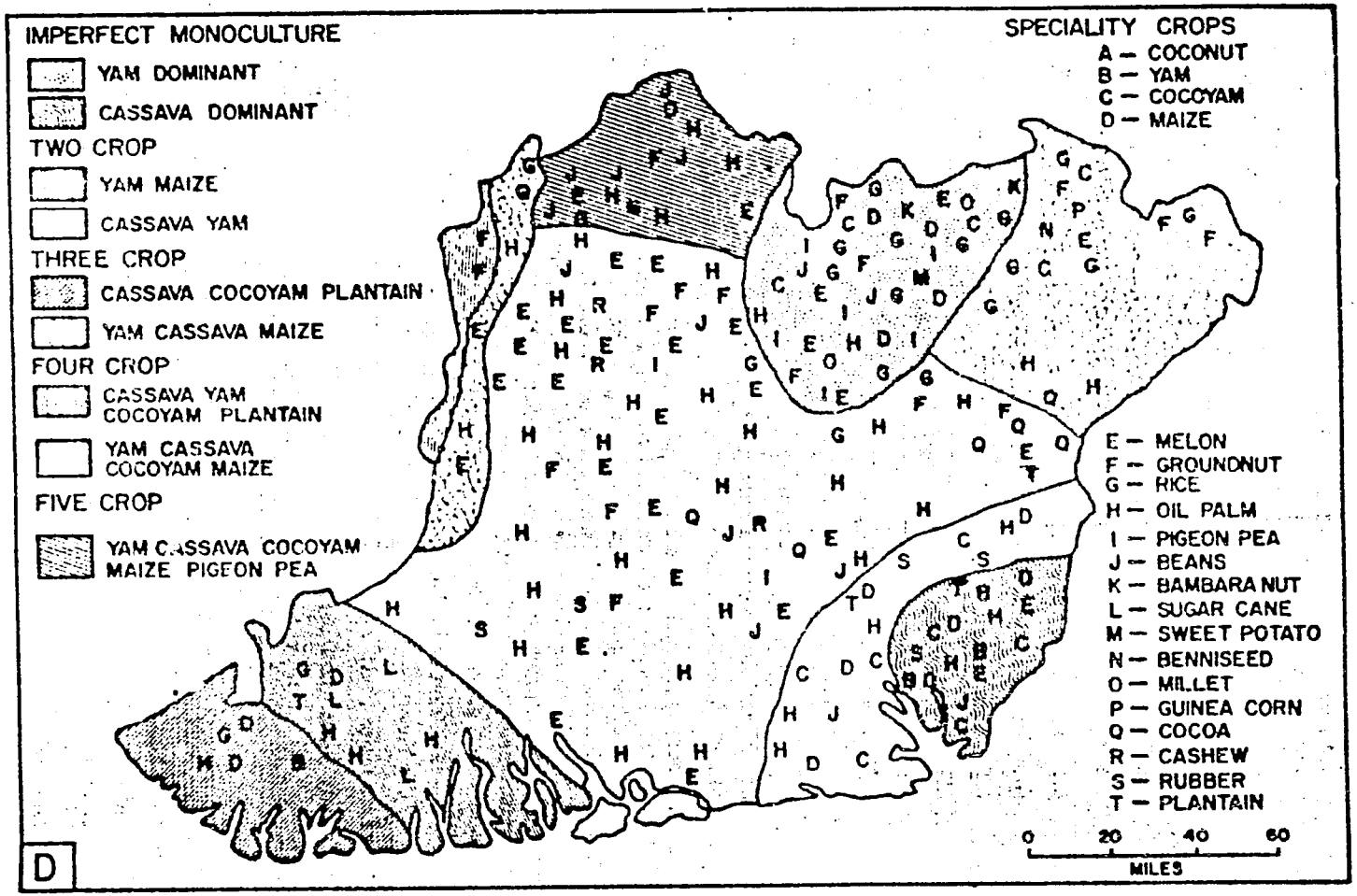


Fig 15. Crop combination areas in southeastern Nigeria (Uzozie, 1971).

Fig 15. Crop combination areas in southeastern Nigeria (Uzozie, 1971).

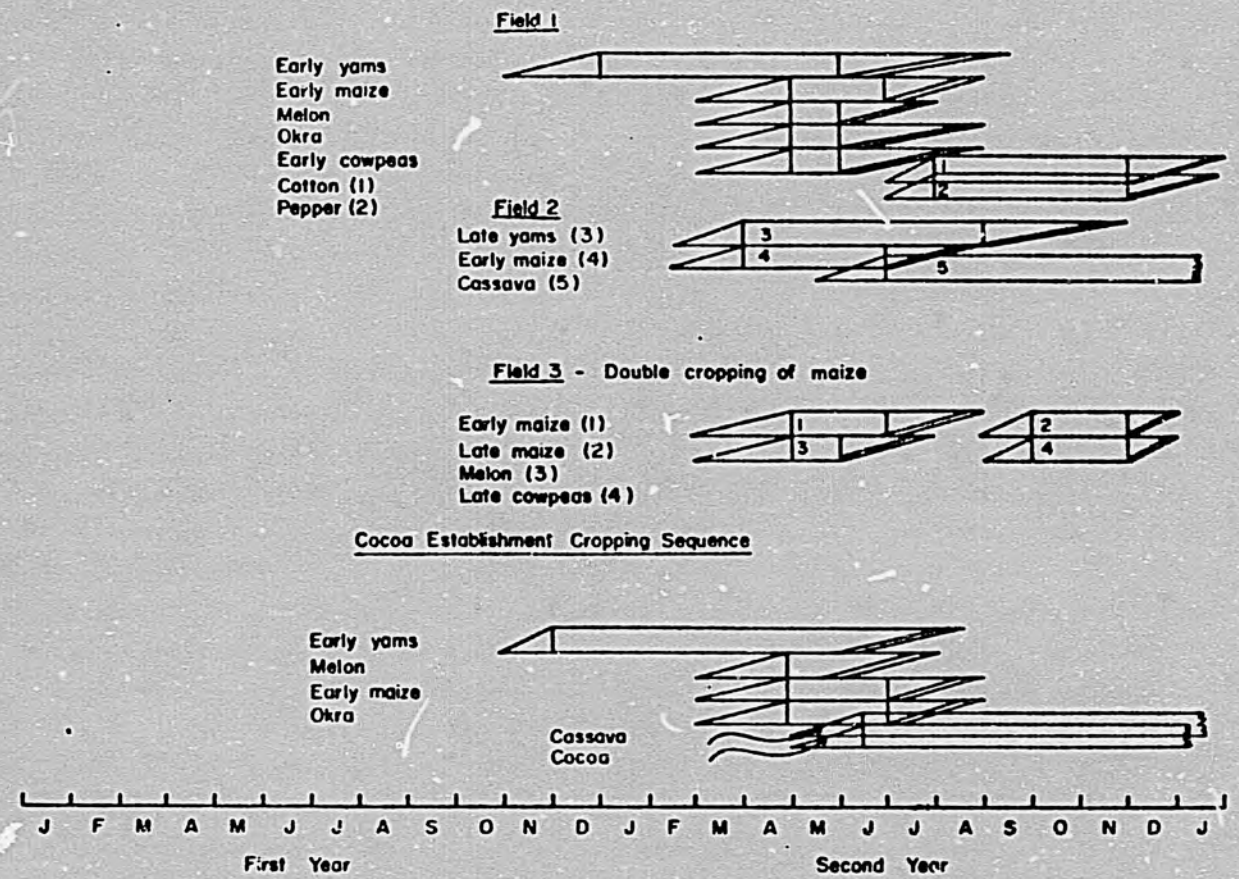


Fig 16. cropping Schedules in Ibadan area. Western Nigeria

Rotation for Cocoa Establishment, Ibadan Area

1st Year	*2nd Year*	*3rd Year*	*4th Year*	*5th Year*
Early yams (Nov.)	Early maize	Cassava	Cocoa	Cocoa
	Okra	Cocoyam	Cocoyam	
	Melon	Cocoa (cont.)		
	Vegetables			
	Late cassava			
	Cocoa			

In both midwestern and southwestern Nigeria, small plots of tree crops such as cocoa and rubber may be grown in semi-wild groves or carefully established plantations. Otherwise most tree crops including oilpalms, citrus fruits, avocado, etc. are usually scattered about the farms at different spacings from each other. More of the perennial fruit trees are located nearer the homestead than non-fruit trees such as rubber. In his studies of some villages in the then Midwestern (now Bendel State) and Western Nigeria (now Oyo, Ogun and Ondo States) Upton (1967) observed the following numbers of trees owned by a farm family:

Oil palms	39 — 106
Plantains and bananas	0 — 83
Kola trees	0 — 64
Citrus trees	0 — 38

In Southern Nigeria, the number of species and individual tree crops per unit area decreases with increasing distance inland until in the Derived Savanna belt in the northermost parts of the rainforest zone where there are intrusions of savanna cereals and other crops that thrive best in moderate to low rainfall areas. These crops include sorghum, millet, cotton and various grain legumes. In the northern part of Oyo State (north of Ibadan), crops of sorghum usually precede yams and the broken culms of the sorghum are used as stakes or trellises for yams.

Middle Belt of Nigeria

The Middle Belt of Nigeria is a transition zone between the root crops/oilpalm/cocoa belt of the south and the sorghum/millet/cotton/groundnut belt of the northern states. This area is the mixed grain and root crops belt sometimes designated as the benniseed belt. It is in this belt that the Jos Plateau is located. On certain defensive positions, there are villages with terraced farms in which some traditional farming systems are being practised. More recently in the same area, there has sprung up a number of largescale farms for the production of more temperate or subtropical fruits and vegetables for the urban centres of the southern states. These crops include tomatoes, *(Lycopersicon esculentum)*; Irish potato, *(Solanum tuberosum)*; carrots *(Daucus carota)* and water melon *(Citrullus lanatus)*. The region is noted for its multiplicity of crops including sorghum *(Sorghum vulgare)*, pearl millet *(Pennisetum typhoideum)*, two idigenous African grain crops: the hungry rice or Acha *(Digitaria exilis* and *D. iburua)* and finger millet *(Eleusine corocana)*; root and tuber crops consisting of yams *(Dioscorea* spp.),

cassava *(Manibot esculenta)* and cocoyams *(Xanthosoma* spp. and *Colocasia esculenta)* in addition to the ancient root and tuber crops *Plectranthus esculentus* (risga) and *Solenestemon rotunalflorus* (tumuku); cotton, *(Gossypium* spp.) sesame, *(Sesamum indicum)*, indigo *(Indigofera tinctoric)* soyabeans *(Glycine max.)*, groundnuts *(Arachis bypogaea)* and cowpeas *(Vigna unguiculata)*. Other crops grown in the area include onions *(Allium cepa)* rice *(Oryza sativa)* sweet potatoes *(Ipomea batatas)*, tobacco, *(Nicotiana tabacum)* peppers *(Capsicum)* and henna *(Lawsonia inermis)*. As in other parts of the tropics intercropping is a widespread practice.

Netting (1968) studied the Kofyar of the Benue Plateau and details of their cropping systems are presented in Figures 17 and 18. The Kofyar grow at least thirty species of crops in (1) farms, (2) village gardens close to the continuously farmed homestead gardens, (3) bush farms lying just outside the settled village perimeter and (4) 'migrant bush' farms which may be located several hours walk from the village. The homestead farms are permanently cultivated with maize, cocoyams and cowpeas in addition to various subsidiary crops and vegetables. Early millet is often interplanted with sorghum, cowpeas, pumpkins, okra, maize and Guinea sorrel or roselle *(Hibiscus sabdariffa)*. Several subsidiary crops such as tobacco, groundnuts, Bambara groundnuts *(Voandzeia subterranea)* and sweet potatoes are planted on separate plots in different parts of the homestead or village farms. Tree crops such as mangoes, *(Mangifera indica), Canarium schweinfurthii* and papaya *(Carica papaya)* are located near the homestead entrance and may also be dotted about the farms. Details of the planting schedule and spartial arrangement close to the compound of the Bong who live in this area are presented in Figure 18. Average size of farms is about 1 hectare but many of them are less than half a hectare.

Northern Nigeria

Northern Nigeria stretches from about latitude 10°N to almost 14°N and lies in the semi-arid zone of West Africa where the duration of the dry season is over five months and the growing season less than 200 days. The major food crops are sorghum and millet while the minor crops are rice, ginger *(Zingiber officinale)* cowpeas, maize, sweet potatoes, yams, pepper and onions. The main cash crops are groundnuts and cotton.

As in other parts of tropical Africa intercropping is widely practised (see Tables 1 and 2). Norman (1974) in a study of intercropping combinations in Zaria province of the Kaduna State of Nigeria reported up to 156 different crop mixtures consisting of sole crops, two, three, four, five and six crop mixtures accounting for 16.6, 42.1, 23.7, 12.1 and 5.5 percent of the mixtures respectively. The seven most frequent mixtures were:

Millet/sorghum (25.8%)

Sorghum/groundnuts (2.8%)

Cotton/cowpeas (3.9%)

Millet/sorghum/groundnuts (5.0%)

Millet/sorghum/cowpeas (3.9%)

Cotton/cowpeas/sweet potatoes (4.3%)

Millet/sorghum/groundnut/cowpeas (5.4%)

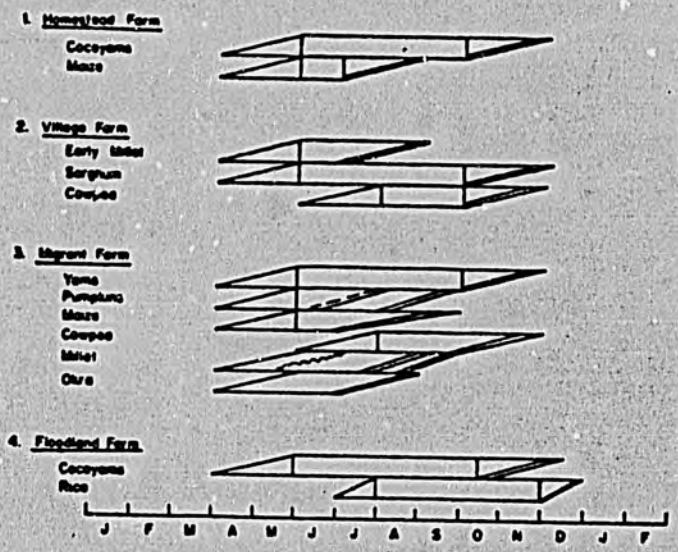
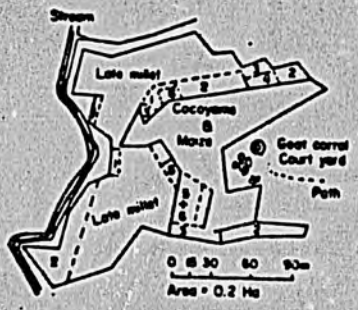


Fig 17. Cropping schedule and combinations of the Kofyar



MIGRANT BUSH FARM ROTATION

1st Year	2nd Year	3rd - 8th Year	9th - 11th Year	12th Year
Yam	Millet Sorghum Cowpea	Millet Sorghum Cowpea	Cotton or Groundnuts	Follow

Fig 18 Homestead and bush field land use and cropping pattern at Dalung, Bong, Benue Plateau (Netting, 1968)

These seven crops combinations covered 61 percent of the area under crop mixtures. Of the total cultivated areas 8.4, 3.1, 1.8 and 3.3 percent were under sole crops of sorghum, cotton, groundnuts and other crops respectively. Sorghum was found to be the most important food crop of the area and cotton and groundnuts the most important cash crops.

