FAO SOILS BULLETIN 24

shifting cultivation and soil conservation in africa

papers presented at the fao/sida/arcn regional seminar

held at

ibadan, nigeria, 2 - 21 july 1973

soil resources, development and conservation service
land and water development division

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome 1974

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ISBN 92-5-100393-9

FOREWORD

One of the most efficient ways to grow more food for Earth's future populations is to increase production on land that is already cultivated. Nowhere is this approach more relevant than on the 36 million square kilometres of land representing 25 percent of the world's cultivated soils, which are presently under shifting cultivation. Shifting cultivation is practised in Africa, South America, Oceania and Southeast Asia, by people of widely varying origins and cultures, on a very wide range of soils with many different types of vegetation. These lands feed 250 million people or 7 percent of mankind. Their potential for increased production is considerable.

FAO, within its mandate to provide a forum for the discussion of agricultural development problems as well as to collect, analyse and disseminate information, has organized, with the financial support of the Swedish International Development Authority (SIDA) and in close cooperation with the Agricultural Research Council of Nigeria (ARCN) a Seminar on Shifting Cultivation and Soil Conservation in Africa which was held in Ibadan, Nigeria, from 2 to 21 July 1973. The main purpose of the Seminar was to make countries aware of the role and problems of shifting cultivation in relation to soil conservation and the rational use of natural resources in the framework of agricultural development and to work out jointly guidelines for improvements in these fields.

The programme of the Seminar focussed first on identifying the nature of the shifting cultivation problem both in general and in Africa in particular, with a review of the positive and negative effects of the farming practices involved. The papers and discussion which followed covered current work on the problem, the need to make areas of shifting cultivation more productive, the possibilities of doing so, and the interrelation between shifting cultivation and soil conservation. Finally, proposals were worked out for the introduction of changes in shifting cultivation that would meet the objectives of soils conservation in the context of practical agriculture.

A large number of internationally recognized scientists and agronomists from Africa and other parts of the world, including scientists from the International Institute of Tropical Agriculture (IITA), Ibadan, contributed to the Seminar. Never before had these problems been studied and discussed in such breadth and depth at a single meeting. The Seminar may be considered to be a milestone in the improvement of traditional forms of agriculture.

It is sincerely hoped that the wealth of information contained in the papers presented at the Seminar and made available in this Soils Bulletin will provide help and encouragement to scientists and agronomists in Africa and other parts of the world in their efforts to make areas presently under shifting cultivation more productive.

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TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd)

INTRODUCTION

by

F.W. Hauck*

This Regional Seminar on Shifting Cultivation and Soil Conservation in Africa has been sponsored by the Swedish International Development Authority and organized by FAO in close cooperation with the Federal Government of Nigeria, the host country. There has also been substantial cooperation with the International Institute of Tropical Agriculture.

The Seminar is the outcome of numerous recommendations and proposals made to FAO during recent years by meetings of different types, by countries and by persons concerned with the problems of traditional farming in relation to changing requirements. It is not surprising that the need for improvements in this field has always been most emphasized in Africa, although similar problems exist also in Asia and Latin America.

At the Seventh FAO Regional Conference for Africa, held at Libreville, Gabon, in September 1972, concern was expressed by several delegates that the reduction in soil fertility and soil degradation, particularly aggravated by reduced fallow rotation cycles, had become critical. While recognizing that the problems involved were complex and that their solution demanded a long-term approach, the Conference supported the forthcoming FAO Seminar on Shifting Cultivation and Soil Conservation in Africa.

FAO has been watching shifting cultivation and has been collecting information on it for about 15 years. One of the first FAO publications on the subject was on 'Dynamics of Tropical Soils in relation to their Fallowing Techniques'. Shifting cultivation problems were also discussed at conferences on soil fertility and fertilizer use in Ibadan (1962), Dakar (1965) and Addis Ababa (1970). Questionnaires were sent to all countries in FAO's Africa Region in order to obtain more specific information. Whenever possible, shifting cultivation and soil conservation have been discussed with Institutes and persons dealing with these subjects. Within FAO's Programme of Work, high priority is given to shifting cultivation and soil conservation, War on Waste and the programme on 'Conservation of environment and natural resources'. Great emphasis on this area of activity has been given by FAO's Governing Bodies during the Medium-Term Plan, which is valid until 1979.

It cannot be the purpose of this Introduction to go into details of the subject. However, a few figures and considerations which have guided FAO in proposing the Seminar should be mentioned.

About 36 million square kilometres of land, or about 30 percent of the world's exploitable soils, are at present under shifting cultivation. They produce the bulk of the food for more than 250 million people or about 8 percent of the world population. Shifting cultivation is practised in Africa, South America, Oceania and Southeast Asia, by people of widely varying origins and cultures, on a very wide range of soils with many different types of vegetation. There are great variations in the types of crop grown, the length of cropping and fallow periods, and methods of cultivation. Although precise figures are not available it is estimated that in Africa the area under shifting cultivation represents a larger proportion of the total exploitable area than the world figure of 30 percent.

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In connection with development efforts in agriculture, the question that is being raised more and more frequently is whether shifting cultivation is still adequate, and the answer is increasingly 'no'. The following factors are usually related to this:

Yield levels

Although shifting cultivation is considered in many areas to be the only available means, under the circumstances, of maintaining the productivity of the soil, it is also realized that the maximum level of productivity that can be reached by this system is well below the yields of more modern types of cultivation. Maize yields in an African country, for instance, are influenced by shifting cultivation in the following way:

Yield of grain in the last year before fallow: 700 kg/ha

First year after fallow:	1100 hg/ha
Second " " "	800/900 kg/ha
Third " " "	700 kg/ha

The whole effect of 7 to 10 years fallow, plus the high labour input of clearing 1 ha of land, is therefore an additional 600 kg of maize in 2 years. The effect of fallow is improved to a limited extent by mixed cropping, but the improvement of soil fertility by shifting cultivation is short-lived.

Considering agricultural production at a country and regional level, it was stated at the Seventh FAO Regional Conference for Africa, that agricultural production rose only by 1% and food production by 2% per caput in 1971. This is considerably lower than the target for production increases of the Indicative World Plan, which calls for a yearly increase of 4%. It is also lower than the actual average increase of production in developing countries which reached only 2.7% in 1971.

The UN Economic Commission for Africa informed the Conference that in spite of the efforts by Governments, with the assistance of UNDP, IBRD, FAO and bilateral donor programmes, food production was lagging behind growing demand, and food imports in the Africa Region still represent 20% or more of total imports in value. Two-thirds of West African food imports came from outside the continent and the requests for food aid were increasing, owing to seasonal and inter-regional differences in prices of food.

Population pressure

If the population pressure becomes too great, the cropping periods are usually extended and the fallow periods are shortened, so leading to irreversible soil degradation. Under normal conditions of shifting cultivation, degradation of the soil and vegetation is bound to occur when the population density exceeds 25 persons per square kilometre. This figure may vary from one region to the other, but it can probably help to identify areas in which the critical stage has already been reached. The increasing population pressure in a country as a whole will make it necessary to rely more and more on the areas of shifting cultivation.

Economic aspects

The increasing need of the country for more food and the improving infrastructure (marketing of produce) encourage subsistence farmers to produce crops partly for sale. The possibility of a higher profit leads to an extension of the cropping periods.

Inputs

The technical and economic knowledge about the effects and efficient use of agricultural inputs such as fertilizers, pesticides, weed-killers and seeds is growing rapidly. In particular the rational use of fertilizers is being investigated at present under practical conditions in many African countries. The improving availability of inputs to individual farmers at economic prices introduces changes in the shifting cultivation system.

General development

The general improvement of agricultural production, including mechanization of different types, irrigation, use of high-yielding varieties, crop diversification and the increasing use of inputs, calls for changes in the system of production. In view of the apparent need for such changes and the opportunities for improvements in the interest of the economy of the countries and the individual farmers, it would appear that the time has come for tackling the problem systematically.

The need to consider the problems of soil conservation in relation to shifting cultivation is obvious. If shifting cultivation, under given conditions, has been considered as the best possible form of land use by which the fertility status is maintained and the soil is conserved, the system increasingly fails to satisfy the requirements for higher production per unit area. The need for higher productivity with all the changes it can bring about in the traditional systems can mean increased danger of soil erosion, of which there are already numerous examples. Modernized systems aim at a high level of productivity, a continuous high level of soil fertility and a soil which is not eroded.

In accordance with the foregoing requirements and the wishes of FAO's Member Countries in Africa, the purpose of this Seminar has been defined as follows:

- to make countries aware of the role and problems of shifting cultivation in relation to soil conservation and the rational use of natural resources in the framework of agricultural development.

- to work out jointly plans of action for improvements in these fields.

The Seminar Programme, which has been distributed to the participants, covers the following fields:

Identification of the problem of shifting cultivation in general and in Africa in particular

Under this heading as much relevant information as possible, including country reports, will be brought together as a basis for a better common understanding of the problems. A discussion on terminology will also be included.

Results and effects of shifting cultivation

Positive and negative results will be presented as well as technical, sociological and economic aspects.

Current work, needs, possibilities for making areas of shifting cultivation more productive

It has been found important to present information at the Seminar on what has been, or is being, done in terms of improvements in research as well as in the more practical aspects and in farming systems including agri-silviculture, weed control and the use of fertilizers. It is hoped particularly that the discussions on these items may lead to guidelines for future work that will be useful afterwards in the countries.

Soil conservation and shifting cultivation

After a lecture on the classification of soils for their use capability and conservation requirements, a number of lectures will deal with possibilities for improvements in this field.

Introduction of changes in shifting cultivation and of soil conservation into practical agriculture

FAO is always being urged by its Member Countries to place strong emphasis on its activities dealing with the practical outcome of proposals being offered to the countries. Although the whole Seminar should be oriented towards these needs of the countries, the lecture under this item will deal specifically with practical requirements.

Development of action programmes

Arrangements have been made for the main points discussed during the Seminar to be summarized with a view to the joint development of guidelines for action programmes. The draft of these will be presented for discussion and adoption towards the end of the Seminar so that they can be considered as a contribution from all persons present.

Closing remarks

This Seminar is very fortunate to have obtained the cooperation of a number of internationally recognized authorities on the complex problems of shifting cultivation and soil conservation. These include individual scientists from various parts of the world and groups of scientists from the International Institute of Tropical Agriculture and from Nigeria. We are also well aware that all of you - the delegates from the African countries - have your own knowledge and sometimes long standing experience of the subjects which the Seminar is dealing with. In addition to the lectures and presentation of country reports, time has been reserved for discussions aiming at useful results for the benefit of all countries interest in the further development of agriculture.

EVOLUTION AND DEVELOPMENT OF DIFFERENT TYPES OF SHIFTING CULTIVATION

by

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Introduction

For present purposes, shifting cultivation is defined very broadly as any system under which food is produced for less than 10 years from one area of land, after which that area is abandoned temporarily and another piece of land cultivated. The houses of the cultivators may or may not be abandoned when the land is abandoned; usually they are not. The abandoned land will be recultivated after its fertility is judged to be restored, or sooner if other land is not available for use.

The development of shifting cultivation as defined here is a natural and normal response to need to produce food, without the continuing benefit of soil replenishment by manures, fertilizers or alluvial deposition.

The system differs from 'alternate husbandry' only in that the abandoned land is not 'managed' in any way; there is no seeding, no controlled grazing, and no fertilizer or pesticide applications.

Shifting cultivation as defined here is not confined to the cultivation of tropical soils, nor is its use confined to any group of peoples. It has been extremely widely practised throughout the world, and is an essential response to the problem of obtaining food where the soil itself is incapable of sustaining the continuous production of crops for an unlimited period.

Until the relatively recent discovery of techniques for the manufacture of inorganic fertilizers, high population densities could only be sustained on soils of quite exceptionally high inherent fertility, or where fertility was restored by fresh deposits of alluvial materials at frequent intervals. The intense concentrations of people on the alluvial soils of Asia and along the Nile are obvious examples. Elsewhere fertility fell as cropping the soil removed the immediately available nutrients, and it had to be abandoned until it returned to its former state while the natural vegetation re-developed. In its least sophisticated form, and with very low population densities, shifting cultivation follows this simple pattern, the cultivators cropping one area to apparent exhaustion and then moving on to where the land appears in good condition. In an early Unesco publication (Unesco 1952) it was suggested that the term 'shifting cultivation' be confined to this type of practice. Many tendencies towards condemning shifting cultivation as a malpractice can be traced to the idea that it involves cropping one piece of ground to exhaustion, probably more or less permanent, and then moving to the next and destroying it in turn. Fortunately, as a general rule yields tend to fall, and weeds become difficult to control before irreversible changes occur in the soil. Thus, provided land which has been sufficiently long in fallow is available, cultivation will normally shift before much serious damage is done.