With the exception of the Kano and other mixed farm or high population density areas of northern Nigeria, bush fallowing is the common practice with fallow periods ranging from four to sometimes over eight years in areas of low population density. Compound farms are as usual, common to all areas and are cropped every year with such crops as maize, okra, pepper, roselle, rama *(Hibiscus cannabinus)*, pumpkins, tobacco and various vegetables. In addition to compound farms and bush fallow fields located at varying distances from the homestead, there are fadama fields or hydromorphic areas where bananas, rice, sugarcane *(Saccharum officinarum)* and vegetables are usually grown. In the flood plains of streams irrigation is possible and this facilitates the growing of rice, sugarcane and other field crops. As in many other areas of Nigeria, apart from fruit trees such as mangoes and oranges which are grown in compound gardens, protected plants such as Shea butter tree *(Butyrospermum paradoxum)*, locust beans (Parkia spp.) and baobab *(Adansonia digitata)* are usually found dotted about the outlying fields. In areas where ridges are used there is usually a definite spatial arrangement of crops with millet occupying the furrow areas while sorghum and cotton are often grown on the ridges. Some of the southern crops such as yams and cassava are grown on ridges or mounds. The cassava farms or gardens are usually fenced off from other crops as a protection against damage by livestock. Some of the mixed cropping schedules used in the area are presented in Figure 19.

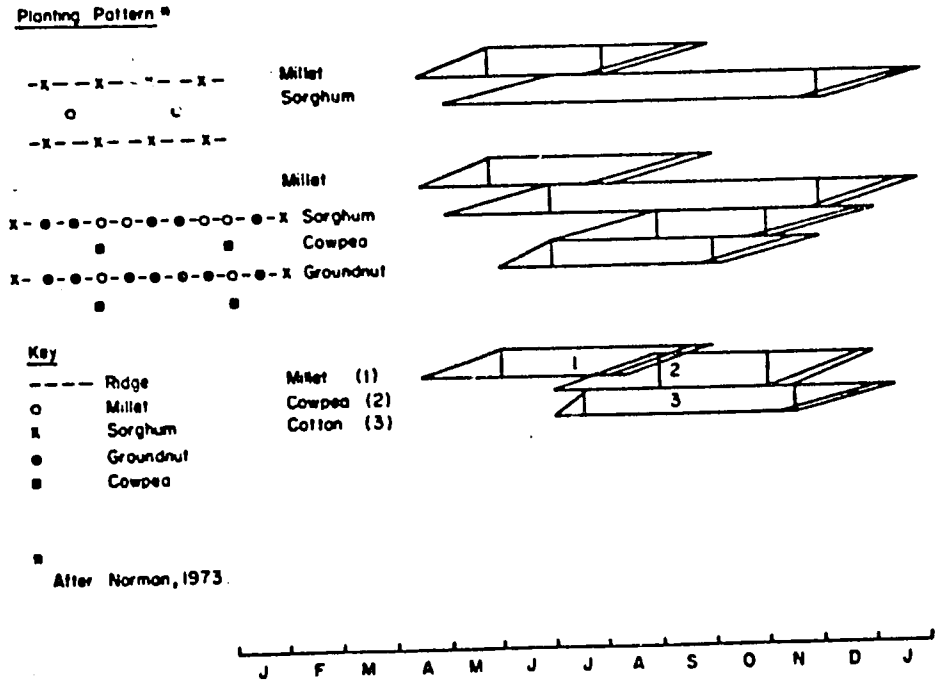


Fig 19 Cropping schedules and pattern of planting for some crop combinations in northern Nigeria

Other Countries of West Africa

Various aspects of the cropping systems of West Africa have been reported by Faulkner and Mackie (1933), Allison (1941), Irvine (1969), Porteres (1952, 1955), Johnston (1958), Guinard (1961), Hardcastle (1959), Wills (1962), Bourke (1963), Anyane (1963), Catherinet (1965), Jordan *et al* (1966), De Sapir (1969), Hartoungh (1969), Jones (1959), Kline *et al* (1969). Morgan (1969), Morgan and Pugh (1969), Weil (1969), Donald (1970), Grove (1970), Muckle (1971), Thornton (1973), Spencer (1973), Charreau (1974) and Van Santen (1974). Porteres (1955) reported changes in crops grown in northern, central and southern Senegal as a result of emergence of groundnuts as a commercial crop. He noted the absence of groundnuts in cropping systems and rotations of Senegal in 1850 and the replacement of seed cotton and sesame by groundnuts in the cropping systems of northern, central and southern zones of Senegal by 1950 in addition to the inroad made by cassava into the cropping systems of southern Senegal. Charreau (1974) observed that mixed cropping was widely practised in the peasant cropping systems in the Francophone countries of West Africa.

Wills (1962) listed various crops grown in compound and outlying farms in various parts of Ghana and stressed the increasing importance of market gardening close to urban areas; the occurrence of mixed groves of horticultural crops such as the coconut *(Cocos nucifera)*, orange *(Citrus aurantium)*, lime *(Citrus aurantifolia)* grape fruit *(Citrus paradisi)*, lemon *(Citrus limon)* avocado *(Persea americana)* and akee apple *(Blighia sapbida)* near homesteads; the growing of tomatoes, shallot, lettuce *(Lactuca sativa)* and other vegetables in valley bottom soils close to urban centres; and the production of maize, rice and guinea corn in the fadamas of northwestern Ghana. All the works cited above emphasize the widespread practice of mixed cropping of the kinds found in similar ecological and vegetation zones of Nigeria. Examples of cropping systems which differ somewhat from those of Nigeria include the intensive shallot and vegetable cropping systems of Anloga in Ghana (Irvine, 1950 and 1955, and Grove, 1970) and the upland rice intercropping systems of Liberia and Sierra Leone (Figure 20).

At the edge of the Keta Lagoon, in the Anloga area of Ghana there is an intensive shallot *(Allium escalonicum)* industry involving three crops of shallot in one year. The shallot is grown in small patches on beds and vegetables are grown as sole crops or mixtures between the harvesting of one and planting of another shallot crop. The duration of each crop is six weeks and tomatoes, okra, maize and pepper are intercropped with the shallot especially the third crop. The fertility of the alluvial soils on which they are grown is maintained with bat and cow dungs, crop residues, fish manure and household refuse. The shallot farmers usually divide themselves into three groups each of which plants its own shallots two weeks after the other to avoid glut in the shallot market. Most of the shallot is sold at Accra.

Van Santen (1974) reported that in the Foya area of Upper Lofa in Liberia upland rice which is planted in May to July is usually intercropped with pepper *(Capsicum* sp.), bitterball *(Solanum* sp.), beans, maize, bananas *(Musa* sp.) plan-

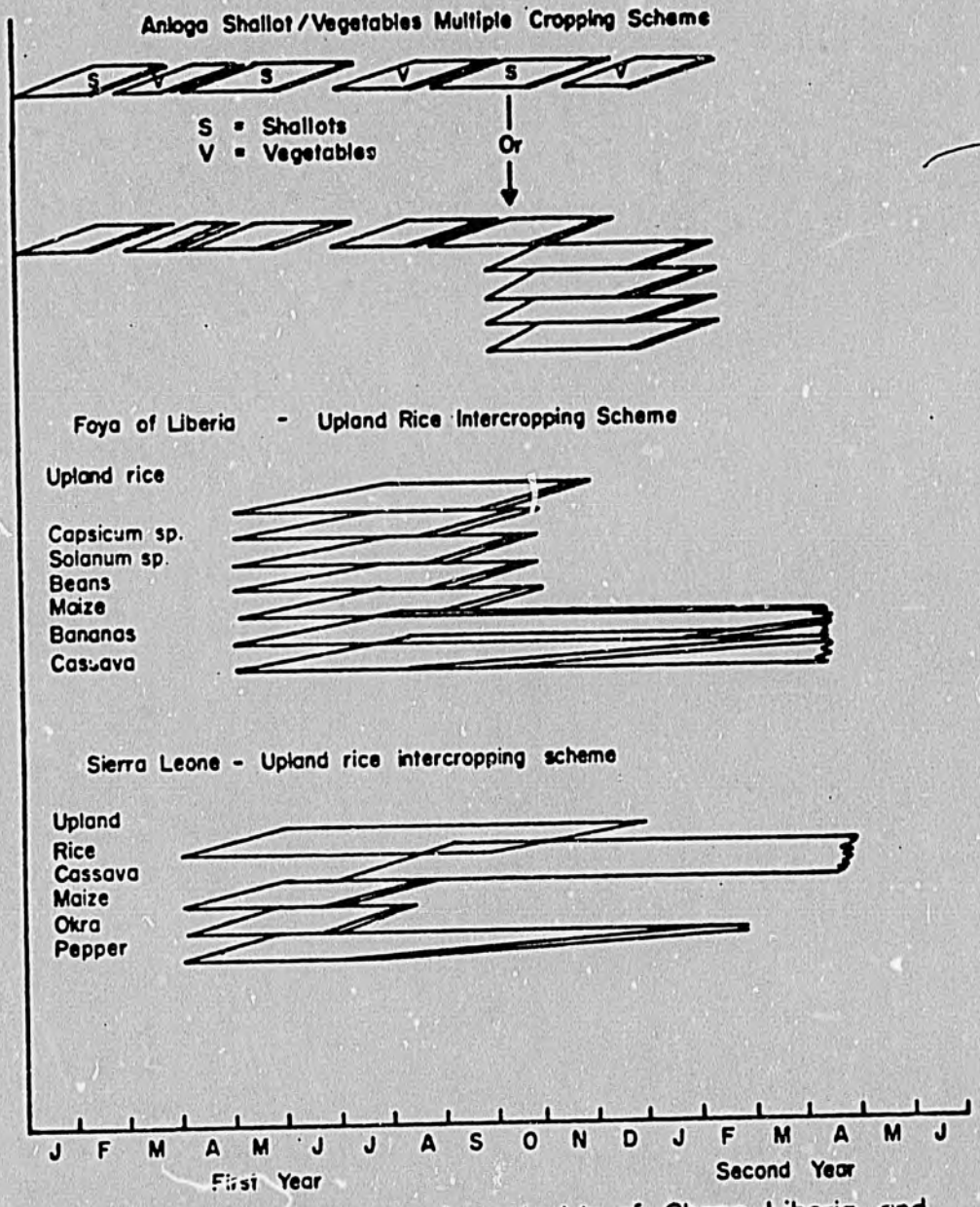


Fig 20. Some 'multiple' cropping schedule of Ghana, Liberia and Sierra Leone

tains (*Musa* sp.) and cassava. Similarly, Spencer (1973) observed that of the 75% of the rice crop of Sierra Leone which is upland rice, 19.7% is intercropped with cassava, maize, cotton, pigeon peas, and/or okra. Planting and harvesting schedules of the upland rice intercropping systems in Liberia and Sierra Leone are presented in Figure 20.

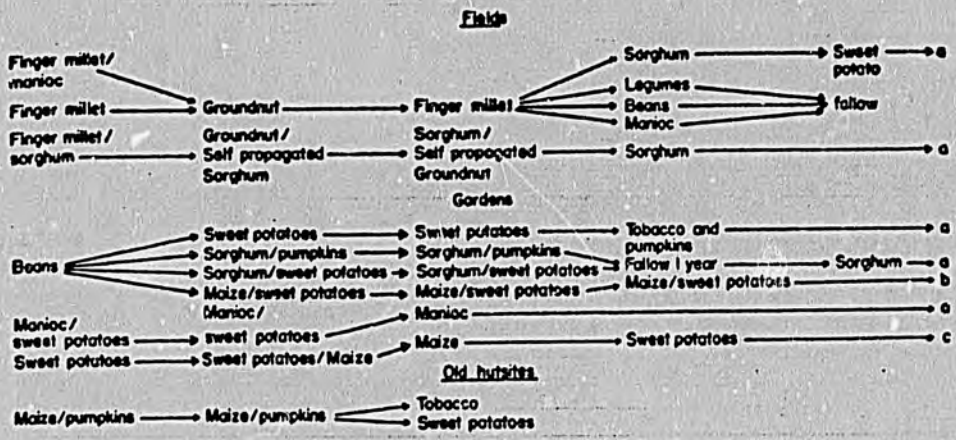
CENTRAL AND SOUTHERN AFRICA

Several complex cropping systems which are associated with shifting cultivation, bush fallow and semi-permanent farming systems are found in the Congo, Northern Rhodesia and adjacent regions.

The Congo

The agricultural systems of the Congo basin and adjacent areas of the Sudan and the Central African Republic have been described by De Schlippe (1956) and Miracle (1967). Johnston (1958) and Morgan (1969) also reviewed the crop association regions of the area. Space does not allow a detailed coverage of the cropping systems of the region and only a brief review of cropping systems will be presented here with emphasis on the aspects in which they differ from those of West Africa. The farming systems of the Congo include bush fallow systems and field types encountered in West Africa but lower population densities in some areas have resulted in longer periods of fallow than in West Africa. Miracle (1967) identified four major groups of cropping systems in the Congo—classic tropical long fallows, ash fertilizer dependent long fallow systems, compost dependent fallow systems and short fallow systems. Each of these exhibit variations in terms of sequences of field operations associated with planting. Within each system various kinds of crop associations, 'rotations' or crop sequences occur. The crop combinations are related to the field systems. Only the cropping systems of the Bemba and Azande are considered here.

The Bemba who practise the *chitemene* system, clear woodlands 5 to 20 times the area to be cropped, pile the wood and burn it to obtain the ash which is used as fertilizer (Ruthenberg, 1971). Bemba field systems described by Miracle (1967) and based on the works of Richards (1939) and Trapnell (1953) included typical bush fallow field cultivation, anthill cultivation, coleus potato gardens, river gardens and hutsite gardens. The Bemba crop sequences on fields, gardens and old hutsites studied by Richards are presented in Figure 21. Some of the striking characteristics of these cropping systems include (i) the use of volunteer self-propagated sorghum and groundnuts as components of traditional crop mixtures, (ii) elaborate piling up of wood and trash for burning to obtain ash fertilizer in a system designated as *chitemene* or *citemene* by the Bemba, and (iii) movement of homesteads to facilitate cropping of fertile hutsites. In West Africa, volunteer crops involved in traditional agriculture do not involve major stables but are limited to protected useful tree crops such as the oil palm *(Elaeis guineensis)* and semi-wild and indigenous vegetables such as *Corchorus olitorus, Ocimum viride* and several species of *Amaranthus*. Reasons for movement of homesteads other than restoration of soil fertility include superstition, witchcraft and reduction of distance between homesteads and fields (Miracle, 1967). In addition to the nine crop sequences



a Source: Richards (1939) according to Miracle (1967).
a. No information given on what follows
b. Maize and sweet potatoes planted year after year until soil is exhausted, then sweet potato alone as last crop.
c. Maize and pumpkins sown so long as soil is fertile, then tobacco or sweet potatoes.

Fig 21. Bemba crop sequences (Richards, 1939 according to Miracle, 1967).

described by Richards (1939) as characteristic of all Bemba, Trapnell (1953) reported 46 other field sequences in northeastern, northwestern, southern, western and eastern Bemba.

The highest numbers of crops in the mixtures of the different main garden crop sequences occur during the first and second years. Moreover, the crop associations involve non-food crops such as *Tephrosia* sp. which is purposely planted for fish poisoning but is also incidentally a legume in the nodules of which nitrogen fixation occurs. Differences between crop sequences described by Richards (1939) and those of Trapnell (1953) may be related to the fact that Trapnell's work was more detailed and may have involved different farms in the same location. Moreover, the possibility of some of the farms having undergone changes between the periods that the studies of Richards and Trapnell were carried out could not be ruled out.

The Azande Cropping System

De Schlippe (1956) and Reinig (1970) studied the agricultural systems of the Azande, the third largest tribe in Congo Kinshasha (now Zaire), small sections of which are also found in the southern Sudan and the Central African Republic. In their cropping systems, the Azande tackled the short-run problems of decreasing soil fertility by alternation of crops and the long-term by shifting homesteads. As with the Bemba, other seasons given for shifting of homesteads included death of a wife, crop failure due to pests and disease epidemics and repeated illness suspected to be due to witchcraft. Whenever homesteads were moved the courtyard gardens were first cultivated for a while before they are left to revert to bush by which time the fertility that was built up during years of human habitation has been almost exhausted. There are several field types each involving association of a number of crops

intercropped or sequences of crops sown successively in a given environmental setting and entailing clearing and cultural practices that are timed according to the season. Certain crop sequences and associations were found in gardens and others in fields. De Schlippe identified several field types, namely (1) the main finger millet (*Eleusine* spp.) association, (2) the groundnut/finger millet succession, (3) finger millet through grass, (4) bean patch, (5) ridge cultivation, (6) maize through sweet potato or sweet potato strip, (7) maize and oilseed gourd association and (8) cassava fallow. In addition to the main field types that are located outside the ridge which defines the outer perimeter of the compound farm or courtyard, there were eleven specialized environments with their special crops. These consist of (i) the courtyard on which vegetables, condiment plants, fruit trees, medicinal plants and other useful plants are found, (ii) the minor ridge in the courtyard on which are grown okra, yams, groundnut (vegetable) and other vegetables, (iii) old refuse heaps with rice, bananas, cowpea, sesame, maize, etc., (iv) thatch overhang under the shade of which tobacco nurseries were located, (v) ash accumulations on which tobacco vegetables, cowpea , climbing plants are grown, (vi) living trees used as supports for yams, (vii) termitaria which were flattened for the production of sorghum, rice and cowpeas, (viii) satellite cultivations located in patches or strips on the borders of fields of main staples, (ix) rubbish heaps in fields on which the farmers grow crops requiring higher fertility, (x) spontaneous or volunteer crops and (xi) valley cultivation beside streams or inside the forest gallery on silt deposited by erosive floods. Some of the above field types and spatial environments are shown in Figure 22. The cropping schedule and associations of the common field types are presented in Figures 23 and 24.

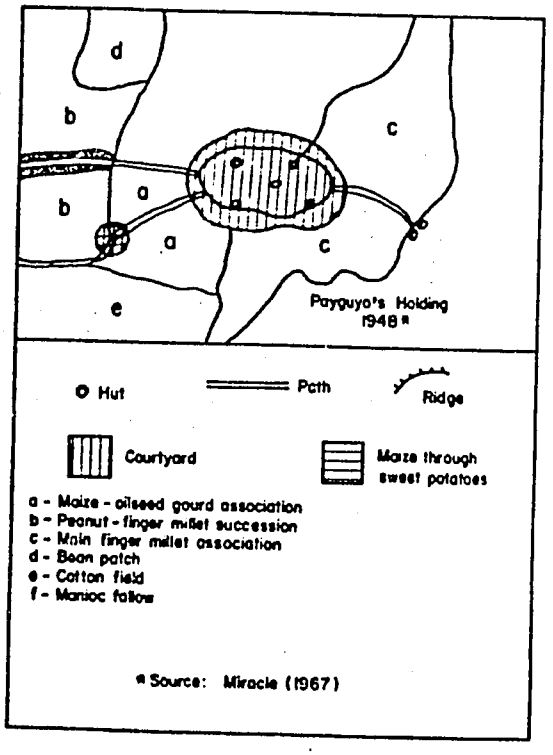


Fig 22. Azande field types

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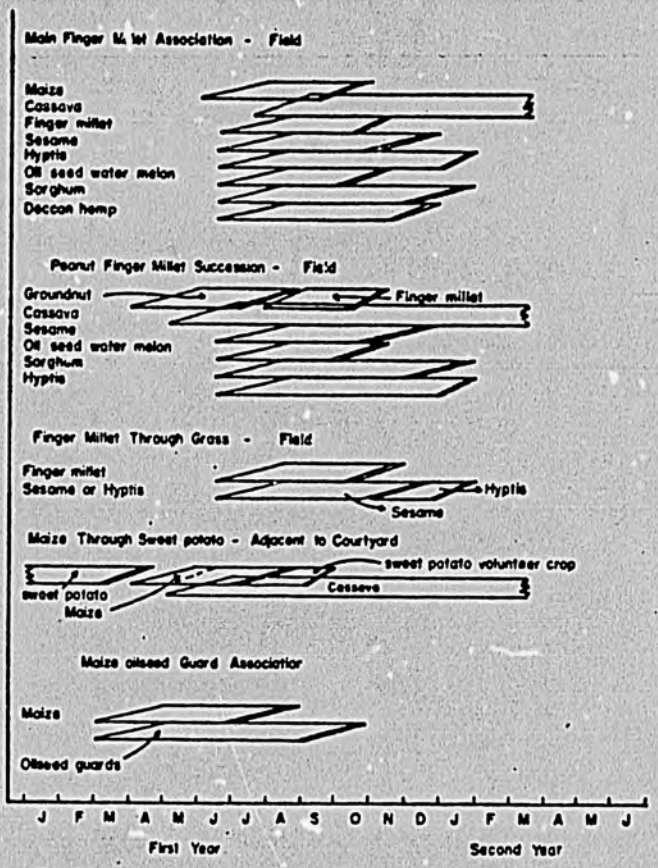
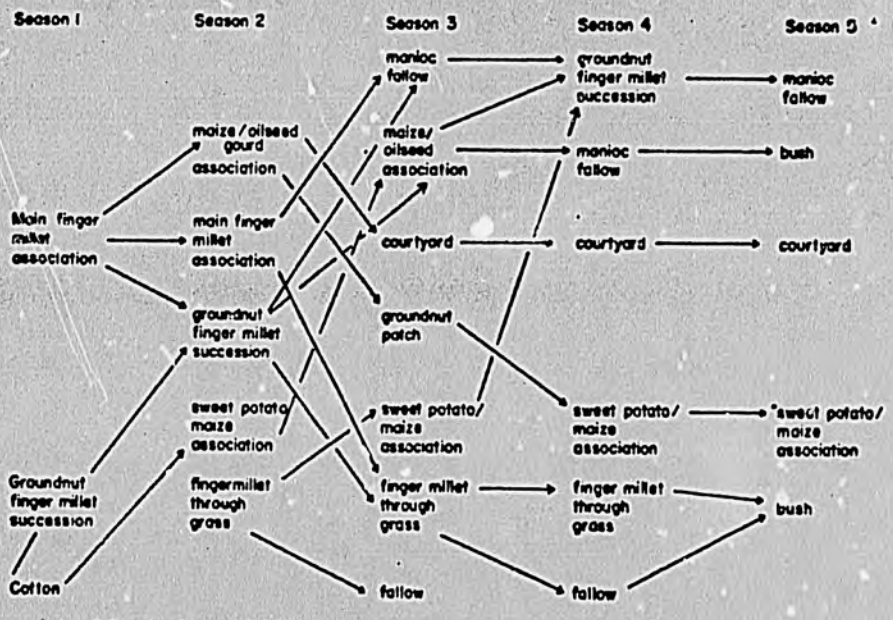


Fig 23. Azande crop associations and cropping schedule



* Source: Miracle (1967)

Fig 24. Azande crop sequences *

In general, it may be concluded that the cropping systems of the Congo are similar to those of West Africa in forest clearing techniques, use of mounds and ridges in some areas, growing of crops to take advantage of special ecological situations on farms, lack of clearcut rotational sequences, and the diversity of crops grown. Although intercropping is as widespread in the Congo as in West Africa, there is greater dominance of single crops in some of the initial and terminal crop associations (Table 8). Thus in the forest zone of the Congo, most crop sequences began with bananas-plantains and their associations in 44.1% and 8.0% of the sequences, respectively, followed by maize (11.8%) and maize associations (21.3%). The terminal associations were dominated by cassava (41.7%), cassava associations (25%) and bananas-plantains association (16.7%). In the savanna, initial crop sequences consisted of millet–sorghum (16.7%), groundnuts (14.3%), beans (*Phaseolus* sp.) (10.0%), sweet potato (7.4%) and cassava associations (19.4%) as compared to the terminal sequences dominated by cassava (36.2%) and cassava associations (15.1%) followed by beans and peas (14.5%) and millet sorghum (7.7%). The dominance of cassava in terminal crop sequences in forest areas is similar to the situation in the forest zone of West Africa where cassava is usually

Table 8: *Initial and terminal crop combinations observed in farms of different tribes of the Congo*

Crop or Crop Association	Initial Position		Final Position	
	Forest	Savanna	Forest	Savanna
Banana — plantains	44.1	0.0	16.7	2.7
Millet — sorghum	0.0	16.7	0.0	7.7
Maize	11.8	3.8	8.3	0.0
Manioc	8.4	3.2	41.7	36.2
Groundnut	0.0	14.3	0.0	5.0
Beans or peas	0.0	10.0	0.0	14.5
Sugarcane	5.9	0.0	0.0	0.0
Yams	5.9	0.0	8.3	1.9
Sweet potato	0.0	7.4	0.0	5.0
Maize/banana-plantains	3.0	0.0	0.0	0.0
Banana-plantains/maize/yams/tobacco	3.0	0.0	0.0	0.0
Manior/maize	0.0	1.9	16.7	2.3
Manior/groundnuts	0.0	4.2	0.0	0.7
Manioc/beans/maize	3.0	0.4	0.0	0.0
Gourds/maize/manioc	0.0	0.4	0.0	3.8
Maize/groundnuts	3.0	0.4	0.0	0.0
Maize/sweet potato	3.0	0.0	0.0	0.0
Tobacco/maize	3.0	0.0	0.0	0.0
Groundnuts/beans	3.0	5.4	0.0	0.0
Millet/sorghum/beans/oil seed gourds	0.0	3.8	0.0	0.0
	97.1	71.9	77.7	79.8

the last crop before the fallow. In most areas of West Africa, annual starchy staples (e.g. maize, yams and rice) are more likely to dominate the initial crop association than bananas-plantains and their associations as in the Congo basin. In the savanna areas of West Africa, cassava does not attain such dominance of terminal crop associations as in the Congo. However, in both areas there are fewer choices of crops to be grown at the terminal stage of the cropping cycle due to the marked reduction in soil fertility.

Northern and Southern Rhodesia

Allan (1965), Miracle (1967) and Morgan (1969) described the agricultural systems of Zambia and Yudelman (1964) dealt with the agriculture of Southern Rhodesia. The agriculture of this area consists broadly of two main systems, namely, the European system and the African system. The European system involved commercial agriculture similar to mechanized large scale farming systems of Europe and America, involving sole cropping and classical crop rotations. Alienation and reservation of land for Europeans in Southern Africa and East Africa prior to the recent wind of change and other political developments in Kenya and Tanzania made available to Europeans proportionately more land per capita than for Africans.

African agriculture in this area involves the same chitemene shifting cultivation system of the Bemba. But unlike the Bemba who use large ash circles each covering over 0.4ha, the Lala, Lamba and Ndembu of Northern Rhodesia (Allan, 1965 and Miracle, 1967) and some tribes of Southern Rhodesia (Yudelman, 1964) employ several small circles (each about 7—11m in diameter) in place of each large ash circle. Field systems of the small circle chitemene are however similar to those of the Bemba. For example, the Lala fields consist of (i) the *main chitemene garden* planted with finger millet with patches of gourds and pumpkins, (ii) *second year ash gardens* with ground beans, *(Kerstingiella geocarpa)*, and sometimes groundnuts or cowpeas, (iii) sorghum gardens on which are grown maize, sorghum and sweet potatoes instead of finger millet and in between which sorghum is usually interplanted with cowpeas and groundnuts with cassava planted on mounds, (iv) *maize and bean gardens* located close to termite hills, (v) *cassava gardens* in which cassava planted on mounds are intercropped with a few maize and sorghum plants, (vi) *seepage gardens* planted with maize and beans on streamsides and (vii) Livingstone potato beds sometimes bordered with cassava (Allan, 1965).

SOUTH AFRICA

The Environment

South Africa consists of a plateau with a pronounced escarpment to the east and surrounded by a coastal plain of varying width on the south, east and west. In the southeast the coastal plain rises in series of steps towards the plateau culminating in the Lebombo mountains between Transvaal and Mozambique. In the southwest the coastal plain is broken up by the Cape fold mountains and in the east the escarpment reaches its highest peak in the Drakensberg mountains. The plateau is more than 900m.above sea level except in the Kalahari depression and over 40% of South Africa is above 1200m altitude. About 90% of the country receives most of its rain in summer and the rains are accompanied with storms and hail resulting in serious erosion hazard. The winter which is in July is rainless with clear weather

except in Cape province which receives 650mm 75% of which is in winter. Summer is in January and its rains are most pronounced in the east. The Mediterrean area of South Africa is restricted to extreme southwest in Cape Province. Rainfall decreases from east to west ranging annually from over 1000mm in the southeast to less than 250mm in the northwest. Temperatures are drastically reduced by altitude. As in north Africa, most of the population is concentrated east of the 500mm isohyet where rainfall is highest in the coasts of Natal and eastern Cape Province. Most of the rivers cut deep into the plateau and dry up during the dry season necessitating construction of dams for hydroelectric power and irrigation e.g. Oppermansdorf dam on the Vaal River and Hendrick Verwoerd dam on the Orange River. The geography of southern Africa and aspects of its agriculture are described by Broullette, Graves and Last (1974), Murray (1976, Jarrett (1974) and Grove (1970). The rainfall of south Africa is characterized by its irregularity which affects agricultural productivity and the farming systems practised.

Agriculture

In general, there is the traditional and peasant agriculture on small farms involving minimal use of improved inputs and mechanization and a modern European Agriculture which is largescale and highly mechanized and specialized. The farming systems may be classified into arable crop production, fruit farming, livestock farming, market gardening and mixed farming . arable crop farming, continuous maize or wheat monoculture is common and in some areas with little use of fertilizer. This has resulted in serious erosion and dust bowls in northwestern Orange Free State and southwestern Transvaal. Maize is the chief feed grain and its production is associated with cattle rearing. About 70% of the maize is produced in the Maize Triangle of Orange Free State and Transvaal (see Figure 9). Wheat is a winter crop of the Meditarranean area of Cape province, in Orange Free State and under irrigation in Transvaal. Sugarcane is important in the warm and wet coastline areas of Natal which has 6 months of frost free weather and Swaziland. Other arable crops include (1) tobacco consisting of Virginia tobacco) in Transvaal under irrigation and Turkish tobacco under rainfed conditions in Cape province, (2) cotton which without irrigation is grown with difficulty because of drought and (3) barley, oats, dry beans and potatoes.

Fruits are important since they find winter markets in Europe and include grapes in Mediterranean area of Cape province, deciduous fruits (apples, pears and peaches) in the same area, citrus in Transvaal, figs, pineapples and bananas in Natal and eastern Cape province.

In addition to the strict animal production agriculture of pastoral peoples in arid areas of the country, sheep (especially in the Cape), cattle, pigs, poultry and goats are also produced. The cattle, sheep and pigs are increasingly being produced in mixed farming systems in which their production is associated with crop production for feed and other purposes. Some measures used in their production to control erosion such as intercropping legumes between rows of maize, rotations and fallowing have had marked effects on the intensities of the cropping systems. The diversity of the environmental conditions in South Africa has resulted in a diversity of crops and other commodities that can be produced.