Most people prefer a settled, to a wandering mode of living, and what may be termed 'simple shifting cultivation', seems soon to be replaced, wherever the physical conditions allow, by a pattern of 'recurrent cultivation', where the dwelling is at least temporarily fixed

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The Phases of Land Cultivation

Phase I	Phase II	Phase III	Phase IV
Simple shifting cultivation	Recurrent cultivation	Recurrent cultivation with continuously cultivated plots.	Continuous cultivation.
(Dwellings and cultivated area shift together)	Cultivated area shifts more frequently than dwelling.	Always complex, with several field types.	May involve alternate husbandry with planted and cultivated pastures or fallow crops.
	May be complex, with several field types.		

but the piece of land cultivated shifts frequently. We may consider these as Phases I and II in the general pattern of land cultivation. A third phase emerges when some, but not all, of the cultivated land is cultivated continuously, this being made possible by the practice of manuring, or by using some land which is annually rejuvenated by alluvial deposition. Continuous cultivation of all land constitutes a fourth phase.

Practices in each of Phases I, II and III fall within the definition of shifting cultivation used here. The simple form of Phase I needs little subdivision, but several distinct categories can be recognized in Phases II and III, depending on the intensity of land use. Within each of these categories there are of course very many local variations, associated with differences in soils, topography, climate, vegetation, the involvement of animals and the influence of population density. The introduction of new varieties of crops, particularly cash crops, and improved implements is also not without influence.

The Phases of Land Cultivation

(a) Phase I - This is associated with movement of the dwelling, as well as the cultivated land, at each 'shift'. In most instances animals are owned and extensively grazed on surrounding land. Hence it is a form of semi-nomadism.

(b) Phase II - Phase II which replaces it has been variously termed 'land rotation', 'bush fallowing', 'rotational bush fallowing' or 'recurrent cultivation'. In this phase the dwelling place is relatively permanent. Usually more than one class of land is cultivated, with at least 'home fields' and 'far fields'. The 'far fields' shift usually after a brief cropping phase, and their fallow period extends over many years. By contrast the home fields tend to be cropped for longer periods, and their fallow period to be shorter. In addition to these fields, fields on wetter areas may be particularly valued for dry season cultivation; other special areas, such as old hut sites which have a higher than average level of fertility, may be sought and specially designated for use for more demanding crops.

Ideally the system would be essentially conservative, and there would be no need at all for a shift of dwelling place, other than when it is desired to build a better house. However, in the normal course of events the population in a given area tends to increase, so that the frequency of cultivation of any one area of land must increase, ot land farther and farther from the dwelling must be brought into use. This will lead eventually to a move of dwelling, although extraneous factors, social, political or medical, may also precipitate plans for a move.

Phase II is a normal stage in the evolution of agriculture. Obviously there are many possibilities for variation in the plan of cultivation followed, and these will depend upon ecological conditions, giving rise to various categories.

(c) Phase III. Phase II will tend to merge into a further Phase III, in which some, but not all, fields are being continuously cultivated. This will normally entail some form of manuring. In Europe this development was associated with mixed farming, and the use of animal manures on a small area of continuously cropped land (Parain, 1942; Orwin & Orwin, 1954). There are many examples from Africa and other parts of the world where similar developments have occurred. Household refuse as well as animal manures may be used. Usually the animals belong to the household and graze fallow land, but a variant occurs when pastoralists and cultivators are essentially independent of each other, but exchange products. This can lead to developments such as that at Kano, where animals are concentrated at central market areas, and manure sold or exchanged. It is then used by the cultivators to enable them to maintain continuously productive, cropped fields (Mortimore, 1967).

Shifting cultivation associated with a planted area of permanent tree crops or other cash crop, is another example of development towards continuously cultivated land, and must also be included in Phase III.

(d) Phase IV - Most cultivation systems will attain a stage where all land is continuously cultivated. This we may term Phase IV. It is likely to arise most rapidly where only a finite area of land is available, as it has done for example on Ukara Island in Lake Victoria (Allan, 1965). For present purposes there is little reason to consider its subdivisions. However, it is relevant to make the point that there is an essential difference between alternate husbandry systems, in which production of arable crops alternate with pastures, and shifting cultivation systems in Phase II or III where 'far fields' revert to natural grassland and are grazed. The essential difference is that the pastures are planted, they usually receive fertilizer, and their botanical composition is controlled if necessary by herbicides or cultivations.

<u>The categories of shifting cultivation</u>

In Phase II Shifting Cultivation a surprising degree of sophistication is often attained. The cultivator becomes extremely aware of, and responsive to, ecological factors. De Schlippe's account (1956) of Zande agriculture shows many aspects of such a responsiveness, and Allan (1965) provides further examples.

Because the response of the cultivators is to ecological factors, the different categories of shifting cultivation developed in Phases II and III tend to be limited to different ecological zones. There will obviously be extremely wide variations in a practice which occurs throughout the world. No systematic attempt to classify the different types of shifting cultivation has been attempted, at least in the context of the relationship between soils and shifting cultivation. Kellogg (personal communication) has collected some 200 names used to refer to the practice of shifting cultivation. The practices described by these terms will obviously differ in detail from each other in many instances.

The relationship between ecological conditions and cultivation practice does, however, impose a degree of uniformity on the different systems. Allan (1965) has described the practices followed in six different ecological divisions. These are defined by a 'land-use factor', which is the ratio of the sum of the lenght of the cropping period, C, plus fallow period, F, to the lenght of the cropping period, or $L = \frac{C+F}{C}$. Thus for land cultivated continuously, L = 1, with equal lengths of crop and fallow, L = 2, and for 2 years cropping and five years rest, L = 3.5 etc. Allan's six categories are:

1. Permanent cultivation land		$L < 2$
2. Semi-permanent land		L = 2.5 to 3
3. Recurrent cultivation land		L = 3 to 10
subdivided into	(short term	L = 3 to 5
	(medium term	L = 5 to 7
	(long term	L = 7 to 10
4. Shifting cultivation land		$L > 10$
5. Partial cultivation land		
6. Uncultivable or waste land		

Of these, category 4 is land used essentially in the manner described as falling in Phase I. Categories 5 and 6 represent land essentially impossible to cultivate, but in 5 including pockets which fall into categories 1, 2 or 3. The first three of these categories provide not only an ecological division of land types, but also a useful basis for classifying cultivation practices.

The Categories of Recurrent Cultivation.

1.	Intensive recurrent cultivation	Only on inherently highly fertile soils.
2.	Intermittent intensive recurrent cultivation	Usually on highly fertile soils.
3.	(a) Short-term recurrent cultivation)	May be degraded by population pressure to shorter-term or more intensive system.
	(b) Medium-term recurrent cultivation)	
	(c) Long-term recurrent cultivation)	

Intensive recurrent cultivation

Permanent cultivation is a misnomer, as the condition described is intensive recurrent cultivation of one area. It is normally only possible on soils of high inherent fertility, where the function of the fallow is not to restore nutrients but to control weeds and diseases. On some highly fertile soils developed on basic rock in Zambia Allan (1965) describes systems where ten years of cropping are followed by 2 to 4 years of fallow. On the volcanic soils of Mt. Elgon, and similar soils in Ethiopia, plantains may be used in a system consisting of five years or more of cropping, followed by only one or two years of fallow. Where a particularly vigorous and deep rooted fallow develops it can happen that three years of cropping followed by three years of fallow provide a stable and productive system. The areas of Nigeria where Acioa barteri grows as a natural or planted fallow come into this category. However, where this is a planted fallow we are perhaps in Phase IV, rather than Phase II.

Intermittent intensive recurrent cultivation

Semi-permanent land again seems something of a misnomer. It is intended to describe areas used for intensive recurrent cultivation for two, three or four cycles, but where the fertility is not maintained by this practice, and the land is, or has to be, abandoned after a few cycles for a very much longer period. A more accurate description would be intermittent intensive recurrent cultivation. Allan says that 'fairly strong' red earths and allied red loams under Brachystegia-Julbernardia woodland, and similar areas in Zambia, may be cropped for 5 to 8 years, followed by a fallow of similar duration, then a further cultivation period, after which they would be left fallow for very much longer. As the total cycle is very long (in this example, say 30 years or more) it is difficult to see how such a system could be developed by deliberate choice. It probably results from the fact that on soils unable to maintain fertility with a land use factor of 2, deterioration becomes rather apparent after two or three short fallows, and this may well coincide with the stage where extraneous factors make a shift of dwelling desirable.

Short, medium and long-term recurrent cultivation

In most examples of shifting cultivation the largest proportion of the cultivated land receives a resting period such that the land use factor falls in the range 3 to 10. Nye & Greenland (1960) listed 22 examples of shifting cultivation distributed between the moist evergreen forest, the moist semideciduous forest and the savanna zone, and of these 22, the land use factor normally falls within this range for 18.

Where lack of available land does not cause the land use factor to be artificially reduced, the frequency of recurrence of cultivation will be determined by ecological factors. There will then be a relation between soils and land use factors, and we may subdivide recurrent cultivation into short, medium and long term, corresponding to a range of land use factors from 4-5, 5-7 and 7-10 respectively.

It should also be recognized that where recurrent cultivation is practised, several different types of field are normally cultivated, each with a different land use factor. The largest area will normally be that with the highest land use factor, but a smaller area on sites of unusually high fertility (old hut sites, former animal compounds, sometimes old termitaria) may be more intensively cultivated, a 'home garden' may receive manure and refuse and be almost continuously cultivated, and in addition areas of wet land may be selected for special crops and be cultivated at another intensity. Recurrent cultivation in Phase III is always complex, but in Phase II may or may not be complex. The term complex refers here to whether the system includes fields cultivated with a different land use factor.

The influence of ecological factors

(a) Soils. Soils are clearly a major determinant of cultivation practices, as is demonstrated by their influence on the categories discussed above. However, in addition to the general relationship of soil fertility to frequency of cultivation, certain special relationships may be mentioned. Thus the 'citimene' system of shifting cultivation has been evolved on the sandy soils of low fertility in Zambia (Allan 1965). The cultivated area has to be enriched not only by burning the vegetation which has grown on it, but by cutting vegetation from surrounding areas and burning it on that to be cultivated. At the other extreme are the patterns of intensive recurrent use developed on eutrophic brown soils. While such soils are able to sustain continued nutrient removal, they are often susceptible to degradation by erosion. Hence, special measures have been adopted for their protection, and examples of terraced gardens are associated with shifting cultivation practices in many parts of the world.

(b) Topography. Topography determines the relative areas of lower slope and upper slope soils, and hence the proportions of land that can be used for dry season gardens. It also has an extremely important bearing on the incidence of erosion. One of the most frequent causes of serious land degradation by shifting cultivation is associated with cultivation of steep slopes in a system that does not lead to adequate control of erosion. There are, however, systems such as the 'pit system' of the Matengo of Tanzania which is closely analogous to tied ridge cultivation, and enables even very steep slopes to be cultivated safely (Allan, 1965).

(c) Climate. There are marked differences in the practice of shifting cultivation as climate changes from semi-arid to perhumid. In the drier areas Phase I shifting cultivation and long term recurrent cultivation is common. Intensification is difficult because the rate of regrowth of vegetation is slow, being limited by the short period when soil water is adequate. Similarly while leaching may not be severe, soil deterioration by wind and water erosion may be serious, since it is difficult to keep a vegetative cover on the soil. In the perhumid areas of moist evergreen forest, Phase I and long-term recurrent cultivation again tend to be the more common types of shifting cultivation. The extremely rapid regrowth of vegetation severely restricts the length of the cropping period. Regrowth of vegetation is normally allowed to continue for 12 to 20 years (Jurion & Henry, 1967; Nye & Greenland, 1960). The relatively long period seems to be necessary if the nutrient levels are to be restored in conditions where leaching losses are large.

In the regions of less extreme climate, the moist semi-deciduous forest zone, the areas of derived savanna and the Guinea and Sudan savanna, a much greater range of practices is found, and within the various categories there is a greater diversity of field types.

(d) Vegetation. The influence of vegetation is of course intricately enmeshed with that of soils and climate. Nevertheless, there are specific influences of certain species within ecological communities that in some instances determine the pattern of shifting cultivation. For instance the aggressiveness of lalang, Imperata cylindrica var. major, and the difficulty of cultivating areas dominated by it without resort to mechanized and chemical methods, determines a length of fallow of at least ten years, since it is not displaced by other vegetation in a shorter time than this. By contrast natural, rapid redevelopment of the deep rooted shrub Acioa barteri can bring about a relatively rapid replenishment of surface soils, and so enable intensive recurrent cultivation to be practised.

Certain crops and crop varieties also determine the type of shifting cultivation practised. For instance, the system of the Baganda is determined by the dominant place occupied by plantains.

(e) Population pressure. Shifting cultivation evolves in situations where land is plentiful. As the concentration of people living in a particular area increases, so flexibility is lost, and the system has to be modified. This is usually done by shortening the fallow period. Restoration of soil fertility may then be incomplete, and so a degenerative cycle commences. Many examples of this type have been collected by Prothero (1972). Where shifting cultivation has been adversely affected by population pressure it should perhaps be described as a degraded system.