EAST AFRICA

In this paper, East Africa broadly speaking consists of Mozambique, Tanzania, Kenya, Uganda, Ethiopia and Somalia. Most of these states have large areas of savanna with pastoral peoples who are nomadic and regard crop cultivation as secondary to livestock raising. Consequently crop production is adapted to their own way of life and it is often the business of women and children. Moreover, until the advent of land reforms in Kenya and independence of Tanzania and recently Mozambique, agriculture in this region with the exception of Ethiopia was a dualistic economy consisting of European Agriculture and African agriculture. The former was commercial, large scale, specialized, more mechanized and involved sole cropping and classical rotations while the latter was subsistence, small scale in size and usually involved mixed cropping. In most of East Africa and Ethiopia a wide range of crops (tropical, subtropical and temperate) can be grown as a result of the prevailing range of altitudes of from below 500 to 4,000m. Thus a few specified crops can be grown only at those elevations at which they are adapted. Examples of some of the altitude range of certain crops in Kenya are shown in Figure 25 and in Ethiopia as reported by Westphal (1975) are as follows:

Crop	*Range*	*Most suitable range*
Maize	500 — 2000m	500 — 2000m
Finger millet	500 — 2000m	1000 — 1800m
Bulrush millet	500 — 1600m	500 — 1500m
Sorghum	500 — 2500m	500 — 2000m
Tref (Eragrastistef)	1500 — 2500m	1700 — 2300m
Wheat	1500 — 2500m	1700 — 2300m
Groundnut	500 — 1600m	1000 — 1500m
Sesame	500 — 1500m	1000 — 1300m
Cassava	500 — 2000m	1500 — 1800m
Sweet potato	500 — 2100m	1250 — 1700m
Cowpeas	500 — 2000m	1250 — 1700m
Okra	500 — 1800m	1200 — 1700m
Sugarcane	500 — 2000m	1000 — 1500m
Coffee	1200 — 2400m	1500 — 2000m
Banana	500 — 2000m	1500 — 1700m
Mango	500 — 1700m	1100 — 1600m

Kenya, Uganda and Tanzania

The extent of mixed or intercropping involved in the production of various crops grown in Uganda are presented in Tables 3 and 4. Akyland (1971) reported that although any crop grown in East Africa may be grown in pure culture especially in commercial farms, the common bean (*Phaseolus vulgaris*), hyacinth bean (*Lablab niger*), bulrush millet (*Pennisetum typhoides*) cassava (*Manihot esculenta*), castor (*Ricinus communis*) cocoyams (*Colocasia* sp.), cowpea (*Vigna*

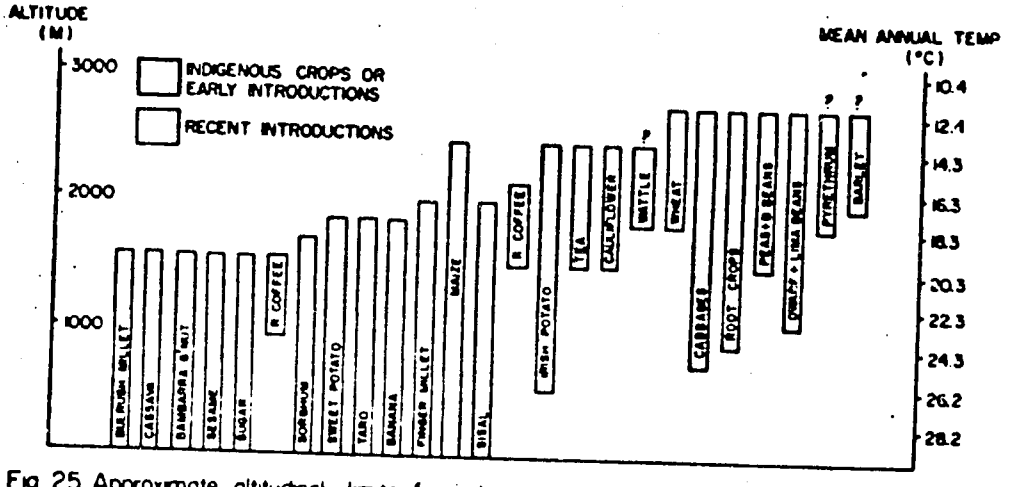


Fig 25 Approximate altitudinal limits for indigenous and introduced crops in the Kenya highlands (Morgan 1973).

unguiculata), finger millet *(Eleusine corocanc)*, grams *(Phaseolus aureus, P. mungo)*, potato *(Solanum tuberosum)*, sweet potato *(Ipomoea batatas)*, sesame, sorghum, plantains and bananas, cashew *(Anacardium officinalis)*, coconut, coffee *(Coffea arabica)*, sisal *(Agave sisalina)* and tea have been observed in mixed culture. Examples of mixtures in which some of the above have been associated include (i) bananas grown with maize, potatoes, cowpea, sugarcane etc. in the Central Province of Kenya, (ii) beans mostly intercropped with maize except in important agricultural areas of the coast but in Uganda a small proportion of beans is intercropped with cassava, (iii) hyacinth bean *(Dolichos lablab)* is often intercropped with maize, beans, potatoes, peas, banana etc., (iv) bulrush millet intercropped with Bambara groundnuts in Ukara Island in Tanzania and with cowpea, pigeon pea, beans or maize in the Machakos district of Kenya, (v) cashew along the southern Kenya coast of East Africa may be planted at random among coconuts, mango trees, bananas, cassava etc., (vi) cassava which is usually last crop before the fallow and is often inter- or relay cropped with crops such as sweet potato, maize and beans, bananas, yams and sugarcane on the coastal strip of East Africa, (vii) coconuts intersown with pastures along the coast or planted at wide spacing with bananas, cashew and mango (it is common practice to intercrop annual food crops with young coconuts in plantations for the first two years), (viii) interplanting of coffee with shade trees, e.g. *Albizzia* sp. in Tanzania and *Cordia abyssinica* in Kenya, (ix) cowpea intersown with other food crops but may be grown for their leaves in patches of pure stands near homesteads, (x) grams intercropped with cereals, root crops and other legumes, (xi) pigeon pea relay cropped with finger millet and after millet harvest is intersown with sesame or cowpea ; also intercropped with maize and beans, and (xii) sisal intercropped with beans, maize, cotton, pineapple, or cover crops which are customarily grown with it.

The farming systems of Kenya have undergone changes due to (1) European settlement and introduction of European farming systems, techniques and crops, for example the large scale mixed farming involving integration of crops and animals and specialized horticulture with emphasis on vegetables, (2) land consolidation in the 1950s; (3) introduction of white maize in 1940 and (4) increased interest in commercial agriculture. As a result of these although mixed cropping is practised with many crops in traditional cropping systems, in Kenya greater transformation than those of Tanzania and Uganda has taken place as a result of land reform and African take over of European farms on the White Highlands following the Mau Mau episode.

Von Rotenham (1968) reported that mixed cropping was originally widespread in Sukumaland in Tanzania but the cultivation of cotton has led to considerable amount of sole cropping despite the fact that it was recommended to be grown as a mixed crop in German colonial times. He noted that although sole cropping is common with crops such as rice and only one third of the area is under mixed cropping, it would appear that there are local adaptations of mixed cropping, staggering of plantings and rotations to soils and local situations. The Wasukuma, for example, practise relay cropping of maize, beans, groundnuts and sweet potatoes. The maize is first planted, then when it is about two weeks old groundnuts and beans are sown in between the maize; and after first weeding, sweet potatoes are added. Crop rotations in several parts of Sukumaland carry both pure cotton and mixed cropping of various kinds according to location and soil type as shown below:

Shinyanga

Black cotton soils		*Alluvial soils*
1963	cotton	Maize—sorghum—legume
1962	cotton	Maize—sorghum—legume
1961	maize—sorghum—legume	Fallow
1960	" "	Cotton
1954	cotton	Maize—sorghum—legume
1958	cotton	Maize—sorghum—legume

Ukerewe

Sandy to partly loamy soils		*Alluvial soils*
1963	Cassava	Rice—sweet potato
1962	Cassava	Rice—sweet potato—maize
1961	Cassava	Rice—sweet potato
1960	Cotton	Rice—sweet potato
1959	Cotton	Rice—sweet potato
1958	Cassava	Rice—sweet potato—maize

Ludwig (1968) studied the Wukara permanent cropping system on Ukara Islan on Lake Victoria in Tanzania and observed that in a three-year rotation, that durin the first year bulrush millet is relay intercropped with a late maturing crop, *(Crot laria striata)*, which is dug in as green manure for a recent crop of early bulrus millet during the second year. The second year bulrush millet is again relay inter cropped with late groundnuts and in the third year following harvesting of ground nuts another early bullrush millet is followed by a late crop of sorghum which end the three-year cycle. In addition to these crops, the Wukara have developed severa permanent cropping systems for different contours or catenas for the valleys on the island and fertility is maintained by the use of organic manures, crop residues, and household refuse (Figure 11).

Ethiopia

As indicated above, the varied topographic features of Ethiopia and associated climatic and ecological zones have made it possible for tropical, subtropical and temperate crops to be cultivated. Westphal (1975) described agricultural systems, cropping systems and 'rotations' in Ethiopia and indicated the extent of mixed cropping by various peoples in different parts of the country. He recognized fourteen systems of agriculture but here, examples of mixed or intercropping systems which have been reported are presented for the following: (1) seed farming complex with absence of vegetables, fruit trees and shrubs; (2) seed farming complex where sorghum is dominant with field cropping, home gardening and growing of fruit trees and shrubs; (3) seed farming complex with sorghum dominant but farming is carried out in well constructed terraces; (4) Ensat planting complex with ensat as staple food; and (5) Ensat planting complex with as co-staple with cereals and tubers.

1. In the Begemdir and Simen area where vegetables and fruits are absent, the common practice is to grow two successive crops in the same field each year (double cropping) with emmer *(Triticum dicoccum)*, barley *(Hordeum vulgare)* or lentil *(Lens culinaris)* used as the late crop (Figure 26). Mixed cropping is also practised with barley and wheat *(Triticum* sp.) as the most common mixture. Other mixtures include pea *(Pisum sativum)* and horse-bean, *(Vicia faba)*, t'ef and garden cress *(Lepidium sativum)*, sorghum and finger millet, sorghum and chick pea *(Cicer arietinum)* safflower *(Carthamus tinctorius)*, and t'ef *(Eragrostis tef)*, sesame and common bean and maize and gourds (Westphal, 1975). Cropping systems involve rotations with fallow especially on red soils to restore soil fertility after few years of cropping. Chickpea and niger *(Guizotia abyssinica)* may be included in the cropping system to restore soil fertility. (Table 9).

2. In Hararge area where field systems, home gardening and cultivation of shrubs are widely practised (Westphal, 1975) three cropping zones are encountered, (i) the coffee zone (1400—1700m) with bowl-shaped valleys where there are irrigated banana groves and extensive gardens with mixtures of crops such as coffee, sugarcane, ch'at *(Catha edulis)*, maize, sweet potato and t'ef, (ii) durra zone (1600—2000m) where sorghum is the dominant crop with ch'at and coffee at valley bottoms and (iii) the barley zone (2000—2400m) where barley, wheat, horse-bean, and peas are grown. In the durra zone 'gooseneck' sorghum is the most widely grown and is usually planted in mixtures with maize and sometimes, bullrush millet, finger millet and sesame, with groundnuts and maize or with maize

and beans in between (Figure 26). Hararge is the centre for ch'at which is usually found between 1500 and 2000m elevation and is commonly intercropped with sorghum, maize, bean, sweet potato, *Capsicum* or coffee. Around the city of Harar there are orchards of ch'at, coffee and citrus.

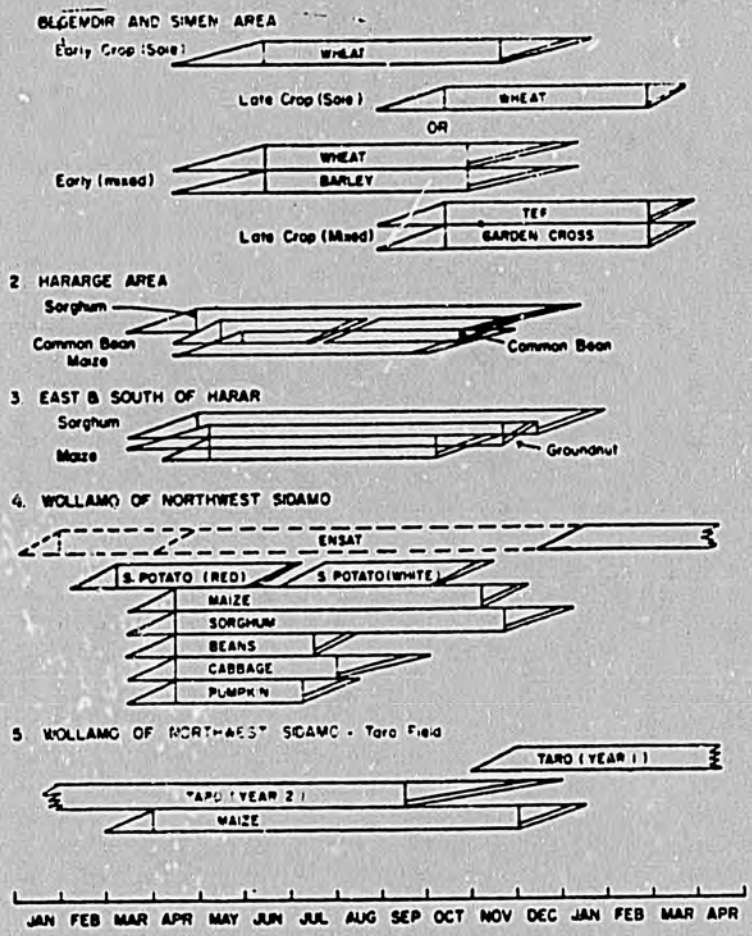


Fig 26 Some Ethiopean crop combinations and sequences
(Adapted from Westphal, 1975)

3. In the sorghum-hoe-terrace complex in Konso area, there are well constructed terraces supporting an intensive agriculture involving permanently cultivated and regularly manured land surrounding the villages. Away from the villages a fallow system without cultivation is used to maintain soil fertility. Crops grown in this area in mixed culture include maize, pulses (common bean, cowpea, hyacinth bean; pigeon pea *(Cajanus cajan)*, chick pea, lentil, horse-bean and pea), tuber crops (taro yam and sweet potato, *Amorphophallus abyssinicus*, and *Sauromatum nubicum)* cabbage tree *(Moringa stenopetala)*, linseed *(Linim usitatissimum)*, sunflower *(Helianthus annuus)* and cotton. Pure cotton occurs in periphery of settlements and yams' *(Dioscorea* sp.) are grown as single plants in gardens near terrace walls. Sorghum is nearly always broadcast with finger millet. Usually the first crop in the mixture to be planted are cormels of *Araceae* which are then followed by cotton,

Table 9: *Crop adaptation to elevation ranges in Ethiopia (Westphal, 1975)*

Crop	Range	Most suitable range
	m above sea level	
Maize	500–2500	500–2000
Finger millet	500–2000	1000–1800
Bullrush millet	500–1600	500–1500
Sorghum	500–2500	500–2000
Tref (*Eragrostis tef*)	1500–2500	1700–2300
Wheat	1500–2500	1700–2400
Groundnut	500–1600	1000–1500
Sesame	500–1500	1000–1300
Cassava	500–2000	1500–1800
Sweet potato	500–2100	1250–2000
Cowpeas	500–2000	1250–1700
Okra	500–1800	1200–1700
Sugarcane	500–2000	1000–1500
Coffee	1200–2400	1400–2000
Banana	500–2000	1500–1700
Mango	500–1700	1100–1600

cereals, and pulses before the seeds are covered with soil. Wheat and barley in the zone between 1700 and 2000m are sown in mixed stands. To minimize competition, sowing is done when other crops are about 10cm high.