The more extensive systems of Phase II or III seem most liable to be affected. Where both home and far fields are cultivated (complex systems) shortening of the fallow period may be followed by disappearance of 'far fields' from the system (see e.g. Middleton and Greenland, 1954).

To compensate for the loss in fertility and lower yields, larger areas may be cultivated (Allan, 1965). There may also be a renewed incentive to find other methods of increasing productivity, though most commonly relief is obtained through labour migration (Prothero, 1972).

(f) Influence of animals. Where substantial numbers of animals are kept they can have a marked influence on shifting cultivation. This is probably most important for recurrent cultivation, where fallow land is used for grazing, and animals may be involved in transferring nutrients and organic matter from fallow to cultivated land. Where tha availability of land is limited, over-grazing can occur, and the animals induce rapid soil erosion, particularly in drier areas and those subject to periodic droughts.

The involvement of animals is affected by many extraneous influences, such as their place in the cultural life of the community and the extent to which they are likely to be attacked by predators and diseases.

The Development of Shifting Cultivation

Throughout the world the practice of shifting cultivation is changing rapidly. In many cases changes have been induced by rapid growth of population and the consequent restriction of land availability. Other changes have arisen from the introduction of new crops, particularly cash crops. These are often produced on land divorced from that used for food crop production. Erosion control measures, fertilizers and manures, and the use of machinery and cultivation implements have all exerted important effects (Boserup, 1965).

It is vitally important to the future prosperity of all lands where shifting cultivation in its various forms is currently practised, that these innovations are introduced in such a way that the productivity of the land is not only maintained but enhanced. This is most effectively done if the introduction of the improvements can be harmonized with an existing agricultural system.

Parain (1942) writing of Europe in the fourteenth century said that 'clearance by burning could only endure where the forests seemed inexhaustible. It involved no application of fertilizers but it squandered precious natural wealth, and often turned forest land into increasingly unproductive moorland'. It is to be hoped that in the twentieth century we will be able to avoid the parallel of turning the remaining tropical forests into less productive savanna.

In 'The African Husbandman' Allan (1965) suggests that the aim of development of shifting cultivation will be best served by maintaining fallows so that the ecological balance is preserved. This may well be true of agriculture in Phases I and II, and for much of the forest, but where areas of shifting cultivation are already in Phase III, a different pattern of development is already occurring. The concern of the agricultural scientist, and particularly of the soil scientist, must be to see that the developments are made in such a way that soil fertility is maintained or enhanced. The basic scientific principles are known, and are the same whether land is cultivated in small plots or large fields, and whether by multiple disc ploughs or the hoe.

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SHIFTING CULTIVATION - REASONS UNDERLYING ITS PRACTICE

by

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The two terms 'shifting cultivation' and 'land rotation' are often confused or used synonymously in describing an agricultural system predominant throughout the tropics and the sub-tropics. In defining the former, the emphasis is on the fact that the land as well as the dwelling is abandoned after farming for a few years. The dwelling is then rebuilt at a new site where land is to be newly cleared for farming. Land rotation, on the other hand, basically assumes permanency of settlement. The system is clearly defined as follows: 'It is the system whereby cultivation is carried on for a few years and then the land allowed to rest, perhaps for a considerable period, before the scrub or grass which grows up is again cleared and the land re-cultivated. In such areas, however, the farms or settlements on which cultivation takes place are fixed and the cultivation of the land is the dominant occupation. The secondary growth which is allowed to appear has little or no economic importance.' (International Geographical Union, 1952). From these two definitions the main difference is only in the permanency of the settlements. Basically, therefore, there must be a common reason or reasons underlying the practice. The term 'shifting cultivation' will, therefore, be used throughout this paper.

Shifting cultivation has been referred to by authors from various disciplines as a backward or primitive form of agriculture. The situation was summed up in an FAO document (1957) thus: 'Shifting cultivation is not only a backward type of agricultural practice. It is also a backward stage of culture in general. In all respects it corresponds to the Neolithic period through which humanity passed between the years 13 000 and 3 000 B.C. considering that the substitution of iron tools for polished stone has made no substantial difference in the way of life.' But despite this realization it has not yet been possible to change successfully or even modify considerably this system of agriculture in the humid tropics. In some instances the prescribed solutions failed miserably perhaps because they were 'imported' and imposed as solutions without considering factors such as the physical, sociological, cultural and religious backgrounds. This was best summed up by Gouron (1952) quoted by Nye & Greenland (1960) as follows: 'The disasters brought on by agricultural methods which have taken no account of the treasures of wisdom and experience accumulated in the old tropical system are a sufficient proof of the latter's value. It can be improved, but only if the reasons for its processes are fully understood.' The diversity of culture, cropping system and environment makes the problem more difficult when considering solutions and modifications to this system of agriculture.

Some of the reasons given for shifting cultivation in one country may not necessarily apply to another country in even a similar climatic zone, and yet the system is widely practised in all tropical areas. For example, the weed problem might be quite important in Southeast Asia while in West Africa this might not be so. Some peasant farmers in Ghana, for example, would normally attribute shifting to the land being 'dead'. In the following paragraphs these various causes for shifting will be examined in detail.

Pests and diseases

In modern agriculture, pests and diseases are mainly controlled through chemical and biological methods and to some extent by the cropping system, e.g., by crop rotation. This has, however, had no impact on the peasant system of agriculture in most parts of the tropics. In some cases even if there is an awareness of these measures financial limitations prevent their application. Peasant farmers are very much alive to their pest problems, but the evidence for this being one of the underlying reasons for abandoning the field for a new clearing is not yet established in West Africa.

The multiplicity of crops growing on the same field to a great extent prevents the increase of specific pests. However, in the monoculture of crops such as yam and maize pests may be serious, e.g. the yam beetle (*Heteroligus meles* and *H. claudius*) and maize stem borer (*Sesamia*). Present knowledge of these pests shows that the common West African practice of

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not planting two yam crops in succession could not be mainly due to this pest, but rather to other soil factors. Buahin (personal communication, 1977) observed that since the adult Heteroligus meles migrates, over distances of 2 km or more before the start of the next yam season, the shift to a new farm site would not afford effective control and the farmers are aware of this. Buahin also considered that the same argument should apply to the incidence of the maize stem borer. Freshly cleared sites for the second season cropping (during the minor rains) during which the pest is most prevalent, also suffer from the pests. It is, therefore, evident that a shift of farm site does not introduce any control measure. This could not therefore be a plausible reason for the shifting cultivation system. In the case of organisms such as nematodes, fungi and parasites, there is no doubt that they become more abundant with continuous cropping and especially with monocropping. The native cropping system is usually an effective control measure and other reasons for abandoning farm sites must therefore be sought.

Weeds

The importance of weeds as a possible cause underlying the shifting cultivation system varies from continent to continent as well as from region to region. Also, within the same country, there may be wide variations depending on ecological zones. As rightly pointed out by Nye & Greenland (1960), one consideration in abandoning a farm for a new site lies in the economics of weed control and the cost of clearing the fresh site. This, however, cannot be completely separated from the factor of a higher fertility status of the newly cleared site - a factor which is to be considered later. Another important consideration is the availability of land and the land tenure system. Certain levels of weed infestation might not cause farmers to abandon their plots were the acquisition of new sites very difficult.

In most cropping systems of the equatorial forest regions in Africa where the main crops include mixed semi-perennials such as cocoyam, cassava and plantain, weeds would hardly constitute a reason for abandoning land. The crops, by their association, indirectly control the weeds. This is clearly outlined by Nye & Greenland (1960) in West Africa and Tondeur (1960) in the central Congo.

There is a strong evidence, however, that with continuous cropping especially in the monsoon type of climate weed infestation plays an important role in declining yields. The mode of weed control also seems to play a vital role in this respect; Morley (1946) pointed out that planting maize after maize in Maya was more successful when weeds were eradicated by pulling out the roots than by slashing with the cutlass. Charter (1941) observed the same decline in yield when bracken infested land under continuous cropping in British Honduras. Grass infestation on continuously cropped land in the marginal forest, for example in Ghana, is sometimes very high, and some farmers interpret this as an indication of reduced soil fertility and therefore move to other sites. In such cases abandoning the site is not due to the farmer's inability to control the weeds.

In contrast to West Africa, the weed problem in the forest region of Southeast Asia seems to be paramount. Conklin (1957), Freeman (1955) quoted by Nye & Greenland (1960), Hutton (1921a, b) and Joachim & Kandiah (1948) outlined clearly the unique position of grasses in causing most farmers to abandon their land.

In the savanna areas of Africa grasses such as Imperata cylindrica and Andropogon gayanus assume much importance as weeds. Annual burning, however, reduces the seriousness of these grasses with the exception of stoloniferous species which are difficult to eradicate. Even though Imperata may pierce yam tubers and affect their appearance, as pointed out by Nye & Greenland (1960), it does not greatly contribute to abandonment of the land.

Cropping system

The cropping system practised in most tropical countries, especially in the forest regions, has largely determined the practice of shifting cultivation. Monoculture is not and never has been common. A freshly cleared forest site for maize may be planted with other crops such as plantain, cocoyam and eventually cassava. The practice of interplanting, no doubt, contributes greatly to erosion control, but its more important function in subsistence farming system is to insure against crop failure. A major difficulty arising out of this combination of crops is the inability of the farmer to replant the original crop (for example, maize) after the first harvest since shade from the semi-perennials would be excessive. The farmer, because of his dietary habits as well as the need of earning his livelihood, is therefore forced to look for a fresh site since the associated crops take much longer to mature. The availability and ease of securing new land for food crops encourages him to clear another site. Much to his advantage also is the fact that clearing is done at a time of year when there is little work to be done on the already established farm.

The situation is different in the savanna areas where, because of the long dry spell, crops cannot be left growing in the field throughout the year. In most of these areas where population density is fairly high, there is some crop rotation amongst a great deal of inter-cropping. This is to be distinguished from the 'compound farm' system, for example in Northern Ghana, where the same field is continuously cropped through the addition of farmyard manure and household refuse.

Soil erosion

In discussing soil erosion as one of the contributory factors in shifting cultivation, the cropping system again assumes great importance. Closely linked with soil erosion are also the types of agricultural implement and method of seed-bed preparation.

The implements commonly used in subsistence farming under shifting cultivation are the hoe and the cutlass. In the forest regions their disturbance of the soil is so minimal, and since the area is never completely stumped, that the effect of cultivation is negligible, unlike that of mechanical equipment. Even more important is the seed-bed preparation for a crop such as the yam. In making yam mounds much of the top soil is heaped together, sometimes dis-regarding slopes. The growth of the crop is so rapid that its foliage and that of the inter-planted crops intercepts the raindrops and thus prevents their direct impact on the soil. The erosion hazard in the forest area is therefore not so serious as to cause the farmer to shift after two croppings, but in the savanna zones, especially where the soils are shallow, erosion hazards are serious. On such soils concretions lie quite close to the surface, and even though the total rainfall is less than that in the forest zone, torrential rain sometimes of short duration may cause serious erosion. Rates of rainfall of more than 203 mm/h for short periods are not unusual in Northern Ghana (Walker, 1962).

Grass burning, which usually precedes cropping in the savanna areas, leaves the ground bare of vegetation so that erosion sets in at the beginning of the rains before the crops are yet established. As a result, the infertile subsoild is exposed and this leads to the farmers abandoning their sites and shifting to more fertile places.

Land tenure and shifting cultivation

Sir Joseph Hutchinson writing on the agricultural revolution in Britain pointed out that 'these agents of our latest revolution (fertilizer and mechinization) are most successful where land is held on modern systems of tenure, and where the art of husbandry has already assimilated the practices of fertility conservation' . One of the basic underlying causes of continuing shifting cultivation in Africa today is the complete lack of an effective land tenure system, especially in food growing areas. This has resulted in labour being regarded as the only capital to be invested in the farm. Maintenance of soil fertility is left to nature to perform, hence the long fallow periods for recuperation. Also the lack of a land tenure system encourages farmers to cultivate as many patches of land as the family labour can manage, since 'ownership' of the land is vested in them as long as their crops are on it. One of the effective ways of modernizing the agricultural system, therefore, is an efficient land tenure system.

Effect of population and economy

Of the many reasons given for practising shifting cultivation, deterioration in fertility status of the soil has received most prominence. Unfortunately, the demographic factor which has so far received little attention seems to be the main factor perpetuating the system in Africa. De Haan (1959) regarded this factor as the most decisive. In parts of Africa, particularly savanna areas, and Asia where population density has increased considerably, a more serious attempt has been made to evolve crop rotational systems which favour a settled form instead of an exploitive form of agriculture.

The economy in areas of shifting cultivation has also unfortunately not favoured any change in the system but rather has encouraged its practice. De Haan (1959) rightly described the economy as 'local, isolated, and self dependent. In most cases the production of a surplus can earn no income and no means outside the local community are available to improve production and raise the level of living.' It is therefore apparent that where there is a great improvement in communications the isolated economy will be expanded, marketing developed, and agricultural products exported. It is at this stage that shifting cultivation will undergo a change.

Soil fertility

The most widely publicized and accepted reason for shifting cultivation is the decline in the fertility status of the soils after a few seasons of cropping. Tropical soils are subjected to severe climatic conditions; prominent among these are heavy rainfall and excessive leaching in the forest regions. In the savanna regions the long drought coupled with the usual annual burning allows little accumulation of organic matter. The nutrient contents of these soils are therefore low.

The soils in Africa are old and contain mostly kaolinitic clay, and after heavy leaching their nutrient holding capacity is low. This is in contrast to some of the very fertile alluvial and volcanic soils which are cropped continuously in some parts of the tropics.

Shifting cultivation is an exploitive agricultural system and improvement of soil fertility by man is non-existent. Since the ecological zones differ widely in respect of climate and vegetation, so too do the fertility problems differ from one ecological zone to another. Two broad ecological divisions, (a) forest zone and (b) savanna which cover most parts of Africa will now be considered.

(a) Forest zone

In the dense forest areas in the tropics, on virgin land as well as on lands that have been under fallow for periods of more than 10-15 years, there is a large accummulation of organic matter through the leaf litter and the fine root remains of the vegetation. The nutrient level of these soils is generally high, and cropping after clearing could be sustained through the inherent fertility for periods longer than the customary two to three years. Experience with secondary forests in Ghana with fallow periods of about 10 to 12 years showed no response to fertilizer nitrogen by maize crops grown continuously for three to four seasons, nor to nitrogen in 8 years of rotation although large responses to phosphate were obtained. Under such circumstances, therefore, abondonment of the farm site may not be so much the result of a decline in fertility as the favourable land/population ratio and the impossibility of planting a second short-term crop among established semi-perennials.

In areas where the fallow period has been reduced to one year in extreme cases or to 5 or 6 years in moderate cases fertility is insufficiently restored as to sustain a high crop yield for two to three continuous croppings, and it is under these conditions that the farmers realize that their land is 'dead' and shift to newareas where fertility is much higher. There is usually a marked contrast between the crops of the first and second years because the first crop benefits from the nutrients released by the usual practice of burning the trash. Results of a large number of fertilizer experiments conducted throughout tropical

Africa have clearly established large responses to nitrogen and phosphorus after the short fallow rest. Piggott (1954), under such conditions in Sierra Leone, obtained large responses to superphosphate on cereals, groundnuts and cassava. Similar results on yam, maize, cassava and melon were obtained by Irving (1954) in southeastern Nigeria. Nye (1952) in Ghana found increases of 27 per cent in maize yield after applying superphosphate at 135 kg/ha (120 lb/acre).

Hauck (1967), summarizing the results of 715 fertilizer trials on peasant farms with short fallow periods conducted by FAO on maize in Ghana, found that the increase in yield atributable to the fallow was reduced by half in the second cropping year and to a negligible amount in the third (Table 1).

Table 1

Yield of Maize in Successive Years After Clearing Secondary forest fallows in Ghana: (Hauck 1967)

Yield before the fallow started:	... ...	700 kg/ha
1st Year: Yield increase by fallow	....	400 kg/ha
" " " fertilizer:	... ...	400 kg/ha
		Total 1500 kg
2nd Year: Yield increase by fallow:	... ...	200 kg/ha
" " " fertilizer	... ...	400 kg/ha
		Total 1300 kg
3rd Year: Yield increase by fallow:	... ...	0 kg/ha
" " " fertilizer:	... ...	400 kg/ha
		Total 1100 kg

It is interesting to note from the same results that a moderate application of 22.5 kg/ha of N and P was equivalent in its effect to that of the fallow on grain yield in the first year.

Further evidence of maintaining yields above those obtained by farmers using the hoe only was obtained by Ofori (1973) on land cropped continuously for 19 years with moderate fertilizer applications. The mean yield of cassava after 19 years was 14572 lb/acre (16335 kg/ha) and that of maize was 1326 lb/acre (1486 kg/ha).

Cassava growth on plots without fertilizer was poor; at an age of 6 months the stems were thin and only 1.2 m tall and the leaves showed acute nutrient deficiencies, but on plots receiving fertilizer the plants were healthy and averaged 2.1 m in height.

(b) Savanna

The savanna soils very rapidly lose fertility with successive cropping, and in contrast to the forest soils very little organic matter accumulates under the grass cover. This is worsened by the usual practice of annual burning. Fallow periods of 3 to 5 years are too short under most savanna conditions to restore fertility of the soil to a reasonable level. The type of grass in the fallow plays a decisive role in the restoration of fertility. Nye (1951) in Ghana and Vine (1953) in Nigeria found in their experiments that a general deficiency of nitrogen occurs when fallows under a tall grass cover are cleared for cropping. The peasant farmers has realized this and has adopted the practice of opening up the fallow with a yam crop which is less sensitive than cereals. The practice, as pointed out by Nye and Greenland (1960), is widespread in West Africa.

Phosphorus deficiency throughout the savanna area is widespread since there is very little accumulated organic matter to be mineralized. Moderate to large responses to superphosphate have been obtained in the numerous fertilizer experiments carried out in the savanna zone.

The trend towards falling yields of maize grown successively after clearing a grass fallow site is shown in Table 2.

Table 2

Yield of Maize Under Continuous Cropping in Transitional Savanna Zone in Ejura (Ghana)
Grain Yield in kg/ha

	1st crop	3rd crop	5th crop
Without fertilizer (F_0)	2262	1726	932
With fertilizer (F_1)	3031	3341	2916
$F_0/F_1 \times 100$	74.6	51.7	32.0

Annual rainfall = 1499 mm. Fertilizer dressing was 72 kg N, 48 kg P and kg K/hectare.

The yields shown were those obtained in the major season cropping only. The maize crops in the minor seasons (2nd and 4th croppings) failed.

The rapid decline in grain yield of the crops grown without fertilizer illustrates the reason why the farmer would shift to a new site if land were to be available. The peasant farmer's yield would be even lower as he would not have controlled weeds, used good planting material or planted at the best spacing. On the other hand, the results demonstrate that under these same conditions high yields could be achieved through the use of mineral fertilizers, and the need to shift might not therefore arise.

Conclusions

The various causes underlying the system of shifting cultivation have been discussed. The principle in this system is exploitation, with no attempt by the land user himself to conserve and improve the fertility of the soil. The natural restoration of fertility has usually so far been possible because land has been available and the land/population ratio has been favourable. The economic level of production, which has been at subsistence level, and sometimes weed infestation, have tended to perpetuate shifting cultivation. Religious belief does not seem to play any role. There is a growing tendency, especially in the densely populated areas in the tropics, to develop suitable crop rotations. With the application of the basic principles of fertility conservation and improvement, taking local environments into consideration, it should be possible gradually to transform the shifting cultivation system to a more settled and productive agriculture.

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SHIFTING CULTIVATION IN AFRICA

(Evaluation of Questionnaires)

by

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INTRODUCTION

For some time FAO has been repeatedly requested at various conferences and other meetings to take the initiative, in conjunction with its member countries, in solving the problem of shifting cultivation and the need for increased agricultural production.

As one of the follow-up actions of the Third Conference on Soil Fertility and Fertilizer Use in Africa, Addis Ababa, November 1970, on which occasion these problems were discussed in more detail, questionnaires on shifting cultivation and soil conservation were sent out in 1971 to the Member Nations of FAO's African Region.

Replies were received from ten countries, i.e. Peoples Republic of the Congo (Brazzaville), Dahomey, Liberia, Madagascar, Malawi, Mali, Niger, Uganda, Zaire and Zambia. In other countries shifting cultivation was either not practised or the subject matter personnel were occupied with other problems.

This evaluation is incomplete, however, it serves as a useful introduction to some countries not represented at the Seminar, particularly those in which French, rather than English, is spoken.

The Country Reports which have been contributed to the Seminar together with the completed questionnaires and those which will, hopefully, be received after a renewed invitation, will form the basis for an annex to the report on the Seminar which will provide information on the kind and magnitude of problems encountered as well as on the work completed or under way for their solution.

Summary of evaluation of Questionnaires

The characteristics of shifting cultivation and the respective factors which influence further trends and demonstrate the need for action in the countries under review are summarized in Table 1.

The importance of the area under shifting cultivation in these countries is indicated. The area for Niger, 8 million hectares under shifting cultivation of a total of 12 million hectares, can be considered as an example of the magnitude of the problem in the Sahelian Zone of West Africa which is further aggravated by other ecological conditions such as climate and soil.

The cropping/fallow periods reflect ecological conditions and natural soil fertility conditions as well as the population pressure on the land.

The decrease in yields, which are basically already relatively low, during the cropping period represents another characteristic of the system which appears to be inadequate even for a subsistence economy.

The population pressure on the cropped land is an average density only and is locally much heavier in certain regions of the countries. The ratio of cropped land to the population varies from about 3 ha (7.5 acre) per inhabitant to 0.4 ha (1 acre).

By considering a linear growth rate of population of 2.4 percent as an example, this cropping area per inhabitant will be reduced to 0.3 ha (0.75 acre) within 10 years time and to 0.2 ha (0.5 acre) in 20 years, thus necessitating a further extension of the cropped land or an increased production from the presently cultivated area.

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Table 1

Shifting cultivation in some African countries

Country	Area under shifting cultivation (ha)	Cropping/fallow periods (years)	Decline of productivity during crop period (%)	Population per hectare of cropped land	Annual population growth rate (%)	Annual fertilizer consumption ($N-P_2O_5-K_2O$) (kg/ha)
Congo, Peoples Rep.	90 000	2-5/2-10	20-50	1.4	1.2	1.1
Dahomey	900 000	2-3/3-10	25-60	1.8	2.9	3.0
Liberia	75 000	1.5-2.5/3-7	NR	0.3	1.7	0.6
Madagascar	200 000	3-5/NR	NR	2.3	2.4	5.0
Malawi	NR	1-2/3-20	Rapidly declining	1.6	3.0	4.5
Mali	NR	NR	NR	0.7	2.0	0.8
Niger	8 000 000	5-6/5	30-60	0.3	2.8	0.02
Uganda	3 200 000	1-2/0-10	30-50	1.9	2.6	1.4
Zaïre	NR	2-3/5-20	Rapidly declining	2.5	2.4	0.9
Zambia	1 900 000	2-5/8-20	Declining	0.9	3.4	4.6

NR: denotes no reply in questionnaire.

Data based on: questionnaire, FAO Production Yearbook and FAO Annual Fertilizer Review.

Data are for use as information and do not represent an official record.

The annual fertilizer consumption in kilogrammes of principal nutrients per hectare (approximately equal to lb/acre) provides an indication of the agricultural inputs actually used to increase crop production per unit area.

(A) CONGO PEOPLES REPUBLIC

I. Conditions and problems

1. Estimated area under shifting cultivation: 90 000 ha

2. Type of rotation:

	Crops	Cropping/fallow period
Grass-fallow (Type 1)	Pumpkin, maize, yams (mixed stands), followed by groundnuts and 2 years of cassava	4 years cropping, 6-10 years fallow
Grass-fallow (Type 2)	Clearing, 6 months rest, 2 years groundnuts	2 years cropping 4-6 years fallow
Grass-fallow (Type 3)	Groundnuts	1-2 years cropping 2-4 years fallow
Bush fallow (Type 1)	Groundnuts, followed by maize, pumpkin, yam, cassava (mixed)	3 years cropping 3-5 years fallow
Bush fallow (Type 2)	Tobacco, pumpkin, sweet potatoes followed either by fallow or two years of yams, pumpkins and cassava	1-3 years cropping 8-10 years fallow
Bush fallow (Type 3)	After incorporation of grass in ridges, 2 years pumpkins and cassava, 2-3 years fallow, followed by groundnuts	2 years cropping, 2-3 years fallow, 1 year cropping 8-10 years fallow
Bush fallow (Type 4)	Two years beans, 3 years tobacco	5 years cropping 5-10 years fallow

3. Crop yields per hectare:

Cassava	8-10 t
Groundnuts	600-800 kg
Maize	500-600 kg
Sweet potatoes	5 t
Rice (paddy)	600-1 000 kg
Plantains	8-15 t

4. Soil fertility trends in consequence of rotation practices: Yields decreasing from 20 to 50 percent depending on duration of cropping and fallow period.

II. Population and land

5. Total population: 900 000 persons

6. Population density per km^2: 2.6 persons

7. Annual increase: 1.2 percent

8. Total agricultural population: 585 000 persons (65 percent)

9. Total arable land and land under permanent crops: 630 000 ha

10. Population density per cropped land area - (see item 9)

(i) Total population per hectare: 1.4 person
(ii) Agricultural population per hectare: 0.9 person

III. Fertilizer use

11. Annual consumption (N, P_2O_5, K_2O): 7 140/t

12. In kg/ha of cropped land area (see item 9): 1.1

13. In kg per caput: 8 kg

IV. Research and policy

14. Research organizations

(i) Government Agricultural Research Stations
(ii) ''Office pour la Recherche Scientifique des Territoires d'Outre-Mer'' (ORSTOM) - Bureau for scientific research in overseas territories

15. Research objectives:

Agronomic research applicable to improvement of shifting cultivation. Socio-economic studies combined with agricultural aspects.