The ensat planting complex in which ensat (*Ensete ventricosum*) is the main food source is found among the Gurage, Sidamo and other peoples in southeastern part of the Ethiopia highlands, in the Rift valley and in the eastern Sidamo Highlands (Westphal, 1975). The Sidamo who live south of Lake Awasa grow large plantations of ensat in addition to coffee gardens especially around Dila and cereals around Amhara settlements. Near the homestead there are gardens in which ensat is planted in age classes on previously cropped land and only near huts are age classes mixed. The ensat is often mixed with coffee and sometimes a legume (*Erytbrina* sp.) is often interplanted. Part of the homestead garden carries small irregular patches of wheat, barley, t'ef and pea. The limited area of patches of cereals and pulses rotate with ensat and coffee plots. Outside the homestead gardens, maize, sorghum and t'ef and rarely wheat and barley are grown during the cropping cycle after the fallow. In the ensat area, there are different altitude zones for (i) coffee (1800–2000m) where small patches of t'ef wheat, taro, beans (in mixed culture), sweet potatoes and tobacco; (ii) wheat-pulse zone (2000–2500m) where maize, sorghum and coffee decrease and wheat, barley and horse bean appear; and (iii) the upper ensat and barley zone (2400–2500m to 3000m) where barley, cabbage (*Brassica oleracea* var. *capitata*) near huts and ensat are important.

In the Gurage area south of Addis Ababa, new ensat circle are planted each planting season with two overlapping circles planted in a given time—the number of plants depending on family size.

4. In the ensat co-staple area, ensat is regarded as important as cereals and tubers. This area is inhabited by (1) the Wollamo tribe of northwest Sidamo north of Lake Abaya and between Omo and Billate rivers; (2) the Amarro of the steep mountain range on the east side of the Rift; (3) east Gamu Goffa tribes of the Gamu Highlands west of the Rift Valley; (4) The Janjero in the area between Little Gibbe and Omo rivers; (5) the Kaffa of the old Kaffa Kingdom south of the Gojeb Kefa province; and (6) the West Game tribes in the mountains. In the Wollamo area, there is a regular planting pattern and patch intercropping is common. The pattern is almost fixed around the homestead especially in eastern Wollamo. The exit to huts always leads to an ensat plantation. On both sides of the entrance there are planted cabbage, tobacco, *capsicum* and other spices. Behind the hut is the first semi-circle of coffee shrubs and then in areas above 1600m a small ensat plantation. Then the field with mixtures of maize, sorghum, beans and cabbage follow (Figure 26). Various remote parts are occupied by pure stands of wheat, barley, pulses and tuber crops. Farming activities start in February with clearing and planting of a cultivar of sweet potatoes with white large tubers. In March a mixture of maize, sorghum and beans is planted. Sometimes cabbage and pumpkins are also intercropped with them. This mixture may be grown every year for several years before a fallow period of one year or another cropping. Successively fields of wheat, pulses and barley are planted in May to June and a second variety of sweet potato with dark tubers is planted while the February one is harvested. This is followed by weeding after which t'ef is planted in July.

Cultivation of taro and Gallo potato *(Coleus edulis)* requires special attention. They are planted in November at a time cereals are harvested (Fig. 26). Taro is usually planted near streams to facilitate irrigation. Yams *(Dioscorea abyssinica)* and(*D. bulbifera*) are also grown. As indicated above each zone has its own crop and as ensat appears at 1500—1800m, larger areas are devoted to other crops and up to 2100m ensat is grown with maize, sorghum, taro, sweet potato and yam. As higher altitudes are reached *Coleus* and Irish potato become more important until after 2300m, sorghum and maize give way to barley and cabbage. Wollamo crop calendar is shown in Figure 20.

NORTH AFRICA

In this paper North Africa consists of the northernmost part of the African continent lying north of latitude 20°N and bounded by the Mediterranean sea to the north, the Sahara desert to the south, Red Sea to the east and Atlantic to the west. Politically, it consists of the Maghreb countries of Morocco, Algeria and Tunisia in addition to Libya and Egypt. It is more homogeneous in its peoples than other parts of Africa and consists mainly of peoples of Arab and Berber stock, with Arabic and Islam as common language and religion, respectively. These

countries have similar past colonial experience and have only attained independence within the last 10 - 20 years—a factor which is the basis of their agricultural economy consisting of a small sector of largescale commercial agriculture of European origin and a predominant small scale traditional peasant subsistence agriculture. Pertinent basic geographical and agricultural information about the area is given by Brouillete, Graves and Last (1974) and Jarrett (1974). A description of the agriculture of the region is given by ERS (1965), El-Tobgy (1974) and Nasr (1976).

The Environment

The physical features of the area which determine the nature of agricultural production consist of its mountainous terrain and aridity of a desert environment. The area is dominated by the Atlas mountain running from east to west with the average elevation ranging from 600—1500m and a few peaks up to 3000m.

The region has typical Mediterranean climate of two contrasting seasons—a hot dry summer (April to October) alternating with a cool rainy winter (December to February). Annual rainfall ranges from less than 100mm close to the northern edge of the Sahara to over 1000mm on some points along the Mediterranean coastline. The elevation, location, nearness to the sea and variation in rainfall determine the agricultural productivity (ERS 1965). Consequently, the slopes of the Atlas Mountains to the Atlantic in the west, Meditarranean to the north, Sahara desert to the south and high areas in between the ranges compartmentalize the area into (1) a narrow coastline of varying width, (2) enclosed well watered areas with snowfields that melt to provide irrigation water in the dry summer and (3) plateaux, slopes and flat areas each with its unique characteristics for production of certain agricultural products. It should however, be stressed that although the area has a very sparse population of about 80—90 million with about half of them living in Egypt, less than 2% of the land including fallows is under cultivation. Over 60% is unsuitable for agriculture while the remainder is under permanent meadows and pastures (ERS 1965).

Mediterranean Agriculture

With the above background, it is obvious that since the region is characterised by cool rainy winters and hot dry summers the agricultural commodities produced are such as to consist of (1) rainfed short duration winter crops such as wheat and barley, (2) all year round crops that are adapted or tolerant to drought such as olive, cork oak and citrus, (3) all year round and summer crops that are grown under irrigation and (4) livestock such as camels which is adapted to desert environment. Other livestock such as cattle and sheep are seasonally moved to sources of feed or are grazed on natural ranges, planted fallows and stubble left after harvesting. Thus, depending on location and rainfall, diverse commodities may be produced and usually livestock rearing may be integrated with crop production. Semi-arid parts of the region are inhabited primarily by pastoral nomads who keep mixed herds of animals.

With the exception of Egypt where agriculture depends mainly on irrigation, the farming systems are so closely related to environmental conditions that (1) areas between mountain ranges and the sea constitute the most important crop land for vegetables in market gardens, orchards for fruit trees and vineyards (ERS, 1965); (2) further inland on the plains and valleys are areas suitable for vineyards, cereals, citrus, olives, forages; (3) areas of rough terrain and high altitude

land closer to the mountains are used for livestock production, vines (grapes) and tree crops and (4) the Sahara being too dry is unable to support animals except camels and goats. In some areas close to the desert, nomadic herding is important and in summer the herdsmen migrate northwards to the mountains and steppes where they stay until the autumn rains when they move down to the winter grazing grounds. Intermittent steams, underground water supplies close to the surface and mountain streams from melted snows in summer offer opportunity for irrigation facilitating production of a range of crops. The diversity of crops produced and animals kept is shown in Table (10).

Table 10: *Countries of North Africa and their main agricultural commodities*

Commodity	COUNTRY				
	Algeria	Egypt (United Arab Republic)	Libya	Morocco	Tunisia
Arable crops	Wheat Barley Cotton Tobacco Vegetables	Cotton Maize Wheat Rice Millet Barley Beans Lentils Sugarcane Sugarcane	Wheat Barley Millet Groundnut Potatoes Vegetables	Wheat Barley Maize Cotton Pulses Potato Vegetables Cotton Tobacco Tobacco	Soft wheat Hard wheat Sugarbeet Cotton
Fruits and Tree crops	Citrus Olives Dates Grapes Figs Apples Almonds Plums Apricot	Olives Plums Grapes Citrus Dates Figs	Citrus Almonds Olives Grapes Figs Dates Apricot Peaches	Olives Citrus Almonds Grapes Banana Pomegranate Dates	Citrus Figs Pomegranate Grapes Dates Olives
Livestock	Sheep Goats Cattle Camels Chickens	Cattle Buffalo Sheep Donkeys Goats Camels Horses Chickens	Sheep Goats Cattle Camels	Sheep Goats Cattle Pigs Horses Camels	Sheep Cattle Goats Camels Asses Mules Horses
Misc. and Cover crops	Alfalfa Esparto grass Cork oak	Berseem	Alfalfa Berseem	Cork oat	Esparto grass Alfalfa Cork oak

The traditional Sector

This is the largest sector of agricultural production employing over 60% of the people and consists of small peasant farmers operating small farms of crops and livestock mainly for subsistence. In Egypt, for example, 94% of the farms had an average farm size of 0.44ha and in Morocco 88.7% were 2.4ha on average. Usually most of the arable land is under cereals and up to 40% is in fallow and 10% is in fruits, vegetables and other crops. Crops are sown broadcast in the early autumn rains (November/December) and harvested in eariy summer. Very little of improved technology is used. Small amounts of animal manures or fertilizers are used as evidenced by the fact that although Egypt farms about 5% of the land in the area, it uses as much fertilizers as is used on the remaining 95%. Continuous cropping may be practised but usually a fallow period of at least one winter followed by a summer is allowed after harvest. This is done to conserve moisture but ploughing during the fallow period which is a widely practised dry farming technique in modern farms of arid areas is not done. Rotation with legumes is not a common practice.

Modern Sector

Most of the modern sector farms were started by European settlers as commercial farms of relatively larger size than traditional farms. They are highly specialized, heavily capitalized, largescale, mechanized and produce is primarily for sale. Since independence in many north African countries, and reforms have been introduced in Morocco, Egypt, Algeria and Tunisia involving take over of these European farms by government and their reallocation to individuals or cooperatives.

ALGERIA

Bouillette, Graves and Last (1974) described typical traditional and more modern farming systems in Algeria. On a traditional farm among the Kabyles who live in the Great Kabylia mountains, olives and fig trees are planted on mountain slopes and around the houses and near springs. There are small gardens of tomatoes, peppers and onions looked after by women. There are also different plots for summer wheat, barley, sorghum, or millet. A communal threshing floor is located at the entrance to the village. Since the production of such farms cannot support high population densities such as those of Egypt, the men migrate to cities and urban centres to find work. The result is that the olives and fig plantations are neglected and in poor condition.

Bouillette, Grave and Last (1974) also reported two case studies of modern sector commercial farms one of which consisted of 11¼ha started by European immigrants from Switzerland in 1843 and sold to an Algerian citizen in 1950. The farm was divided into six plots one of which is the kitchen garden of ¾ha and opens into the courtyard. Here are grown tomatoes, peppers, potatoes, onions and condiments for domestic use. The five plots of farmland one of which is up to 1 km from the village consisted of 4¼ha of grapes (3½ha for wine and 1ha for grapes), 3ha of cereals (wheat and barley) for loaves and couscous for horses and ¼ha of spring carrots for export. Labourers are employed for a few days during peak periods.

Another more commercialized farm reported by Bouillette, Graves and Last (1974) is a single crop farm of 600ha of vines. The farming methods here require heavy agricultural machinery and credit support from the bank. It was owned by a European immigrant and after independence it was taken over by government and placed under a workers' assembly of heads of 20 families. Unlike the first of the Algerian farms which is mainly for subsistence, and the second which is only partly so, the third is primarily commercial.

EGYPT

Agriculture in Egypt is flood land agriculture dependent on silt brought down by the Nile. The ancient practice involved use of water lifting devices such as the shaduf, water-wheel or the basin system in which water is ponded in earthen embankments called hod or basins during the flood season. Water is let out at the end of six weeks after silt has been deposited and the flood level falls early in October. The basin is then ploughed up and sown to wheat and berseem *(Trifolium alexandrinum)* as winter crops. Since 1840, attempts have been made to irrigate and grow summer crops such as cotton. The first storage dam was built in 1899—1902. Since then several have been built at various times culminating in the Aswam High Dam of the 1960s. With the perennial irrigation system, all year round cropping is possible involving three overlapping seasons of:

1. Autumn to Spring Crops (November - June) — wheat, barley, clover, vegetables, etc.,
2. Summer crops (Low Nile) (February - October) — Sugarcane and cotton, and
3. Summer crops (High Nile) or 'Nili' crops (July - October) — Maize and rice in the Delta area of Egypt.

In upper Egypt, Autumn crops consists of maize, millet, rice and vegetables and winter crops are wheat, barley, clover (berseem), pulses, maize and vegetables. Animals are kept everywhere and fed on clover and crop stubble.

Egyptian Crop Rotations

Since agriculture is fully under irrigation, continuous cropping is the practice and typical rotations used in Egypt have been described by El-Tobgy (1974) and Nasr (1976). Three-year or two-year rotations are used (Figure 27), and many crops can be grown depending on the fertility of the soil. Three-year rotation is the commonest and involves dividing the land into three blocks. The first one is planted temporarily to clover in November. From this, one or two cuttings are obtained. In March it is followed by cotton. The second block is planted in winter to clover or any other legume and the third is planted to wheat or barley to be followed by either rice, maize, sorghum or summer vegetables. The sequence is rotated every three years.

The second commonest rotation involves a two-year rotation in which there are two blocks. The first block is planted in winter to temporary clover to be followed by cotton as a summer crop while the second is divided into two parts with or

planted to clover or any other legumes and the other to wheat or barley with both to be followed by either maize, rice, sorghum or any other summer crop or vegetables. The sequence is rotated every second year.

A THREE - YEAR COTTON* ROTATION

SEASON	YEAR 1	2	3
WINTER	CLOVER (berseem) (1 - 2 Cuttings)	CLOVER (berseem) or other winter legume	WHEAT or barley
SUMMER	Cotton	Maize Rice Sorghum, or Summer vegetable	Maize Rice Sorghum, or Summer vegetable

B TWO - YEAR COTTON* ROTATION

SEASON	YEAR 1	2
WINTER	CLOVER (berseem) (Temporary)	CLOVER (berseem) or winter legume	WHEAT or barley
SUMMER	Cotton	Corn rice, or Sorghum	Maize rice, or Sorghum

* Cotton main Egyptian cash crop

Fig 27 Examples of typical Egyptian three-year and two-year rotations (EL-Tobgy 1974 and Nasr, 1976).

The clover is used for animal feed and for maintaining soil fertility. In the 3-year rotation, every block has a full season of clover once every three years and in the 2-year rotation clover occurs for a full season once every four years. The following regional variations occur in different parts of Egypt.

1. Rice Belt (Northern half of Delta): Rice follows winter cereals and legumes.
2. Maize summer crop area (Southern half of Delta and Middle Egypt): Maize (summer crop) follows winter cereals and legumes.
3. Sorghum Belt (Southern Egypt): Sorghum replaces cotton as the cash crop; cotton rotations are replaced by special sugarcane rotations which last 3—6 years depending on number of years the crop is rotationed.
4. Other Variations: Winter legumes may be grown instead of clover. The winter legumes include broad bean, lentil, fenugreek, chickpea and lupine. Onions, barley, flax or safflower may be planted in part of the areas alloted to clover and wheat. Summer crops such as groundnuts sesame, kenaf and sunflower may be planted in some areas reserved for maize.