16. Improvement Policy:

Official policy towards regrouping of villages in view of a collective approach to modern agricultural techniques and improved marketing of produce.

- Improvement Practices:
Improvement of rotations; improved seeds and plant population.
Economy of fertilizer use on farmers fields not yet entirely known. Other feasible improvements would be the use of local limestone and draught animals in the Savanna Zone.

V. Soil conservation

17. On plantations: Ridging and rotation.

18. On farmers level: Individual or continuous ridging, mulching between ridges on steep slopes.

(B) DAHOMEY

I. Conditions and problems

1. Estimated area under shifting cultivation: 900 000 ha

2. Type of rotation:

Region	Crops	Cropping/fallow period
South and Centre	First year maize, second year maize or groundnuts or beans, possibly third year yams or cotton	2-3 years cropping 3-18 years fallow
North	First year yams and beans, second year maize and sorghum, possibly third year cotton	2-3 years cropping 3-10 years fallow

3. Average crop yields per hectare

Maize	1 000 - 300 kg
Yams	10 000 - 6 000 kg
Cassava	9 000 - 5 000 kg
Groundnuts	800 - 400 kg
Cotton	700 - 300 kg

4. Soil fertility trends in consequence of rotational practices:

After several cropping periods, yields decrease by 25 to 60 percent, depending on the duration of fallow.

II. Population and land

5. Total population: 2 850 000 persons

6. Population density per km^2: 25.3 persons

7. Annual increase: 2.9 percent

8. Total agricultural population: 2 394 600 persons (84 percent)

9. Total arable land and land under permanent crops: 1 546 000 ha.

10. Population density per cropped land area (see item 9):

(i) Total population per hectare of cropped land area: 1.8 person.
(ii) Agricultural population per hectare of cropped land area: 1.5 person.

III. Fertilizer use

11. Annual consumption (N, P_2O_5, K_2O): 6 700 t

12. In kg/ha of cropped land area (see item 9): 4.3

13. In kg per capita: 2.3

IV. Research and policy

14. Research organizations: No reply

15. Research objectives: No reply

16. Improvement policy:

Organization of cooperatives and pre-cooperative units combined with reinforced agricultural extension.
Use of improved high yielding seeds and new cultural practices.
Fertilizer subsidies.
Introduction and extension of use of draught animals and animal drawn equipment.

V. SOIL CONSERVATION

17. In plantations: No reply

18. On farmers level: Planted fallow (*Pueraria*, *Centrosema*, *Stylosanthes*, etc.)

(C) LIBERIA

I. Conditions and problems

1. Estimated area under shifting cultivation: 75 000 ha

2. Type of rotation:

Region	Crops	Cropping/fallow period
Coastal region	Cassava, maize, rice, yams, sweet potatoes	18 months cropping 3-5 years fallow
Central region	Rice, maize, cassava, groundnuts, okra, sweet potatoes	18-30 months cropping 3-7 years fallow
Northern region	Rice, maize, cassava, okra	18 months cropping 2-7 years fallow

3. Average crop yields per hectare:

Rice (paddy, 1st year)	600 kg
Cassava (2nd and 3rd year)	5 000 kg
Groundnuts (in shell)	600 kg

4. Soil fertility trends in consequence of rotational practices:

Natural fallow system mainly to restore soil fertility; land still available.

II. Population and land

5. Total population: 1 210 000 persons

6. Population density per km^2: 12 persons

7. Annual increase: about 1.7 percent

8. Total agricultural population: 968 000 persons (80 percent)

9. Total arable land and land under permanent crops: 3 850 000 ha

10. Population density per cropped land area (see item 9)

(i) Total population per hectare: 0.3 person
(ii) Agricultural population per hectare: 0.2 person.

III. Fertilizer use

11. Annual fertilizer consumption (N, P_2O_5, K_2O): 2 300 t

12. In kg/hectare cropped land area (see item 9): 0.6

13. In kg per capita: 1.9

IV. Research and policy

14. Research organizations:

Research stations of Department of Agriculture
School of Agriculture, University of Liberia

15. Research objectives:

All as per questionnaire plus: irrigation for extension of cropping period and fish farming.

16. Improvement policy:

Targets are improvement of farm family income and reduction of rice importations.

Intensification plans concentrated on tree crops, pasture establishment combined with animal husbandry, swamp reclamation and irrigated rice growing.

V. Soil conservation

17. In plantations: No reply.

18. On farmers level: Tree crops and forest conservation.

(D) MADAGASCAR

I. Conditions and problems

1. Estimated area under shifting cultivation: 200 000 ha (forest)

2. Types of rotation:

	Crops	Cropping/fallow period
No differentiation	Type 1: 1st year rice (80 o/o) 2nd year manioc; 2-3 years bananas;	4-5 years cropping
	Type 2: Rice - manioc - maize; others: perennial crops (banana, coffee, vanilla, etc.)	3 years cropping fallow period n.a.

3. Average crop yields per hectare:

	1st year	2nd year
Rice (paddy)	500 kg	300 kg
Cassava	7-8 t	5 t
Maize	800-1 000 kg	200 kg

4. Soil fertility trends in consequence of rotational practices:

Shifting cultivation in the forest zone is practised mainly because there is no more land available in the fertile plains.

II. Population and land

5. Total population: 6 643 000 persons

6. Population density per km^2: 11.3 persons

7. Annual increase: 2.4 percent

8. Total agricultural population: 5 089 000 persons (84 percent)

9. Total arable land and land under permanent crops: 2 856 000 ha

10. Population density per cropped land area (see item 9)

(i) total population per hectare: 2.3 persons
(ii) agricultural population per hectare: 1.8 person.

III. Fertilizer use

11. Annual fertilizer consumption (N $P_2O_5K_2O$): 14 400 t

12. In kg/hectare of cropped land area (see item 9): 5.0

13. In kg per capita: 2.2

IV. Research and policy:

14. Research organizations:

- Technical Research Centre for Tropical Forests (Centre Technique Forestier Tropical)
- Bureau for Overseas Scientifical and Technical Research (O.R.S.T.O.M.)
- Malgasy Agricultural Research Institute (I.R.A.M.)

15. Research objectives:

- Research and analytical work in stations and on farmers' fields.
- Fertilizer use
- Weed control
- Reduction of fallow

- Natural and planted fallows
- Replacement by permanent cropping (fertilizer use and improved management).

16. Improvement policy:

Fertilizer use, crop rotation; planted grass and forest fallow (white Grevillea)

V. Soil conservation

17. In plantations: No reply.

18. On farmers level: Contour cropping with alternate strips.

(E) MALI

I. Conditions and problems

1. Estimated area under shifting cultivation: No reply.

2. Types of rotation: No reply.

3. Average crop yields per hectare: No reply.

4. Soil fertility trends in consequence of rotational practices: No reply.

II. Population and land

5. Total population: 4 930 000 persons

6. Population density per km^2: 4 persons

7. Annual increase: 2 percent

8. Total agricultural population: 4 440 000 persons (90 percent)

9. Total arable land and land under permanent crops: 7 200 000 ha crops:

10. Population density per cropped land area (see item 9)

(i) total population per hectare: 0.7 person
(ii) agricultural population per hectare: 0.6 person.

III. Fertilizer use

11. Annual fertilizer consumption (N, P_2O_5, K_2O): 5 500 t

12. In kg/hectare of cropped land area (see item 9): 0.8

13. In kg per capita: 1.1

IV. Research and policy

14. Research organizations:

- Research Institute for Tropical Agriculture (IRAT)
- Research Institute for Cotton and Textile Fibres (IRCT)

15. Research objectives:

- Research and analytical work in stations
- Extension of cropping period and reduction of fallow period
- Crop rotation
- Replacement by permanent cropping (fertilizer use and improved management).

Note: The questionnaire provided basic information on the research work carried out and the results obtained by the Mali Research Institute for Tropical Agriculture (IRAT) which are as follows:

A. Research work carried out:

- Varietal improvement of millet, maize, guinea corn and groundnuts;
- Fertilization of dryland cereals and groundnuts, problem of organic manure and especially chemical fertilizers;
- Productivity of soils, evolution of soils under cropping, physical properties of soils;
- Initiation of soil management and conservation studies;
  - soil mapping at large scale;
  - soil testing laboratory.

B. Results obtained

- Formulation of fertilizer recommendations for millet, maize, guinea corn, groundnuts (predominantly N and P_2O_5), either under annual cropping or under rotation;
- Rates and methods of application of rock phosphates existing in the country (Tilemsi), within the framework of the crop rotation;
- Importance of organic manure for the physical and chemical properties of the soils;
- Productivity of cotton soils in the region of FANA and mapping of these soils;
- Soil reconnaissance in various parts of the country in connection with opening of new research stations.

(F) MALAWI

I. Conditions and problems

1. No reply.

2. Type of rotation:

Type	Crops	Cropping/fallow period
Grass fallow	Opening crops maize and/or millet followed	1-3 years cropping 1-3 years fallow
Bush fallow	by guinea corn; finally cassava or maize	1-3 years cropping 6-10 years fallow
Forest fallow		1-3 years cropping 20-25 years fallow

Predominant is a grass-bush fallow with 1-3 years of cropping and 3-4 years of fallow.

3. Average crop yields:

Maize - 500 kg/ha, cassava 5-30 t/ha, millets 200-300 kg/ha.

4. Rapid decline of soil fertility, lowering of organic matter, reduced retention of exchangeable ions and nitrogen.

II. Population and land

5. Total population: 4 770 000 persons

6. Population density per km^2: 50 persons

7. Annual increase: 3.1 percent

8. Total agricultural population: 3 816 000 (80 percent)

9. Total arable land and land under permanent crops: 2 927 000 ha

10. Population density per cropped land area (see item 9)

(i) total population per hectare: 1.6 person
(ii) total agricultural population per hectare: 1.3 person

III. Fertilizer use

11. Annual fertilizer consumption (N, P_2O_5, K_2O): 13 300 t

12. In kg/hectare of cropped land area (see item 9): 4.5

13. In kg per capita: 3.0

IV. Research and policy

14. Government research stations.

15. Closer spacing, fertilizer use (important), weed control, reduction of fallow, crop rotations.

16. Under increasing population pressure, optimum use of existing land and water resources to meet internal needs by intensive cultivation coupled with suitable inputs of fertilizers, high yielding varieties, better crop husbandry.

V. Soil conservation

17. In plantations: A wide range of techniques used, depending on type of crop.

18. Farmers level: Needs improvement.

(G) NIGER

I. Conditions and problems

1. Estimated area under shifting cultivation: 8 000 000 ha

2. Types of rotation:

Region	Crops	Cropping/fallow period
No differentiation	Type 1:	
	1st year groundnut 2nd-7th year millet in association with legumes	6 years cropping/5 years fallow
	Type 2:	
	1st year millet in association with legumes, 2nd year groundnuts, 3rd-5th year millet in association with legumes	5 years cropping/5 years fallow

3. Average crop yields per hectare:

millet	600 kg
groundnut	100 kg
guinea corn	900 kg

4. Soil fertility trends in consequence of rotational practices: Yields decrease at an average annual rate of 10 percent. Shifting cultivation is mainly practised to maintain natural soil fertility.

II. Population and land

5. Total population: 3 909 000 persons (mid-year estimate 1969)

6. Population density per km^2: 3.2 persons

7. Annual increase: 2.8 percent

8. Total agricultural population: 3 267 000 persons (93 percent)

9. Total arable land and land under permanent crops: 12 177 000 ha

10. Population density per cropped land area (see item 9)

(i) total population per hectare: 0,3 person
(ii) agricultural population per hectare: 0,2 person.

III. Fertilizer use

11. Annual fertilizer consumption (N, P_2O_5, K_2O): 300 t

12. In kg/hectare of cropped land area (see item 9): 0.02

13. In kg per capita: 0.07.

IV. Research and policy

14. Research organizations:

- Research Institute for Tropical Agricultural (IRAT)
- Research Institute for Cotton and other Textile Fibres (IRCT)
- Tropical Forest Research Centre (CTFT)

15. Research objectives:

- Research and analytical work in stations
- Higher plant production
- Extension of cropping period (seasonal water storage)
- Fertilizer use and weed control
- Replacement of shifting cultivation by appropriate rotation acceptable to farmers and use of agricultural inputs

16. Improvement policy:

As population is concentrated in the southern quarter of the country (crop production possible from southern border up to the 400 mm isohyet) and is rapidly growing, fallow periods are continuously decreasing and higher crop production is extremely urgent.

Actual policy is concentrated on:

- improved varieties
- remunerative produce prices and organization of produce marketing
- mixed farming
- improved practices (animal drawn implements - utilization still limited, fertilizers - 1 percent of cultivated area, seed dressing - 10 percent of cultivated area)

V. Soil Conservation

17. In plantations: No plantations.

18. Maintenance of tree belts.

19. On farmers level: Maintenance of tree belts. Contour cropping on slopes. Contour protection by stone walls.

(H) UGANDA

I. Conditions and problems

1. Estimated area under shifting cultivation: 3 200 000 ha

2. Type(s) of rotation:

Type	Crops	Cropping/fallow period
Only one type reported	Cotton or groundnuts as opening crops, followed by cereals (millet, guinea corn grams with intercropping)	From 1-2 years per 10 years of fallow to continuous cropping depending on population pressure and soil fertility.