In the neighbourhood of urban areas vegetables are grown as winter, summer and nili crops and on sandy soils, groundnut and sesame replace cotton as main summer crop. It should be noted that (1) clover is the only forage crop grown in large areas of the country in winter and spring, (2) the area of forage in summer or nili season is negligible since all available area is occupied by cotton, rice, maize, sorghum, sugarcane and vegetables, (3) alfalfa as a perennial crop is restricted to newly reclaimed land, (4) other than permanent orchards of fruit trees and sugarcane areas, not much place is allowed for perennial or permanent crops, and (5) the traditional practice of fallowing before planting cotton or after harvesting of winter crops when the land is flooded during the nili season has completely disappeared since continuous cropping is the rule.

Recent developments in the cropping system include relay and companion cropping or intercropping. In relay cropping, a new crop is planted with the last irrigation applied to the growing crop and there is a short period of overlap, for example, clover can be relay planted in fields of rice. Relay cropping facilitates multiple cropping. In companion cropping or intercropping a secondary crop is grown simultaneously with the main crop. For example, summer onion is grown as companion crop to cotton in the southern half of the Delta but the onion is harvested earlier in June and cotton later in September. Broad bean may be used as a companion crop to sugarcane.

Apart from Egyptian agriculture constituting a unique example of flood land irrigation over a large area, it also demonstrates what can be achieved in Mediterranean agriculture with irrigation. Diversity of crops and farming systems of high intensity are used to support very high population densities. With the 2-year and 3-year rotations there are always two crops a year from the same field resulting in a cropping index of 2.0 or 200 percent. With vegetables, a cropping index of 3.0 or 300% is possible and in the case of the shallot industry in Ghana described earlier it is up to 4.0. With perennial sugarcane and permanent orchard areas the cropping index is only 1.0 or 100%.

Cropping systems research

Recently, there has been a resurgence of interest in the study of intercropping in Africa because of (1) a realization that research aimed at improving the existing cropping systems must be based on the understanding of the mechanics, economics, advantages and disadvantages of the traditional systems that we desire to change and improve; (2) the disappointing response of most African farmers to improved technology of food crop production systems based on sole cropping transplanted from temperate largescale cropping practices with its attendant high energy and capital requirements and risks; (3) the impact or the potentialities of multiple and relay cropping systems work at the International Rice Research Institute based on

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modifications and improvement of current intensive traditional cropping systems in Taiwan and Indonesia, which significantly increase yield per unit area; (4) the recently recognised fragility of agroecosystems of single varieties of crops grown in sole culture over wide areas of land either with respect to the dramatic build-up of pests and diseases in the "green revolution" areas of Southeast Asia or the widespread devastating epidemic of southern corn blight in the United States where 90% of the corn crop carried a common source of cytoplasm; and finally (5) the recent general concern about the environment and interest in integrated pest management pioneered by ecologists who maintain that mixtures in traditional cropping systems constitute ecologically more stable production systems than large areas of single uniform varieties grown in pure culture. This paper reviews past and recent studies in intercropping in tropical Africa as a basis for the consideration of the scope, strategy, and methodology in research on crop combinations and sequences.

Review of Research on Intercropping

It is now about 40 years since Leakey (1934) observed that although Kukuyu / traditional cropping systems did not arise through scientific experimentation as did European agriculture, the relay and mixed cropping practices it entails had many obvious advantages. He recommended that those involved in agricultural development should give less priority to cash crops and more serious attention to research on traditional food production systems. Sturdy (1939) also in East Africa studied and noted (1) relay intercropping of millet and *Crotolaria* and sorghum and Bambara groundnuts in Ukara; (2) intercropping of groundnuts, cowpeas and grain legumes with maize or millet by the Wanyamwezi and Wasukuma, and (3) double cropping of beans in intercropped coffee and banana plantations of the Bahaya. He emphasized the importance of minor legumes in the diet and the use of 'simultaneous rotations' in maintenance of soil fertility in the indigenous farming systems. Briant and Johns (1940) observed that since cloves and coconuts are planted on the best soil in Zanzibar the practice of utilizing the open spaces in the plantations for growing cassava and other cash crops was a worthwhile and economic proposition. Robertson (1941) indicated that although mixed cropping was regarded as a retrograde step, it has remained a regular practice in plantation crops in farming systems of India, China, and West Africa. He reviewed local mixed cropping practices in East Africa and rotation experiments involving mixed cropping and strip cropping and concluded that (i) cotton lends itself to intercropping, (ii) intercropping reduced labour costs, (iii) in Uganda, the intercropping of cotton and groundnuts resulted in decreased cotton yields but higher total yield and gross returns, (iv) intercropping is an insurance against pests and diseases and (v) intercropping maize with cotton in Tanzania was successful where soils and climate permit e.g. Morogoro and Kilosu but not in drier areas. Edwards (1941) observed that establishment of grass by relay cropping in maize was feasible in good maize seasons. Watson (1941) reviewed aspects of Teso agriculture in Uganda involving mixed cropping and indicated the advantages of these systems under high population pressure. Kerkam (1941) reported results of double cropping of wheat on the slopes of the Ruwenzori and noted marked reduction of yields in the third and fourth years.

Lambers (1940) reported that intercropping of Arabica coffee with bananas in Kuri resulted in beneficial effects of leaf mulch on the coffee and compared this

with the effects of *Pennisetum purpureum* (elephant grass) mulch on coffee in the Congo. Evans (1962) investigated fertilizer and manure applications on maize intercropped with groundnuts and obtained yields presented in Table 11. He concluded that maize gave highly significant responses to fertilizer and manure and these responses were in the same order as the pure stands. But the groundnuts did not respond to fertilizer when intercropped as observed in pure stands where the yields were 227 and 280 kg per ha for manured and fertilized plots respectively. He further observed that alternate row planting could change the situation and compared this with results of fertilizer studies in shaded tea. Evans (1960) reported results of intercropping experiments at Ilonga, Katambili, Nwanhala, Asiriya, and Murtunde and observed that higher total production was obtained by intercropping except at Nwanhala in 1957 where production in pure stands of maize and groundnuts were higher at all populations. He observed that weeds reduced yields to the same extent as another crop but slightly more and concluded that where maize was of interest high maize population with adequate population of groundnut led to overall gain. Where groundnut was of interest, intercropping with low maize population should be used since at high population there is general reduction in groundnut yields. With sorghum, intercropping was markedly superior at all populations to pure stands with medium population of both crops giving highest returns. Grimes (1963) compared random intercropping and alternate row cropping of maize and cotton and obtained the results presented in Table 12. At Masabahe maize in alternate rows gave higher yield than maize in pure stands but cotton in alternate rows gave lower yields than those in pure stands. At Mtwapa alternate row planting gave slightly higher yields of both maize and cotton than pure stands. It was observed that cotton in alternate rows matured later than in pure stands and that pesticide application times and dates should be different from those intercropped in alternate rows.

Table 11: *Yields of maize intercropped with groundnuts as affected by fertilizer application. (Evans, 1962).*

Maize		Groundnuts	
Nil	Fertilizer	Nil	Fertilizer
447.1	1,468.9	365.0	362.4
1,434.9	2,146.1	396.1	332.6

Osiru and Willey (1972) and Willey and Osiru (1972) in Uganda investigated mixtures of maize and beans and dwarf sorghum and beans with respect to plant population and observed that in the maize mixtures, yields of mixtures were higher by 38% than in pure stands. It was concluded that this was due to greater utilization of environmental resources and that higher populations in mixtures

should be used. The maize had higher competitive ability than the beans which suffered from shading. In the dwarf sorghum mixtures, higher yields of up to 55% in mixtures as compared to pure stands were observed. Mixtures consisting of two-thirds sorghum to one-third of beans gave the highest increases and had higher optimum populations than pure stands.

Table 12: *Yields (t/ha) of maize and seed cotton, percentage AR cotton grade and cash returns (sh/ha) in relation to pattern of planting observed at Msabaha and Mtwapa (Grimes, 1963).*

	Seed Cotton kg/ha	% A.R. Grade Cotton	Maize Grain kg/ha	Cash Return Sh/ha
Msabaha				
0.2 Ha Pure Stand	762.4	45	1540.2	1730
0.3 Ha alternate rows	563.6	41	2490.0	1838
Mtwapa				
0.2 Ha Pure Stand	679.1	32	757.4	1375
0.4 Ha alternate rows	758.0	24	760.2	1398

Enyi (1972) studied mixtures of dwarf sorghum and beans at Morogoro, Tanzania and observed that mixtures gave 15% higher yields than pure stands. As observed in earlier experiments, mixtures of two-thirds sorghum one-third beans gave highest yield increases at high populations and had higher optimum populations than pure stands. In contrast to early maize/beans experiments, it was observed that in the two-third sorghum one-third beans mixtures, the sorghum was the more competitive species while in one-third sorghum and two-third beans mixture, the beans was the more competitive. Intra-specific competition was found to be higher than inter-specific competition in both species. Enyi (1973) investigated intercropping with pigeon peas, cowpeas or beans and observed that intercropping reduced leaf area indices, fresh weight yield at anthesis, straw yield at harvest and grain yield of cereal crops. In mixtures with sorghum, pigeon pea and cowpea had greater adverse effects on grain yield than beans, but with maize, beans and cowpea had more adverse effect on grain yield than pigeon peas. While intercropping in maize with either beans or cowpea decreased total yield of grain (cereal and legume) per hectare, intercropping sorghum with pigeon pea increased total grain yield per hectare.

Fisher (1976a and b) carried out comparative studies of productivity and competition of maize/bean and maize/potato mixtures in alternate rows and at different plant densities with pure stands at the Kabete Field Station in Kenya and concluded that (1) in seasons with low rainfall, yield from mixtures fell short of that from pure stands but exceeded those of pure stands in exceptionally wet years, (2) poor performance of mixtures in low rainfall seasons appeared to result from large reductions in maize yield attributable to competition from potato or bean,

(3) in one high rainfall season no such reduction in maize yield occurred and (4) although mixtures gave an apparently yield advantage over pure stands, this could be explained solely by increased population pressure in mixtures (Table 13). Fisher discussed the implications of the results for farming systems with mixtures and for cereal/legume mixtures he related the results with published works and drew a distinction between those sites in East Africa where conclusive yield advantage of mixtures has been found and those where apparent advantage could be explained by higher population pressure.

Table 13: *Yields (t/ha) in pure stands and mixtures, and equivalent areas of mixed crops (Fisher, 1976).*

	Plant density					
	Low	Medium	High	SE	Means	SE of means
Pure maize yield	4.10	7.40	10.44	0.74	7.32	0.43
Mixed maize yield	4.36	6.26	9.75	0.53	6.78	0.31
Pure bean yield	1.05	1.76	2.05	0.18	1.62	0.10
Mixed bean yield	0.32	0.65	0.94	0.13	0.64	0.07
Equivalent area	1.41	1.25	1.52	0.12	1.39	0.07

Yields are corrected to 12% moisture for maize and 15% for beans. 'Equivalent area' is the area of pure stand required to give the same production as unit area of the mixed crop, i.e.

$$\frac{\text{Yield of maize in mixture}}{\text{Yield of maize in pure stand}} + \frac{\text{Yield of beans in mixture}}{\text{Yield of beans in pure stand}}$$

In West Africa, although Faulkner and Mackie (1933) and other workers had observed the benefits of intercropping, research on intercropping did not receive much attention until relatively recently. Sparnaaij (1957) studied temporary mixed cropping in oilpalms and compared it with natural and leguminous covers in oil palm plantation establishment. Annual crops (yams, maize, cocoyam and cassava) were grown with oil palms for the first two years and for as long as possible (i.e. up to the time the canopy of the oilpalm closed). Intercropping was found to stimulate growth of palms in the early years but very little difference was observed between natural cover slashed once a year and leguminous cover except that oilpalm leaf production was reduced by natural cover slashed once a year. Yields of the various annual crops intercropped with the oilpalm from 1940 to 1952 are shown in Table 14. It was concluded that it would be most profitable to intercrop without reducing yield of palms. Thus intercropping had a beneficial effect. This experiment beautifully illustrated how crops of different shade tolerance characteristics can be utilized in intercropping in changing canopy and intensity of shading situations.

Andrews (1970) investigated relay and intercropping as compared to one long season crop at Samaru, Zaria, and observed that 64% more gross monitary returns were obtained by two successive early maturing crops (millet or maize) followed by cowpeas as compared to a long season sorghum. When relay cropping involving alternate row intercropping was carried out with millet and dwarf sorghum, there was twice the gross return per unit of land as compared to sole crop sorghum. On the basis of these results Andrews outlined the criteria affecting yields of intercrops

Table 14: *Yield of food crops (kg/ha) observed in oilpalm establishment experiment at Nkwelle in 1943–1949 (Spanaaij, 1957)*

Date of harvest	Crop	Yield (kg)	
		Treatment C*	Treatment D*
1943 September	Maize (cobs)	473	474
December	Yams	7,663	8,173
1945 June	Cassava	7,011	–
June	Cocoyams	–	4,295
November	Yams	–	3,904
1947 January	Cocoyams	–	824
September	Maize (cobs)	753	267
December	Yams	4,683	3,509
1948 December	Cocoyams	–	1,528
1949 April	Cassava	4,466	–

C Intercropping every 4th year

D Continuous intercropping with manuring

Source: Journal of the West African Inst. for Oilpalm Research, Vol. II, No. 7: Oct. 1957.

in terms of pattern of planting, relative numbers of plants in the mixture, competition between crops for resources during the growing season and soil fertility effects of legumes. Buntjer (1970) described aspects of the Hausa system of cultivation involving intercropping of several crops and different patterns of planting around Zaria. RERU (1974) presented a progress report of the Rural Economy Research Unit and the Department of Agricultural Economics and Rural Sociology of the Institute of Agricultural Research (IAR), Ahmadu Bello University, Zaria, which listed publications on what might be regarded as first systematic and comprehensive socio-economic study of traditional farming systems in Nigeria. In these studies, a methodology was developed for economic analysis of crop mixtures (Norman, 1974) and it was shown that although different spatial arrangements were possible for each of the 156 crop mixtures, a specific arrangement involving systematic spatial

pattern on ridges was the most popular among local farmers. It was observed that (i) yields of sorghum, groundnuts and cotton were depressed in mixtures as compared to sole cropping, probably due to competition for light nutrients and space and, as in the case of sorghum, lower plant population in mixtures, (ii) there were increases in plant population densities in cotton and groundnuts in mixtures as compared to sole crops, and (iii) gross returns for crop mixtures were 62% higher than in sole cropping thus compensating for the 62% more than annual man/hour inputs per acre. The rationale for intercropping as reported in the literature were reviewed and included (i) increased efficiency of utilization of environmental factors (light, water, etc.), (ii) reduction in the adverse effects of diseases, pests and weeds, (iii) protection of the soil from erosion, (iv) greater gross returns and (v) insurance against crop failure. These were compared with the reasons given by farmers themselves for intercropping which included that (i) it is the traditional way of growing crops, (ii) it gives higher profits, (iii) shortage of land, (iv) it provides more efficient use of labour, (v) it is more stable or guarantees certain yield and (vi) it is the best way of utilizing fertile land. The farmers gave various other reasons including the beneficial effects of legumes on other crops, supply of a range of food staffs, etc. Disadvantages of intercropping were reported to consist of difficulties encountered in research on crop mixtures, problems of determining accurately how to use research on improved inputs (e.g. fertilizer rates, varieties, weed control methods, etc.) and the difficulty of mechanization. Norman (1974) showed that the dominance of crop mixtures can be maintained even when improved technology is introduced and mechanization can be successfully introduced where crops are arranged in alternate rows instead of haphazardly or in various intricate traditional patterns.