3. Average crop yields per hectare: No reply.

4. Soil fertility trends in consequence of rotational practices:

On light ferralitic soils without fertilizer or farmyard manure applications, 3 years resting period insufficient to maintain fertility. Yields stabilize ultimately at about 30 percent for cotton and cereals, and at about 50 percent for tubers as compared to the yields where more extended fallow periods are possible.

II. Population and land

5. Total population: 8 940 000 persons

6. Population density per km^2: 2.2 persons

7. Annual increase: 2.6 percent

8. Total agricultural population: 8 046 000 persons (90 percent)

9. Total arable land and land under permanent crops: 4 390 000 ha

10. Population density per cropped land area (see item 9)

(i) total population per hectare: 1.9 person
(ii) agricultural population per hectare: 1.6 person.

III. Fertilizer use

11. Annual fertilizer consumption (N, P_2O_5, K_2O): 7 000 t

12. In kg/hectare of cropped land area (see item 9): 1.4

13. In kg per capita: 0.8.

IV. Research and policy

14. Research organizations:

(i) Department of Agriculture (Serere Research Station, P.O. Soroti)
(ii) Cotton Research Corporation
(iii) Makerere University
(iv) East African Agriculture & Forestry Research Organization

15. Research objectives:

All as per questionnaire plus integration of livestock towards mixed farming.

16. Improvement policy:

From subsistence to commercial farming. Diversification of agriculture, also to depend less on traditional cash crops, e.g. cotton and coffee.

Improved practices are:

(i) Integration of livestock and introduction of planted grass/legume leys into the rotation.
(ii) Increased use of fertilizers.
(iii) Mechanical clearing (hired), annual soil preparation and crop maintenance with ox-drawn equipment.

V. Soil conservation

17. In plantations: No reply.

18. On farmers level: contour strip cropping to control erosion.

(J) ZAMBIA

I. Conditions and problems

1. Estimated area under shifting cultivation: 1 900 000 ha

2. Type(s) of rotation:

Type	Crops	Cropping/fallow period
Grass fallow	Rotation No. 1 cassava, sweet potatoes, maize	2-3 years cropping 8 years fallow
Bush fallow	Rotation No. 2: millet, beans, groundnuts.	2 years cropping 20 years fallow
Stumped fields	Rotation No. 3: maize	5 years cropping 15 years fallow

3. Average crop yields per hectare: generally low.

4. Soil fertility trends in consequence of rotational practices:

Generally declining with increase of population, fallow periods reduced and become too short.

II. Population and land

5. Total population: 4 200 000 persons

6. Population density per km^2: 5.6 persons

7. Annual increase: 3.4 percent

8. Total agricultural population: 3 360 000 persons (80 percent)

9. Total arable land and land under permanent crops: 4 800 000 ha

10. Population density per cropped land area (see item 9)

(i) total population per hectare: 0.9 person
(ii) total agricultural population per hectare: 0.7 person

III. Fertilizer use

11. Annual fertilizer consumption (N, P_2O_5, K_2O): 22 000 t

12. In kg/hectare of cropped land area (see item 9): 4.6

13. In kg per capita: 5.2

IV. Research and policy

14. Research organizations:

- Regional agricultural research stations

15. Reseach objectives:

- All measures to maintain soil fertility
- All measures to increase yields
- All measures to replace shifting cultivation and to assure erosion control.

16. Improvement policy:

- Utmost priority in 2nd development plan because of urgent need to replace shifting cultivation by permanent cropping in view of the rapid growth of population.

V. Soil conservation

17. In plantations: No reply.

18. On farmers level: Soil conservation development would be accepted by farmers, security of land tenure required.

SOIL ASPECTS IN THE PRACTICE OF SHIFTING CULTIVATION IN AFRICA AND THE NEED FOR A COMMON APPROACH TO SOIL AND LAND RESOURCES EVALUATION

by

F. Mouttapa *

INTRODUCTION

The traditional African system of agriculture, south of the Sahara, is based on the practice of shifting cultivation. This system, also called 'bush fallow rotation' prevails in the continent on such a wide range of climate and soils, amid so many types of vegetation, that it shows great variations in the type of crops grown, the length of cropping and fallow periods and the method of cultivation. However, variants of this system, have the following sequence of practices in common:-

a) clearing of the natural vegetation mainly by the use of axes, cutlasses and fire;

b) cultivation of the land thus cleared with various kinds of hoe resulting in little or no disturbance of the surface soil;

c) abandoning the land to fallow after 2 to 3 years of cultivation.

The traditional African farmer has envolved and adapted his cultivation techniques to his environment so as to suit his socio-economic needs. Experience and oral tradition direct the farmers to the soils that are most fertile, easiest to cultivate, or best suited to particular crops; the concept of a catena did not escape them. In many areas the empiric knowledge of soils gained by the African farmer is such that each kind of soil has been given its own name; he can often rate the fertility of a piece of land and its suitability for one or other of his crops by the vegetation which covers it; his index of returning fertility after a fallow period is based on the succession of the vegetation that follows cultivation.

However, socio-economic changes and more particularly demographic pressure on lands reduce the traditional fallow period although all other practices involved in shifting cultivation remain with little change. Thus, the equilibrium empirically evolved and maintained by traditional farmers between the socio-ecological environment, vegetation and crops is broken and leads to a steady degradation of the fallow vegetation and of the land r sources.

The problems of low soil fertility and degradation of land facing African farmers should not therefore be attributed mainly to the consequences of shifting cultivation as initially conceived by their forefathers, but rather to its deterioration brought about by reduction of the fallow period.

This paper will briefly review the effects of shifting cultivation on soils and bring out the need for a concerted and common approach to soil and land evaluation for agricultural development needs in the Region.

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EFFECTS OF SHIFTING CULTIVATION ON SOIL CHARACTERISTICS

Influence of forest and savanna fallow on soils

Water and temperature régime in the soil

It is a well-known fact that run-off is less important under a forest than under a crop or grass cover (Table 1).

Experimental work on the soil moisture regime in a few catchments in East Africa, under forest, and other types of land use on similar soils, with moderate rainfall (1000-1600 mm), shows that available water was present in the forest soil at all levels throughout the year and at no time reached the wilting point, whereas on grassland and on cultivated fields the upper layer of soils dried out rapidly at the onset of the rainy season.

Table 1: Run-off and erosion under various covers of vegetation in West Africa (Charreau, 1972)

Locality	Period of study	Slope (%)	Average annual rainfull (mm)	Annual run-off (%)			Amount of soil eroded (t/ha)		
				Forest	Crop	Barren soil	Forest	Crop	Barren soil
Ouagadougou (Upper Volta)	1967-70	0.5	850	2.5	2-32	40-60	0.1	0.6-8.0	10-20
Sefa (Senegal)	1954-70	12.0	1300	1.0	21.2	39.5	0.2	7.3	21.3
Bouaké (Ivory Coast)	1960-70	4.0	1200	0.3	0.1-26	15-30	0.1-0.2	0.1-26	18-30
Abidjan (Ivory Coast)	1954-70	7.0	2100	0.1	0.5-20	38	0.03	0.1-90	108-170

The soil temperature is generally higher in grassland than under forest. A difference of 8°C was found between the surface soil temperatures under crop and forest in the southern part of Senegal; this difference in temperature increases at the end of the dry season.

Soil structure and erosion

Most of the observations and studies undertaken have indicated the beneficial effect of forest vegetation on soil structure; this is due to better protection of soil against erosion, the high organic matter content and intense microfauna activity in the surface soil of forest lands. Soil structure under savanna or annual crops, is not as good as that under forest.

Soil erosion is almost negligible under forest but, depending upon the inherent soil and land characteristics as well as management practices, it can be very important on cultivated land (Table 1); soil erosion under a grass fallow is considered to occupy an intermediate position between that under forest and that on cultivated land.

Increases of organic matter under fallow

The level of organic matter in soil increases during the fallow. The rate of increase depends on the type and nature of vegetative cover as influenced by climate and men. It has been estimated that in a typical forest regrowth the annual production of litter and root materials can be as high as 6 to 8 t/ha. The amounts of plant material added to the soil annually under a grass fallow vary widely with climate and local conditions and rarely exceed 1 t/ha (Table 2); these additions are mainly produced by roots, the aerial part being lost during the burns.

Table 2: Restitution of organic matter by various types of vegetative covers to soils and organic matter content of soils during fallow (Charreau, 1972)

Locality	Rainfall (mm)	Vegetation	Vegetative material returned (to soil (t/ha/year)			Soil organic matter content (t/ha)
			Aerial part of plant	Roots	Total	
Senegal (Bambey)	650	Crops	0.0	1.5	1.5	11.5
		Herbaceous fallow	0.0	1.0	1.0	13.5
		Acacia albida	4.2	2.1	6.3	22.6
Senegal (Sefa)	1 300	Crops	0.0	2.0	2.0	21.4
		Thin forest	5.0	2.5	7.5	33.8
Zaire	1 830	Forest	10.0	5.0	15.0	93.0

The proportion of fresh organic material converted to soil humus is estimated to be between 10 and 20 percent of the total. The rate of mineralization of the soil humus appears to vary with the amount of organic matter in the soil. In any one set of climate-soil-vegetation conditions there appears to be a humus equilibrium level; under this concept a soil well below its humus equilibrium level may gain humus rapidly at first if given an adequate supply of organic matter, but with the increase of organic matter, the humus content rises up to an equilibrium level above which any further addition of organic matter will only fractionally increase it.

The C/N ratio is reported to vary little during the fallow and the cropping periods; in such a case, the increase in nitrogen will be proportional to the gain in carbon. Assuming that under a good secondary forest the humus content of a soil is about 75 percent of the former amount under the original forest, Nye & Greenland (1960) estimated that the annual increase in nitrogen under forest fallow is around 30 kg/ha in the soil and 60 kg/ha in the vegetation, while in savanna it is 10 kg/ha in the soil and 25 kg/ha in the leaves and stems. These amounts seem to be derived mainly from non-symbiotic fixation.

Total nutrients in the topsoil

There are few data on changes occurring within the soil during a fallow period, as well as on the amounts of nutrients leached from or taken up from the various soil horizons. Nye & Greenland (1960) drew from the results of soil analyses at a few sites under long fallows in Ghana, Zaire, Nigeria, the following broad conclusions from data in Table 3:

- In forest land during a fallow period, more nutrients accumulated in the standing vegetation than in the soil.

- In a forest fallow, there is evidence of a net transfer of nutrients from the subsoil to the topsoil owing to deeper root penetration.

- Soils under forest contain more total phosphorus and calcium in the surface horizon than in the lower horizons. In savanna soils, the accumulation of total P is less marked.

Table 3: Nutrients stored in the aerial cover of fallow vegetation and in the soils (after Nye & Greenland, 1960)

Location	Annual rainfall (mm)	Type of fallow	Nutrients stored in the aerial cover of vegetation and litter (lb/acre)					Nutrients stored in the soils in the first 30cm (lb/acre)				
			N	P	K	Ca	Mg	N	P	K	Ca	Mg
Kade (Ghana)	1625	40 year old mature secondary forest	1634	112	731	2254	309	4100	11	580	2300	330
Yangambi (Zaire)	1825	18 year old secondary forest	499	65	361	501		2000 3000	17	320	89	47
Yangambi (Zaire)	,,	5 year old secondary forest	349	21	307	261						
Ejura (Ghana)	1475	20 year old high grass savanna	24	7	41	31	23	1600	20	170	2600	340
Ejura (Ghana)	,,	Imperata cylindrica	15	5	31	6	12					

Exchangeable nutrients

The amounts of exchangeable potassium, calcium and magnesium in the soil during fallow are small compared with the amounts of these elements stored in the aerial part of the vegetative cover (Table 3).

Effects of clearing and burning on soils

Clearing and burning are the only means by which African farmers can incorporate into the soils some of the nutrients accumulated in the vegetative cover during fallow and clean the land in readiness for cultivation. The effects of burning on soils are as follows:

(a) Certain of the nutrients stored during fallow in the standing vegetation and litter are transferred into the soil as ashes in the forms of carbonates, phosphates and silicates. During the burn most of the nitrogen sulphur and carbon in the vegetative cover are lost as gases, but not that in the soil humus. Analysis of soils after burning shows a substantial increase in the exchangeable cations in the soil and a corresponding rise in the pH. In savanna, the amounts of nutrients released on burning are much less than in forest though dependent largely on the density of the woodland (Table 4).

(b) The direct effect of heat on the soil is negligible except locally where the wood is piled up and temperatures may reach 100°C and 60°C at the 5 and 10 cm depths respectively. Usually, burning of savanna barely affects the surface soil at a depth of 5 cm, although the surface temperature may be as high as 500°C for three to five minutes.

(c) Burning leads to an initial decrease in the microbiological soil population which redevelops to a level greater than before in forest soils, but has relatively little effect in savanna soils.

Table 4: Soil changes following the clearing and burning of fallow (after Nye & Greenland, 1960)

Location	Annual rainfall (mm)	Remarks	Soil depth (cm)	pH	C (%)	N (%)	P (ppm)	K	Ca	Mg	CEC
								mequiv./100g soil			
Kade (Ghana)	1625	40 year forest fallow	0 - 5	5.21	2.22	0.22	9.8	0.41	5.7	1.21	10.1
			5 -15	4.73	1.11	0.11	3.6	0.33	3.6	0.95	7.0
			15 -30	4.63	0.87	0.08	1.9	0.32	3.0	0.94	6.7
		After clearing & burning	0 - 5	7.9	2.26	0.19	30.0	2.01	17.9	2.7	9.9
			5 -15	6.4	1.26	0.11	8.0	0.81	4.6	1.3	5.7
			15 -30	5.7	0.94	0.08	5.0	0.42	3.0	1.1	6.4
Liberia	2000 to 4500	Before clearing	0-7.5	4.5	2.37	0.14	8.9	0.77	1.33	0.62	8.8
			7.5-15	4.1	1.35	0.08	9.2	0.17	0.59	0.38	7.9
		After clearing	0-7.5	5.3	2.77	0.15	18.0	1.22	2.67	0.90	10.6
			7.5-15	4.0	1.62	0.10	9.2	0.42	0.51	0.29	11.2
Benin (Nigeria)	1800	Before clearing	0 -15	5.0	1.16	0.08					5.6
			15 -45	4.4	0.66	0.05					5.3
		After clearing	0 -15	5.9	1.23	0.09					5.9
			15 -45	4.5	0.65	0.05					5.2

Effects of traditional cultivation on soil

The type of traditional cultivation varies considerably from region to region but there are certain features in common:

(a) There is usually very little disturbance of the surface soil which is cultivated with some type of hand hoe. Sometimes, the surface soil is heaped up in small mounds, particularly in the case of sandy, clayey waterlogged or shallow soils.

(b) The practice of mixed cropping (with annuals and perennials) provides good soil coverage and allows the roots to exploit soil nutrients at various soil depths.

(c) The cultivated land is weeded only so long as it is no more laborious than clearing a new site.

(d) The cultivated land is abandoned to return to fallow after 2 to 3 years of cropping.

Effects on soil erosion and structure

Under the traditional system of cultivation, the only period during which the land is without a vegetative cover is immediately after the burn. The erosive effect of the first rains, which in general are progressive, is mitigated by the following features:

- clearing is seldom done over extensive, unbroken traits of land; hence, whole watershades are not bare at any given moment and intervening areas of fallow vegetation check the run-off,

- the root systems, which are resistant to burning, stabilize the surface soil.

Once the first crops are established, the soil remains fairly well covered until the next fallow.

The traditional system of cultivation, at best, may not be conducive to excessive erosion, although repeated cycles of cropping followed by only short fallow periods may induce severe erosion. Table 1 indicates the order of magnitude of soil losses through erosion under different covers of vegetation.

Discussions on the effect of shifting cultivation on the physical properties of soils frequently refer to the degradation of soil structure in particular; they are, however, not supported by enough experimental data.

Effects on the nutrient status of the soil

The results of fertilizer trials and soil analyses indicate in general that the decrease of soil fertility under the traditional system of cropping depends on the type and length of fallow. The following broad conclusions can be drawn from the results of various fertilizer trials carried out in the Region:

(a) Forest lands

Nitrogen response is 0 to 10 percent after a long fallow; on land more intensively cropped followed by a very short fallow the response is over 40 percent.

Phosphate response depends as much on the inherent properties of a soil as on its cropping history.

(b) Savanna lands

Nitrogen response is between 10 to 40 percent on most savanna soils, even on lands not intensively used.

Phosphate response is an inherent soil characteristic, it tends to increase with cropping and shortening of the fallow.

Responses to potash, lime, and micronutrients are always stated to be rare under traditional farming practices.

Very few studies have been made on the changes in the chemical composition of soils under shifting cultivation, but the following very broad conclusions can be drawn from the study of Nye & Greenland (1960).

Humus - It is generally found that humus in areas of soils cultivated for many years by shifting cultivation is still relatively high; a low level of humus is only found in areas subjected to repeated grass burning.

Total soil nitrogen - Lands cultivated after a long fallow are reported to have enough total nitrogen to sustain two good crops, while the amount in savanna land is often only just enough for one crop.

Phosphorus - In both forest and savanna areas, there is evidence of a pronounced fall in the amount of extractable phosphate following cultivation.

Exchangeable cations - There is no large decrease in the amount of exchangeable cations in the soil after a single cropping period of one to two years.

Leaching of soil nutrients

Data on the amount of soil nutrients lost through leaching under traditional cultivation are scarce. However, the results of lysimeter studies carried out in different parts of Africa under improved techniques of cultivation (Table 5) enable the following broad conclusions to be drawn:

(a) Most of the major nutrients are found in the drainage water in variable amounts depending upon the rainfall and inherent soil characteristics.

(b) Among the cations, the highest concentrations are those for calcium and magnesium; those for potassium are somewhat lower.

(c) The loss of phosphorus is generally very small.

The highest concentrations of anions are those of carbonates, nitrates and sulphates.

Table 5: Soil nutrient losses through leaching (after Charreau, 1972)

Location	Period of study	Cultivation	Rainfall (mm)	Drainage (mm)	Nutrient loss (kg/ha) N	P_2O_5	Sr	CaO	MgO	K_2O
Bambey 1/ (Senegal)	1954-66	(1)	660	128	13	0.2	5	43	22	9
		(2)		137	12	0.3	6	42	19	12
Bambey 2/ (Senegal)	1954-66	(1)	660	118	6	0.3	7	44	20	10
		(2)		120	5	0.3	6	43	11	12
Anguededou (Ivory Cost)	1966-69	Rubber plantation	1569	845	79	6.8	-	44	67	76
Azagnie (Ivory Coast)	1966-68	Banana plantation	1758	828	235	2.8	-	360	189	296

1/ Crop rotation without fertilizer 2/ Crop rotation with fertilizer

Effects of reduction of fallow period on soils

Demographic pressure on land, as well as the combined influence of cash cropping, market forces and agricultural extension services, leads to the reduction of the fallow period which is the key factor for crop productivity.

In many parts of the continent, large areas of land once yielding a sufficient food supply have become unproductive owing to shortening of the fallow period and continuous cropping; e.g. 'Terre de barre dégradée' in Togo and the Lekie area in Cameroon.

The steady decrease in fertility of a soil over a period of many years under continuous cropping with a short fallow in the Casamance area (southern Senegal) under a rainfall of 1 300 mm was studied by Siban (1972) and is illustrated in Table 6.

Table 6: Analyses of a surface soil (1-10cm) in Casamance in relation to cropping period after clearing the forest (after Suban, 1972)

Duration of cultivation after clearing the forest (years)	Organic matter C (%)	N (%)	C/N ratio	Available water (%)	Cation exchange (mequiv./100g soil) Ca	Mg	K	CEC	pH
0	16.5	0.90	18.3	4.1	5.0	1.7	0.07	7.8	6.3
3	13.8	0.79	17.5	4.7	2.7	1.2	0.07	5.2	6.0
12	11.6	0.68	17.0	3.7	2.2	1.0	0.04	3.7	5.9
46	6.8	0.43	15.8	2.8	1.4	0.5	0.04	3.8	6.0
90	5.0	0.35	14.3	3.3	1.0	0.5	0.04	2.5	5.9

The effects of long cultivation of soil by traditional methods but with radical fallow periods can be summarized as follows:

(1) The nutrients removed from the superficial soil layer by annual and perennial crops are returned to the soil only in amounts very much less than would have been restored after a long fallow. There is therefore a steady drain on soil fertility through successive cycles of cropping and short fallows heading to rapid depletion of N and P initially and subsequently K and micronutrients. The organic matter content of the surface soil decreases rapidly and with it the base exchange capacity.

(2) The forest regrowth is considerably impaired and leads to the establishment of man-made savanna.

(3) Because of the poor growth of crops and progressive degradation of the natural vegetation the soil becomes increasingly exposed to erosion and compaction.

COORDINATION OF KNOWLEDGE ON SOIL MANAGEMENT IN THE REGION

Long-term data on the changes occurring in soils under the traditional system of cultivation are scanty in the Region. Much is still to be learnt about the restoration of soil fertility under fallow, the loss of nutrients during cropping and the behaviour and response of soil in a given environment to various intensities of use and methods of management if costly errors in farm advisory work are to be avoided.

Trends for standardization of soil resources appraisal in West and East Africa for Agricultural development

Although very scattered in its distribution, a great deal of research and experimental work has been done in East and West Africa on soil management and fertilizer use under sustained crop production. However, the results of these studies are often contradictory and are seldom identifiable with specific soil and land characteristics. The net result is that the research results cannot be correlated with soil and land characteristics,nor can the experience gained in one area be applied to a similar ecological area within a country or a region. A major handicap in appraising soil resources for agricultural development is the lack of agreed methods of appraisal and evaluation in the Region which would permit a concerted approach and an exchange of information and experience. Such an approach is all the more important because urgent problems on soil and land use management await solution, and resources for research are insufficient to satisfy the pressing demands of various agricultural development programmes.

The distributions of the major kinds of soil in Africa are known and it is unlikely that any large areas of undescribed soil remain. There is, however, a very large task ahead, not only in matching the several classification systems that have been used, but also in relating the many experiments that have been done on the different aspects of soil management to the common denominator, i.e. the characteristics of soils and land. The frequent references to these problems made by African delegates at various International Conferences, have led FAO, in consultation with Member Countries in West and East Africa, to establish separate West and East African Soil Correlation Sub-Committees for Soil Evaluation and Management. The starting point for the work of these Committees was the FAO/Unesco Soil Maps of the World, and more particularly the maps of Africa, which for the first time have introduced an internationally agreed system of soil nomenclature and soil definitions.

At present, the FAO/Unesco World Soil Map legend lists 105 major soil units under which most of the main world soil formations can be grouped. There is scope to enlarge this legend for the introduction of new sub-divisions within each major soil unit,should greater detail be needed for the soil maps to be produced.

The way in which the West African Soil Correlation Sub-Committee will assist in the work of soil correlation and evaluation is summarized in their terms of reference which cover the following activities:

(a) Encourage collaboration between West African soil scientists and those of multinational and bilateral research organizations for the exchange of information and experience.

(b) Promote the mutual acceptance of standardized soil evaluation methods by using (i) FAO Guidelines for soil description and (ii) the legend of the FAO/Unesco soil map of the world as a system of reference, to correlate existing national soil classification groupings with the units of this legend; to translate this aim into positive action by compiling a soil map of West Africa at a scale of 1:1 000 000, using present knowledge of soils in the Region.

(c) Promote soil correlation at national and regional levels aiming at a better appraisal and evaluation of soil resources in West Africa.

(d) Review research work already completed or in progress on the evaluation, management and conservation of the soils in West Africa and to correlate the findings with the soil characteristics and environment so as to (i) facilitate exchange of information between similar environments and (ii) determine the extent of additional research to be undertaken in future in this respect.

(e) Determine and recommend a programme of applied research work or immediate use for agricultural development programmes at national and regional levels on specific problems of soil evaluation, management and conservation.

(f) Propose possible 'bench mark sites' so as to lay the basis for a regional cooperative research programme on soil management, with the view to obtaining maximum information on soil technology for improving agricultural production.

Need for a sound land evaluation for agricultural development

There are in the Region a wide range of land classifications derived from the interpretative groupings of various soil mapping units. Most of them are modified versions of the land capability classification developed by the Soil Conservation Service of the United States Department of Agriculture. The environment, soil resources and land uses in Africa are so widely different from those in the U.S.A. that the classification needs revision for use in the Region.

Under the leadership of FAO, an attempt has been made at international level to evolve a standardized approach to land evaluation which can serve the needs of developed as well as developing nations. A first approximation, prepared jointly by two technical working parties (in the form of a Background Document), one in the Netherlands and the other in FAO, Rome, assisted by specialists in land evaluation, was examined and discussed by scientists during the Expert Consultation on Land Evaluation for Rural Purposes held at Wageningen, Holland (October 1972). This approach to land evaluation was accepted in principle and the consultants have invited FAO to produce a publication on guidelines for land evaluation in order to standardize methods (within the framework of the background document discussed) to stimulate their application.

It may be necessary that scientists in Africa adopt progressively the common approach to land evaluation which would be of great assistance in the exchange and transfer of knowledge from one region to another.

In this approach the term 'land' has a broader aspect than 'soil'; it comprises all but the purely socio-economic and human attributes of the environement.