Kassam and Stockinger (1973) in their studies of sorghum/millet mixtures in addition to confirming the results of Andrews (1972) at Samaru showed that intercropping resulted in higher total yields per unit area than when component crops are grown as sole crops even at improved levels of technology. They also demonstrated that the superiority of intercropping as compared to sole cropping may be due to more efficient utilization of environmental resources when alternate rows of short season millet and long season sorghum were planted at the same time on row spacings of 71 cm x 30.5 cm and with application of 627 kg/ha of 21:14:14 fertilizer mixture. The results indicated that (i) maximum leaf area indices of 2.4 for sole crop millet and 1.4 for intercropped millet were reached at the time of flowering after about 2.5 months while those of 5.5 for sole crop sorghum and 1.4 for intercropped sorghum were reached at about 3.25 months or about 1 month before flowering of the sole crop sorghum as compared to about 4.5 months at flowering time for intercropped sorghum, (ii) mean dry matter production during the season for sole millet and sorghum were 18.6 and 10.2 g/m^2/day respectively while growth rates for mixed millet and sorghum were 12.6 and 4.8 g/m^2/day, respectively, amounting to a combined mean value of about 10.5 g/m^2/day, (iii) mean growth rates before harvesting were 14.6 g/m^2/day for sole sorghum and 4.9 for the intercrop as compared to 5.8 and 4.4 g/m^2/day respectively for sole and intercropped millet respectively, (iv) combined yield of intercropped sorghum and millet was 3380 kg/ha as compared to 2845 kg/ha for sole crop sorghum (see Table 15), (v) the yields per plant for sole crop and intercropped sorghum were very similar while that for intercropped millet was higher than in sole crop millet by 37% (Table 15), and (vi) nitrogen uptake by mixed millet was 80% of the available nitrogen resulting in 20% of the available nitrogen left for the intercropped

sorghum which took up a maximum amount of 42 kg/ha as compared to 140 kg/ha for the sole crop sorghum. Thus while the millet used up all the nitrogen it extracted from the soil after flowering plus 16 kg/ha from the stem and leaves for the development of the head, intercropped sorghum used only the nitrogen from the stems and leaves at the flowering time without absorbing any from the soil. A further evaluation of these results indicated that in the millet there was considerable

Table 15: *Total dry weight, grain yield, harvest index and protein content of grain (Kassam & Stockinger, 1973)*

	Total dry weight (kg/ha)	Grain Yield (kg/ha)	Harvest index	Protein content (%)
Sole sorghum	17,630	2,845	0.161	10.2
Sole millet	15,790	2,725	0.172	12.7
Mixed sorghum	8,030	1,426	0.178	9.6
Mixed millet	10,140	1,955	0.193	13.7

overlap between the vegetative phase and head development (reproductive) phase with the head initiated when less than one-fourth of the total number of leaves had expanded. In the sorghum, the vegetative phase overlapped little with the head development phase—the head being initiated when half of the stem growth and more than two-thirds of the total leaf expansion had occurred. Thus the demand for nutrients was higher in the millet than in the sorghum due to the overlap of the vegetative and reproductive (flowering) phases. Head development in the sorghum started about a week before the millet was harvested. While the growth rate per plant of intercropped millet was 35% higher than sole crop millet, that of intercropped sorghum was 33% lower than in the sole crop due to its competition with the millet. After the millet was harvested, the growth rate of intercropped sorghum rose to be 30% higher than in the sole crop sorghum, thus making up for much of the earlier loss in growth. It was also noted that drought which occurred in September did so at a time when the sorghum had twice the land area available to it for water and 50% the leaf area per plant which must have reduced the moisture stress at the grain filling phase resulting in similar values for the sole and intercropped sorghum. These results adequately illustrate the contributions that physiological studies can make in the understanding of the behaviour of crops in mixed culture and the need to study not only the growth cycles of the components of the mixtures but to relate the development phases and phenology of the crops to climatic conditions.

Baker (1975) reviewed the studies in cropping systems in Northern Nigeria and emphasized with examples the lessons scientists can learn initially from farmers as a basis for research in cropping systems improvement. He also listed five steps to be used and the necessary assumptions on which studies on experimental cropping systems should be based. These included (i) choice of crops of widely

differing periods of growth, (ii) measures to eliminate effects of different ratios and plant populations by using 1:1 or 1:1:1 ratios and use of their optimum spacing and plant population in sole cropping, (iii) use of the same rate and time of application of fertilizers which are applied as a blanket application to all mixtures, (iv) use of different experiments ranging from simple mixtures in which different plant populations are studied to series of trials involving more complex mixtures of varieties maturing at the same height over different periods and (v) measuring nutrient uptake and radiation interception by different canopy structures. It was also indicated that different experiments would be conducted to determine pest and disease control practices for intercropping and finally there are studies of the production economics involving estimates of net returns of the different crop mixtures, determination of labour requirements, the level and dependability of profits and the assessment of the technical feasibility and social acceptability of the improved intercropping systems. Baker *et al* (1975) summarised results of previous experiments on cropping systems in which the order of importance of interactions and effects of input factors were studied in multi-factorial experiments involving maize, cowpea, kenaf/roselle, groundnuts and millet/sorghum and indicated the order of importance of input factors in the package which included the sowing date, weeding, variety, fertilizer and or plant population. They also reviewed on-going experiments and some of the results. These included studies of sole crops in comparison with various combinations and spacing of mixtures of selected varieties in addition to (i) relay cropping studies of cereals with cotton and/or cowpeas in different ratios, (ii) striga control with herbicides in mixed crops, (iii) weed control, (iv) tillage studies and (v) crop sequence studies. He reported yields of 2—and 3—crop mixtures in relation to the varieties used (see Tables 16 and 17). In the two crop mixtures, intercropping significantly increased yields of ex Ghana millet, Bomo local maize, Samaru 123 maize and short Kaura sorghum but the yields of ex Bornu millet and 096 maize were not affected by intercropping.

Table 16: *Grain yield in kg/ha at 14% moisture content (Baker et al, 1975)* 5)

Crop	Grown with					
	ex. Ghana	ex. Bornu	B. local	S. 123	O. 96	S. Kaura
ex Ghana	*1923*	1789	1788	1937	2054	2366
ex Bornu	2352	*2239*	2282	2042	2286	2617
B. Local	3530	2786	*3170*	3048	3060	3780
S. 123	4788	4982	4475	*4341*	4373	5976
O 96	3789	3430	3553	3539	*3457*	3770
S. Kaura	3225	3175	3027	2489	2461	*2827*

Table 17 *Yields (kg/ha) of maize, millet and sorghum from mixtures of all three (Baker et al, 1975)*

Mixture			Crop in mixture		
I	II	III	I	II	III
ex. G	B. 1	S.K.	2479	4034	2260
ex. G	S. 123	S.K.	2438	5346	1766
ex. G	O 96	S.K.	2578	3815	2194
ex. B	B. 1	S.K.	2975	3482	2068
ex. B	S. 123	S.K.	2670	4908	2118
ex.B	O 96	S.K.	3243	3930	1084
B. 1	S. 123	O 96	4747	4938	4046

It was observed that the greater the difference between days of maturity, the greater the gain in mixing. In the three crops mixtures, the sorghum exhibited losses in yield but these were not significant. These studies serve to indicate that not only crop species but also their varieties with preferably different dates of maturity and other characteristics that determine their differential performance in mixtures.

At the IITA (Ibadan) intercropping studies are being conducted cooperatively in three crop improvement programs involving cereals, grain legumes, and roots and tubers especially as regards simple mixtures of cereals and legumes or cereals with root and tubers with the objective of evaluating the performance of crops in mixtures and determining the potentialities of certain plant types or structures and different maturity dates in relay and intercropping systems. Studies of more complex intercropping mixtures involving cereals, grain legumes, roots and tubers, and horticultural crops (e.g. plantains, and some vegetables such as tomatoes and okra) are being carried out in the Farming Systems Program with the objectives of developing suitable crop combinations and sequences in addition to studying the effects of different inputs as a prelude to the development of more efficient cropping systems for sustained yields in the humid tropics in the form of components or improved packages of crop production technology consisting of soil management practices, appropriate and low input technology for planting and pest, weeds and disease control. These will be related to improved crop varieties grown in economically viable combinations which are socially acceptable to farmers. It is therefore imperative that these studies should involve soil scientists, economists, physiologists, agronomists, weed scientists, entomologists, plant pathologists, microbiologists and other relevant disciplines.

Results of interdisciplinary intercropping studies on farmers fields, at IITA and cooperating stations presented in the 1972, 1973, 1974 and 1975 Annual Reports and by Nangju (1973) is summarised below:

(i) Village level studies in southwestern and southeastern Nigeria confirmed results of similar studies in other parts of Africa as to the popularity and widespread practice of intercropping, (ii) different crop combinations ranging from 201—290 per village were encountered in parts of the former Western State of Nigeria but of these, mixtures of 1—5 dominant crops accounted for over 54% of the farms in the villages studied, (iii) in southeastern Nigeria, more than 60 species of crops purposely planted for various uses were encountered on about 0.4 ha of farmland in the high population density areas, (iv) time spent on weeding of farms accounted for up to more than 50% of labour inputs in the farms studied, (v) under traditional systems of management, intercropping was more profitable than sole cropping of cowpea or maize (Table 18, IITA 1974) and (vi) returns from use of improved technology in low medium and high population density areas indicated that 19, 12 and 74% of the farmers, respectively, were worse off by using capital intensive technology with sole cropping as compared to relatively low cost systems involving intercrop-

Table 18: *Comparative yields of maize and cowpea in pure stands and in intercropping with cassava and the additional yield of cassava in intercropping systems*

	Pure stand		Intercropping with cassava on mounds		Intercropping with cassava on ridges	
Crop	kg/ha	Calories per ha x 1000	kg/ha	Calories per ha x 1000	kg/ha	Calories per ha x 1000
Maize	5,025	20,585	3,721	15,243	3,380	13,846
Cowpea	831	3,240	527	2,055	489	1,907
Cassava	—	—	18,083	67,979	19,526	73,404
Total	5,856	23,825	22,331	85,277	23,395	9,157

Table 19: *Effect of cowpea plant types and planting method on grain yield of mono-cropped and intercropped cowpeas and maize, first season, 1973*

Variety	Cowpea		Maize45		Total Yield	
	Kg/ha	% Max	Kg/ha	% Max	Kg/ha	% Maximum
Sole Crop						
Prima	572	31	—	—	572	13
Pale Green	1835	100	—	—	1835	40
Sitao Pole	726	40	—	—	726	16
Maize, $AC_1 \times BC_2$	—	—	3937	89	3937	86
Mixed Crop, Cowpea Planted Within Rows of Maize						
Prima	123	7	3757	85	3880	85
Pale Green	658	36	2458	55	3116	68
Sitao Pole	473	26	2631	59	3104	68
Mixed Crop, Cowpea Planted Between Rows of Maize						
Prima	131	7	4444	100	4575	100
Pale Green	548	30	2575	60	3123	68
Sitao Pole	541	29	2724	61	3265	71
LSD (5%)	470	—	640	—	633	—
LSD (1%)	637	—	867	—	949	—

Source: Proc. of First IITA Grain Legume Improvement Workshop, 1973.

Table 20: *Effect of time and method of planting on grain yields (kg/ha) sole and intercropped cowpea and maize, first season, 1973*

Time & Method of Planting G	Cowpea		Maize		Total Yield	
	Kg/ha	% Max	Kg/ha	% Max	Kg/ha	% Max
			Sole Crop			
1. April 19	1804	100	—	—	1804	41
2. May 4	1277	71	—	—	1277	29
3. April 19	—	—	4404	100	4404	100
4. May 4	—	—	3864	88	3864	88
			Mixed Crop			
5. Cowpea on April 19, maize on May 4, within rows	1420	79	1617	37	3037	69
6. Maize on April 19, cowpea on May 4, within rows	515	29	3478	79	3993	91
7. Planted same time, cowpea within rows of maize	768	43	2271	52	3039	69
8. Planted same time, cowpea between rows of maize	1113	62	2606	59	3719	84
9. Planted same time, cowpea and maize in the same holes	1110	62	2950	67	4060	92
LSD (5%)	516	—	884	—	872	—
LSD (1%)	706	—	1210	—	1182	—

Source: Proc. of First IITA Grain Legume Improvement Workshop, 1973.

ping. Results of IITA based cropping systems studies during 1972–1975 indicated that (i) maize with cowpea resulted in 15% higher maize yields in 1973 but not in 1974, (ii) intercropping of creeping plants such as melon and short leguminous plants such as groundnuts and determinate cowpea with much taller plants such as maize at recommended spacings and densities always resulted in markedly depressed yields of the shorter crop species unless the taller plant is grown at very wide spacing (iii) intercropping of maize with cowpeas reduced cowpea branching, nodule weight, and seed yields—the reduction being most pronounced when the cowpea is planted later than the maize, Nangju (1973), (iv) preplanting cultivations, numbers of species in the mixture, planting patterns, times of planting in relation to periods of maturity, plant structure, height and plant populations (see Tables 19 and 21) affected performance of various crops in mixtures and (v) differential pest and disease damage were observed with the damage being always lower in mixtures as compared to sole cropping as evidenced by the fact that *Anoplocnemis curvipes* which damages cowpea pods was found to exhibit greater preference for egg laying on maize than on cowpeas when both crops are intercropped (IITA, 1974).

The strategy being used in the intercropping studies in the farming systems program at IITA consists of the following:

1. Use of village level studies of traditional farming systems to determine dominant crops in mixtures, planting patterns and practices in traditional cropping systems, labour distribution and productivity of various cropping systems in addition to the farmers attitude and experience in the use of improved technology.
2. Use of preliminary trials involving large numbers of simple mixtures to study plant competition at specified spacings, planting patterns and fertilizer applications as basis for selecting compatible crop mixtures and identifying factors which may be studied in multifactorial experiments with fewer treatments at various levels and combinations.
3. Selection of compatible and productive crop mixtures (either in mixed intercropping, relay or strip intercropping systems) and the associated management practices to be tested in multiple cropping sequences, or rotations.
4. Testing of selected different plant types of compatible mixtures where available, in simple combinations at different planting patterns, dates of planting and levels of certain inputs with emphasis on physiological measurements as a basis for clearer understanding of crop behaviour and feedback to plant breeders. This may involve the use of systematic designs or other non-conventional layouts to facilitate study of effects and interactions of different plant populations, patterns of planting, orientation of rows, etc. Cooperation of agronomists and plant physiologists who usually initiate such studies is necessary at this stage.
5. Study of the economics of pest control practices, use of various inputs in intercropping systems in comparison with the best practices for the production of sole crops which are components of the mixtures under study using much larger plot sizes than are recommended for agronomic experiments with the same crops.
6. Testing of promising crop combinations in different locations with different levels of improved technology both at the experimental station level and in extension programs on farmers fields where and whenever possible.

CONCLUSIONS

The above review of traditional cropping systems in Africa indicate that

1. Multiple cropping in terms of double, triple; and related successive sequences of growing several crops in a year exist in traditional farming systems in Africa but they are exceptions that are not as prevalent as in the farming systems of Southeast Asia.
2. The most widespread cropping system in Africa consists of mixed intercropping in which several species of crop plants (both annuals and perennials) develop in compound farms to form a complex fairly stable agroecosystem.
3. Intercropping involving small patches of a few pure stands of crops at varying distances from each other in addition to relay cropping are also more common than successive cropping sequences.
4. Traditional cropping systems involve many field types and elaborate compound farm systems components of which are designed to take advantage of various environmental situations or topographic features on the farms.

Research and observations on mixed cropping, patch intercropping and relay cropping systems in Africa indicate that

1. the traditional farmer practises intercropping because it gives higher total yields and greater returns than the same crops grown in pure culture.
2. As a result of minimized pest and disease losses and losses due to adverse environmental conditions, risk is lower in intercropping than sole cropping.
3. Important factors that should be taken into account in intercropping investigations include (a) plant populations of the component crops, (b) length of the cropping season, (c) plant structure (height, canopy structure, rooting systems, etc.), (d) relative duration of the life cycles of the component crops, (e) nutrient requirements, (f) planting pattern, and (g) soil fertility.
4. According to Wrigley (1969) and various works listed above, the overall advantages of intercropping include:

   i. the soil is better protected against erosion, beating action of the rain and direct sunshine,

   ii. it is an insurance against crop failure,

   iii. labour and harvesting are spread over more evenly during the cropping season and storage problems may be minimized,

iv. locations are found for crops required in small quantities, for a range of products and facilitating production of many commodities in a limited area,

v. it results in efficient utilization of resources by plants of different heights, rooting systems, nutrient requirement, etc.

vi. where legumes are grown with grasses, the grasses may benefit from the nitrogen fixed by the companion crop,

vii. diseases and pests do not spread rapidly in mixed culture as in pure culture since all crops involved are not susceptible to the same extent.

5. Disadvantages of intercropping include:

i. mechanization planting, harvesting etc., is difficult,

ii. it is more difficult to apply improved imputs, e.g. fertilizers, herbicides, etc. as in sole cropping.

iii. experimentation with intercropping is more complex and difficult to manage than with sole cropping.

At present increased priority is being given to research in tropical Africa at the Institute of Agricultural Research (IAR), Samaru, Zaria, the International Institute of Tropical Agriculture at Ibadan, (IITA) and various institutions of higher learning especially at the Universities of Tanzania (Morogoro), Makerere, Ibadan, Ife, Ile-Ife, Nigeria, etc.

Guidelines and scope for research on crop combinations

The above review of research on cropping systems in parts of tropical Africa serves to indicate the scope of studies involved in the research on crop combinations and sequences. Guidelines for these studies, their scope and the measures to be taken to ensure progress and maximum contribution to knowledge and improvement of existing systems consist of:

1. Clear definition of the hypotheses to be tested and the objectives and priorities in crop combinations based on the dominant crop combinations or species and prevailing practices in the traditional cropping systems of the areas of interest.
2. Setting up of an effective interdisciplinary team of specialists in relevant number of disciplines chosen from among agronomists, soil scientists, agricultural engineers, agricultural economists, plant breeders, plant pathologists, entomologists, horticulturists, etc., to draw up a program and tackle the relevant aspects of the problem simultaneously—with *the* number of disciplines and specialists involved determined initially on the basis of the number of crops likely to be studied in the mixtures, the range of ecological zones to be covered and the resources available for the work.
3. Review of previous work on the selected crops and related species of plants in addition to the study of the range of variability in the species involved, the local crop production practices and problems as a basis for determining the studies that are likely to lead to significant advances or progress from among the following topics (see scope of studies below):
4. Establishing priorities as to which crops and studies merit immediate attention and allocating of resources in personnel and facilities accordingly.

Scope of studies that may be involved

Research on crop combinations and sequences may involve one or more of the following topics at one stage or the other—the importance attached to any one of them depending on the crop(s), uses, local customs and practices.

(a) Collection of data on crops that are grown in the area of concern, the dominant species and their uses in addition to local preferences and cropping practices.

(b) Review of existing information and filling of gaps (if any) on socio-economic and physical environment of the farmers of the area, the agricultural production problems and development trends.

(c) Local cropping practices, cropping combinations, patterns and sequences including preplanting cultivations, tillage practices and the ways various crop production management operations are carried out including the nature and extent of mechanical devices used, and trends and progress in mechanization.

(d) Observations on the location-specificity of certain cropping systems and adaptation of cropping systems and practices to certain topographic or other environmental peculiarities, (e.g. rainfall distribution pattern).

(e) Planting rates and spacings associated with various patterns of planting and orientation of rows and spatial arrangements of stands in addition to plant density including the number of plants per stand.

(f) Plant growth cycles, development phases, and photoperiod sensitivity and relative times of maturity in relation to phenological phenomena.

(g) Weeds, pests and disease control practices including the identification of any allelopathic and other biochemical interactions among plants being grown, in the soil or in the air that may render certain plants incompatible with other crops in mixtures or minimise pest and disease damage of associated crops.

(h) Identification of different plant structures within each important species of crops involved in the studies and establishing relationships, if any, between various structural features and productivity, competition, efficiency of resources (e.g. nutrients and light) and general performance in mixtures as compared to sole crop conditions.

(i) Crop improvement work aimed at production, development, and evaluation with many desirable characteristics in addition to (i) differences in heights, canopy structure and other related traits, (ii) different maturity dates, (iii) different leaf shapes, sizes and orientations whichever may be relevant on the basis of physiological and yield component studies and analysis, (iv) adaptation of the crop to various environmental abnormal and suboptimal conditions such as shade and moisture stress that may occur in intercropping situations, (v) characteristics which may facilitate compatibility of crops in mixtures such as lodging resistance or similar crops that may be used to provide support for associated crops such as leguminous climbers and/or in any other way used to advantage in the production of an associated crop such as is commonly done in traditional cropping systems.

(j) Characteristics which may facilitate mechanization, use of improved production inputs such as herbicides, pesticides and fertilizers to advantage or minimization or avoidance of their use in intercrops, for example, disease resistance, weed smothering characteristics, etc.

(k) Study of the efficiency of utilization of resources or inputs in various crop combinations, e.g. efficiency of utilization of fertilizers through study of nutrient uptake and special formulations of fertilizers that could be more efficiently utilized in intercrops, and methods of their application that increase efficiency of their use in mixed culture for

example, studies on water use and any special irrigation practices for intercrops, etc. as may be necessary.

(l) Economic studies of intercropping production systems including the testing of different levels of certain inputs and intensities of management in addition to labour distribution and economics of certain crop combinations and sequences.

(m) Since it would be desirable that traditional cropping systems can be most effectively replaced by continuous production systems with minimum number of years of fallowing and land rotation while still effectively maintaining soil fertility, it is necessary to carry out experiments on intercrop, relay and strip cropping sequences in long term rotations so as to facilitate the development of intercropping systems that maintain soil fertility while minimizing pest and disease damage.

While it may be meaningful under ideal conditions where resources and time are not limiting to engage on studies on most of the topics listed above, it is recommended that much time can be saved and progress made by adopting a strategy which gives due consideration to both short term and long term approaches to the problems. In the short term, keen sense of observation and commonsense are enough to enable one to observe aspects of existing cropping systems the minor modification or adaptations of which may constitute a significant contribution to the improvement of cropping practices. It is also possible that while pursuing long term objectives, one is awake to the opportunities of identifying minor constraints in the traditional crop production systems the removal of which may constitute a major advance even though it may form only part of a desirable but not easily attainable goal of developing a completely new or improved package of technology. One of the major drawbacks in research is that one may always feel very confident that all the answers to the farmers problems can be found on the experiment station level and continue to remain ignorant of what the farmers are doing at the farm level.

Choice and development of standardized experimental methods and techniques

Classical field experimentation methods treated in text books and statistical journals are more applicable to sole cropping and simple rotational sequences than to intercropping and multiple cropping. Even then, rotation experiments, experiments with perennial crops, long term experiments and experiments involving assay of pesticides present special problems for which satisfactory experimental techniques are not always available. Experimentation with mixtures presents peculiar problems related to plant competition, sampling of components of mixtures especially with respect to destructive sampling for physiological studies which modifies spacings and plant population in addition to sampling for yield estimate of crops some of which to facilitate multiple and relay cropping objectives may be harvested and utilized at different stages before the usual physiological stage of maturity or senenscence. Moreover, there are, obvious reasons why normal plot sizes recommended for agronomic experiments are not suitable for production economic studies such as analysis of labour costs for various operations. Pest management and agroecological studies in which pathogens can be blown about by wind and pests easily migrate back and forth from one small plot to another also require larger plots than agronomic experiments.

Recently IRRI (1973), reported the development of experimental designs for coping with large number of multifactor treatments in multiple cropping trials by modification of standard fractional factorial design involving 63 intercropping systems and over 750 possible treatment combinations. The design used consisted of only 256 treatments, only half of which were replicated while the rest had no replication. It was also reported that although measurement of economic data require larger plot sizes than agronomic data, replication as in classical field expriments was not necessary in order to achieve the required precision. At IITA, we are investigating the possibility of a circular systematic design that makes it possible for collection of data on different spacings, plant populations, spatial arrangements and orientation of rows to be carried out in each plot. While not minimizing the complexity of the problems of design of experiments and development of suitable experimental techniques, it should be noted that sometimes certain combinations of factors in multifactorial experiments do not make sense and could be dropped so as to reduce the number of treatments.

In addition to the problem of design there should be associated with the development and standardization of experimental procedures, the need for standardization of terminology used in different cropping systems so as to facilitate reporting of results of intercropping experiments and comm unication among scientists who benefit from sharing information and experience in cropping systems.

Appendix

DEFINITIONS ON CROPPING SYSTEMS

1. *SYSTEMS:* The end result or entity which is the result of interaction or association among different components or processes.
2. *FARMING SYSTEMS:* An agricultural enterprise, activity or business consisting of a combination of inputs (e.g. crop varieties, land, farm practices, etc.) in numbers, amounts, sequences and timing to satisfy specific objectives of the farmer under a specified environmental setting.
3. *CROPPING SYSTEM:* Cropping patterns utilized on a given farm in addition to the management of resources based on available technology all of which determine the nature or make up of the system.
4. *ROTATION:* Systematic growing of different kinds of crops in recurrent succession on the same piece of land (Martin and Leonard, 1970).
5. *CROPPING PATTERN:* The yearly sequence and spatial arrangement of crops, or the alternation of crops and fallow on a given area. The fallow crop may be natural or planted.
6. *SINGLE CROPPING:* The growing (planting to harvest) of only one crop in a given piece of land in one year.
7. *DOUBLE CROPPING:* Growing two crops in sequence, seeding or transplanting one after the harvest of the former (same concept for *Triple Cropping* etc.)
8. *MULTIPLE CROPPING:* Growing more than one crop on the same land in one year. Within this concept there are several possibilities of crop arrangement in space and time.
   (a) *INTERCROPPING:* Growing two or more crops simultaneously on the same land in different but proximate stands.
   (b) *MIXED INTERCROPPING:* Growing two or more crops simultaneously inter-mingled on the same land with no distinct row arrangement.
   (c) *ROW INTERCROPPING:* Growing two or more crops in distinct row arrangement.
   (d) *PATCH INTERCROPPING:* Growing two or more crops on a given piece of land in small contiguous patches of sole or almost sole cropping with the stands in each patch not necessarily arranged in rows or uniform spacing. The patches may be more or less irregular in shape.

(e) *RELAY INTERCROPPING:* Growing two (or more) crops in sequence, seeding or transplainting the succeeding one *before* the harvest but several weeks after the emergence of the former.

9. *STRIP CROPPING:* Growing two or more crops in distinct strips of several rows each.

10. *SOLE CROPPING:* Growing of one crop variety or species alone in pure stands.

11. *RATOON CROPPING:* The cultivation of regrowth from stubble (living stumps) following a harvest not necessarily for grain, e.g. Sugarcane, sorghum, rice, millet etc.

12. *MAXIMUM CROPPING:* The attainment of the highest possible production per unit area (yield) per unit time without regard to cost or net return.

13. *MONOCULTURE:* The repetitive growing of the same crop (annual, biennual or perennial) crop on the same land.

14. *FALLOW:* The period during which the land is left to recover its fertility reduced by cropping. During this period the land may be bare or covered by natural or planted vegetation. The term fallow may be applied to the land itself or to the crop growing on it.

15. *MIXED FARMING:* Agriculture involving growing of crops associated with rearing animals for work or other purposes. In short, it is an integration of crop and animal production.

16. *TRUCK FARMING:* Commercial vegetable production primarily intended for sale in urban areas.

17. *SHIFTING CULTIVATION:* Originally involves a farming system in which the homestead moves with the farm. Now it is applied to a farming system in which the farm is moved from one location to another prior to fallowing.

18. *PLANTATION AGRICULTURE:* Large scale commercial cultivation of tree crops, now sometimes extended to other crops.

19. *FODDER CROP:* A crop which is purposely grown for feeding animals.

20. *GREEN MANURE CROP:* A crop grown for incorporation into the soil in an immature state to increase soil fertility.

21. *CROPPING INDEX:* The number of crops grown per annuam on a given area of land x 100 (applicable to successive types of multiple cropping).

22. *LAND EQUIVALENT RATIO + FORMULA :* The ratio of the area needed under sole cropping to one hectare of mixed inter- or strip cropping at the same management level, to give an equal amount of produce. LER is the sum of the ratios or fractions of the yield of the intercrops relative to their sole crop yields.

$$LER = \frac{(\text{Yield of Intercrop})V_1}{(\text{Sole Crop})V_1} + \frac{(\text{Yield of Intercrop})V_2}{(\text{Sole Crop})V_2}$$

where V_1 is a given crop species grown alone or intercroped with another species V_2 e.g. V_1 = cowpea and V_2 = maize.

Note: *Gross Returns:* = Cowpea Yield x Price/kg + Maize Yield x Price/kg.

23. *LAND USE FACTOR:* $L = \frac{C + F}{C}$

where, C = Cropping period

F = Fallow period

L = Land use factor.

Classification of Farming Systems in Africa[1]

A. Traditional and Transitional Systems

1(a) Nomadic Herding

(b) Shifting Cultivation (Phase 1), L 10*

2. Bush fallowing or Land Rotation (Shifting Cultivation (Phase II) L = 5 — 10

3. Rudimentary Sedentary Agriculture Shifting Cultivation (Phase III) L = 2 — 4

4. Compound Farming & Intensive 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 & Fruit Plantations
   c. Commercial fruit and vegetable production for processing.
6. Mediterranean Agriculture (Modern)

1. Adapted from Whittlesey, 1936; Morgan and Pugh, 1969

1. Adapted from Whittlesey, 1936; Morgan and Pugh, 1969; Floyd, 1969; Laut, 1971; Benneh, 1972; Greenland, 1974.

* $L = \frac{C+F}{C}$ *where* C = *Cropping period*, F = *Fallow period*, L = *Land use factor*

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He returned to his country, Nigeria in 1959 and held the positions of Research Officer (Rice Agronomist) in the Ministry of Agriculture in the then Western Nigeria at Moor Plantation (1959–1960) and Rockefeller Research Fellow in Forage Crops University of Ibadan (1960–1961). He was appointed lecturer in the College of Agriculture, University of Nigeria, Nsukka, in September 1961 and rose to the rank of Professor and Head of the Department of Plant/Soil Science and Dean of the Faculty of Agriculture from 1965–1972. In July 1973 he was appointed Agronomist (Systems) and Assistant Director of Farming Systems Program of the International Institute of Tropical Agriculture (IITA) Ibadan, Nigeria. He is currently Deputy Director General of IITA.

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