A summary of the groupings for land suitability classification for rural development as proposed at Wageningen is given below:

(a) Potential suitability with minor capital expenditure

Refers to the suitability of land, for a specified use, in its present condition (i.e. without major improvements); the suitability is assessed in terms of expected benefits in relation to recurrent and minor capital expenditure required.

(b) Potential suitability classification without amortization of major capital inputs

Refers to the suitability of land for a specified use after major improvements have been effected where necessary; the suitability is assessed in terms of expected benefits in relation to recurrent and minor capital expenditure, but excluding consideration of repayment costs on major capital expenditure.

(c) Potential suitability classification with amortization of major capital inputs

As for (b) above, but includes consideration of repayment costs on identified aspects of major capital expenditure.

Four categories of generalization are proposed in each suitability classification; in order of decreasing generalization, these categories are: Land Suitability Orders, Land Suitability Classes, Land Suitability Sub-Classes and Land Suitability Units.

Land Suitability Orders: Three orders of suitability are distinguished they are:

Order 1: Suitable lands: They are lands the use (sustained) of which, for the defined purpose in the defined manner, is expected to yield benefits that will justify required recurrent inputs without any risk or damage to land resources on the site or in adjacent areas.

Order 2: Conditionally suitable lands: These are lands having characteristics which, in general, render them unsuitable for (sustained) use in the defined manner but which, subject to appropriate management, could be used for the defined purpose and would be expected to yield benefits that justify recurrent inputs without any risk or damage to land resources on the site or in adjacent areas.

Order 3: Unsuitable lands: These are lands having characteristics which appear to preclude their (sustained) use for the defined purpose in the defined manner or which would create production, upkeep and/or conservation problems, requiring a level of recurrent inputs unacceptable at the time of the interpretation.

Land Suitability Classes within each order serve to distinguish the degrees of suitability for the particular land utilization type. The classes would be numbered consecutively in order of increasing limitations, that is to say decreasing suitability for the particular utilization type. The class definitions should reflect a corresponding degree of limitation to the defined use with a consequently reduced margin of benefits due to lower production and/or increasing inputs for production, upkeep and/or conservation. In a given study, the number of classes recognized in any order for each evaluation is left to the discretion of the local interpreter.

Land Suitability Sub-Classes are divisions within each class distinguished by the nature of the limitations (i.e. adverse condition of wetness, topography, etc.) which have determined their classification; the number of sub-classes should be kept to a minimum that will satisfactorily distinguish lands within a class likely to differ significantly in their management requirements, and/or potential for improvement, due to differing limitations; the grouping in sub-class is not only to provide information on the nature of the limitations.

Land Suitability Units would be the sub-divisions of each sub-class; they will refer to the production characteristics of the land or their management requirements. Their recognition permits detailed interpretation at the farm planning level.

Therefore, for arriving at a sound land evaluation for agricultural development needs, the following information is essential:

(1) Soil and land resources appraisal and mapping.

(2) Rating of the land qualities before and after improvement.

(3) The improvement capacities.

(4) The different land utilization types which could be accepted in the area.

CONCLUSIONS

The traditional farming system in the absence of heavy population pressure, is a technically sound method of soil management well adapted to the local ecological environment; it provides a way of making good use of the farmers' limited resources of labour, capital and market facilities; it maintains the soil fertility to a certain level, conserves the soil against erosion and controls the amount of soil borne pests and diseases and pernicious weeds.

The demographic pressure on land, socio-economic changes, introduction of industrial crops and new techniques of cultivation, have shortened considerably the fallow period and to some extent have modified the traditional practices of cultivation; inputs such as fertilizers, which are the key substitutes when the fallow period is reduced, are often within reach of the farmers although the latter soon recognize their usefulness; the consequences are steady decrease of soil fertility leading to poor crops and progressive deterioration of the environment; the fertility of the land thus degraded under years of continuous traditional cropping with short fallows, has proved to be very difficult to restore even with intensive use of fertilizers.

At present, most of the major soil formations in the Region have been identified, but much is still to be learnt about their use and management. There is a long task of soil correlation ahead, not only in matching the several classification systems presently in use but also in relating the many experiments carried out on different aspects of soil management and conservation to the land and soil characteristics.

In view of the limited number of soil and land specialists in the Region, it is important that studies on soil evaluation be standardized, directed towards the critical problems, and be widely publicized so as to avoid needless duplication. There is, therefore, a need for less piecemeal, more systematic, periodic assessment and organization of work for soil resources development at Regional level.

The formation of the West African Soil Correlation Sub-Committee represents a step towards achieving standardization of methodology, coordination of effort, and promotion of the development of soil studies through the concerted and cooperative effort of various institutions in the sub-region. Joint action on an agreed approach by national, bilateral (ORSTOM, IRAT and ODA), multilateral (IITA) and international (FAO) organizations should lead to coordination and economy of experiments and savings in time and money.

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SOIL EROSION AND SHIFTING AGRICULTURE

by

Rattan Lal*

INTRODUCTION

Subsistence farmers are exploiting 5 to 6 billion hectares of land in the tropics. In tropical Africa, shifting cultivation is practised on some 3,5 billion hectares and about 250 million people live on this hand-to-mouth agriculture. It is estimated that in Africa, between the Sahara and the Republic of South Africa, the amount of land cultivated in any one year is 4 to 5 percent of the potential cultivable land. Generally, 15 ha of land under shifting cultivation are required to support one person. At its face value, it is indeed an unproductive system of land use.

One of the most important features of shifting cultivation is heavy reliance on nature, rather than on means involving the use of modern technology and human efforts to restore soil productivity. This system of agriculture can, therefore, work only if the ratio of land to people is high.

One of the factors most limiting replacement of shifting cultivation with a more productive and permanently viable system of land use is soil erosion. Soil erosion implies not only the physical removal of surface soil, but also a deterioration in soil physical properties resulting in low productivity. The failure of agricultural workers, farmers and government officials alike, to comprehend the significance of soil erosion has brought about not only the widespread distribution of shallow, badly eroded and unproductive soils in the tropics, but also encroachment on the forest by savanna vegetation.

The object of this report is to discuss the factors responsible for widespread problems of soil erosion in the tropics, the magnitude of soil erosion under shifting cultivation and the use of cultural practices to control soil erosion under the proposed system of intensive cultivation. Most of the examples of research results are from experiments conducted at the International Institute of Tropical Agriculture (IITA) and thus may be assumed to be valid under similar conditions elsewhere in the tropics.

FACTORS AFFECTING SOIL EROSION IN THE TROPICS

Rainfall characteristics

The potential erosion hazard increases with increase in annual rainfall from 0 - 1000 mm. Rainfall higher than 1 000 mm generally leads to dense forest vegetation, which offers a protective cover to the soil. The removal of this vegetation cover, however, greatly increases the erosion hazard. Based on the rainfall and vegetation, the potential erosion hazard for West Africa is shown in Figure 1.

Soil erosion depends more on the intensity rather than on the total quantity of rainfall received. Rainstorms in the tropics are generally more intense than in temperate countries where the rate rarely exceeds 75 mm/h, while in the tropics storms exceeding 150 mm/h are common. The intensity records taken at IITA during 1972 indicate that of a total of 47 storms, nine had an intensity higher than 75 mm/h.

In addition to the intensity, rainfall distribution in the tropics is concentrated in one (unimodal), or two (bi-modal) seasons with distinct dry periods. The soil is desiccated during this dry period resulting in a poor vegetative cover. The serious erosion occurs, therefore, in the beginning of the rainy season owing to the poor protective cover on the soil. The experiments conducted at IITA show that 75 percent of the annual erosion can be caused by one or two isolated, high intensity storms.

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Structural stability

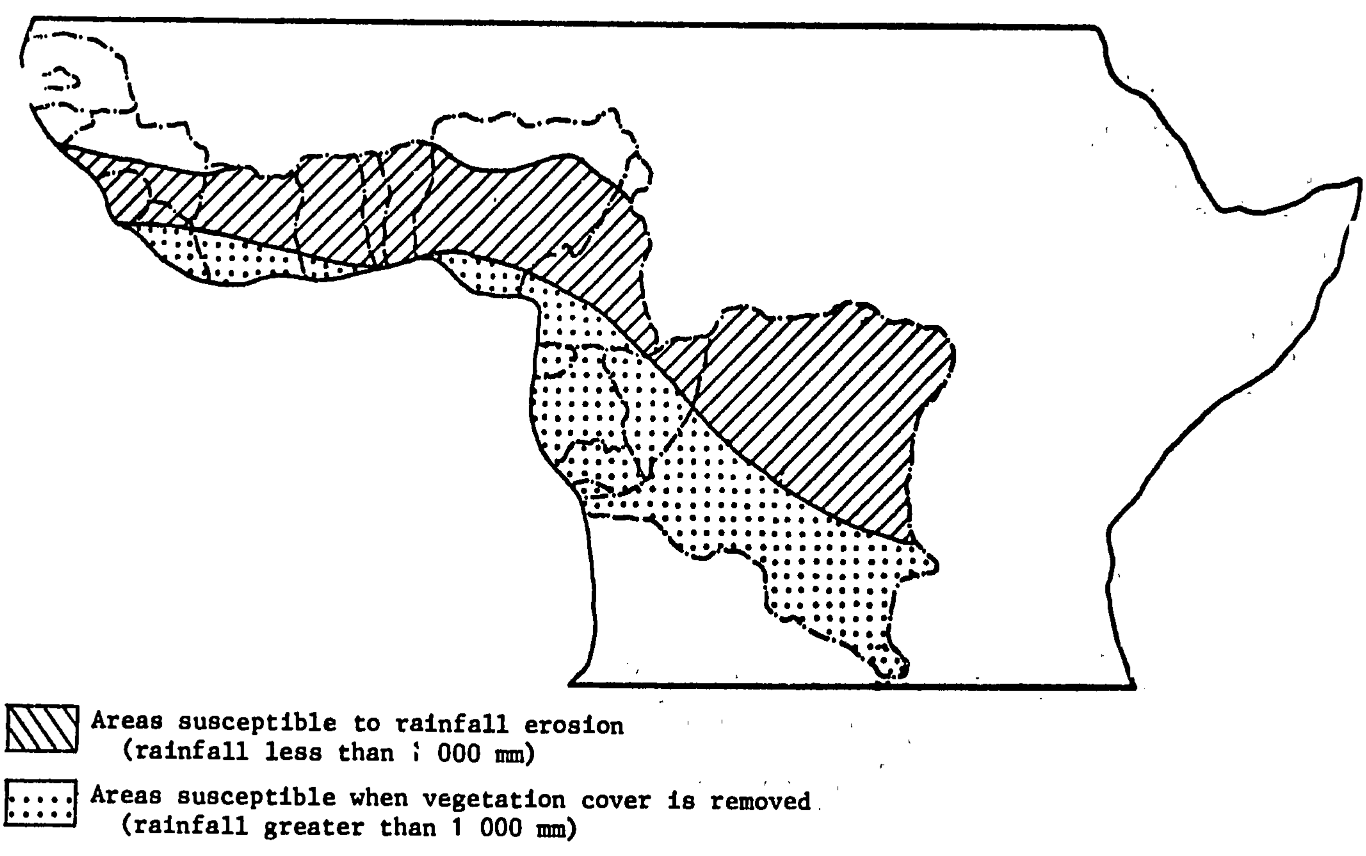
Structural stability governs the erodability of a soil. The detachment of the soil particles by raindrop impact is inversely related to the magnitude of cohesive forces binding the primary particles into natural soil ped. A raindrop impact technique developed at IITA, to evaluate the erodability index of the soil, has shown that some tropical soils require as little as $1,56 \times 10^3$ erg/g of soil ped to disrupt under the impact of falling raindrops. This low structural stability is responsible for the fragility and vulnerability of tropical soils to erosion.

Soil texture

One of the reasons for a low structural stability is the predominance of coarse fractions in most of the soils of the humid tropics of West Africa. Most of the soils are poorly graded, with a small amount of the organic and inorganic colloidal fraction to bind the primary particles together (Figure 2). The individual particles of coarse textured soils are easily detached by the beating action of rain and finer particles are washed off the field with the run-off water.

Though the potential infiltrability of tropical soils is usually high (Figure 3), structural instability results in the formation of a soil crust as a result of splash, thereby reducing the actual infiltration capacity of the soil. If the instantaneous precipitation rate (R_i) is higher than the infiltration capacity of the soil (I_c), the difference (R_i-I_c) results in surface run-off. The velocity, and thus the sediment carrying capacity of the run-off water, depends on R_i, I_c and the degree of soil slope.

Figure 1 Erosion hazard and rainfall distribution in West Africa



Areas susceptible to rainfall erosion (rainfall less than 1 000 mm)

Areas susceptible when vegetation cover is removed (rainfall greater than 1 000 mm)

SOIL EROSION UNDER SHIFTING AGRICULTURE

Though the literature is full of references concerning soil erosion under shifting cultivation, the reports of data from well planned field experiments are rather scanty. This is why, whether shifting agriculture is the cause or effect of soil erosion, is still a controversial issue. While one school of thought maintains that soils under shifting cultivation are

Figure 2. Particle size distribution curves of some Nigerian soils

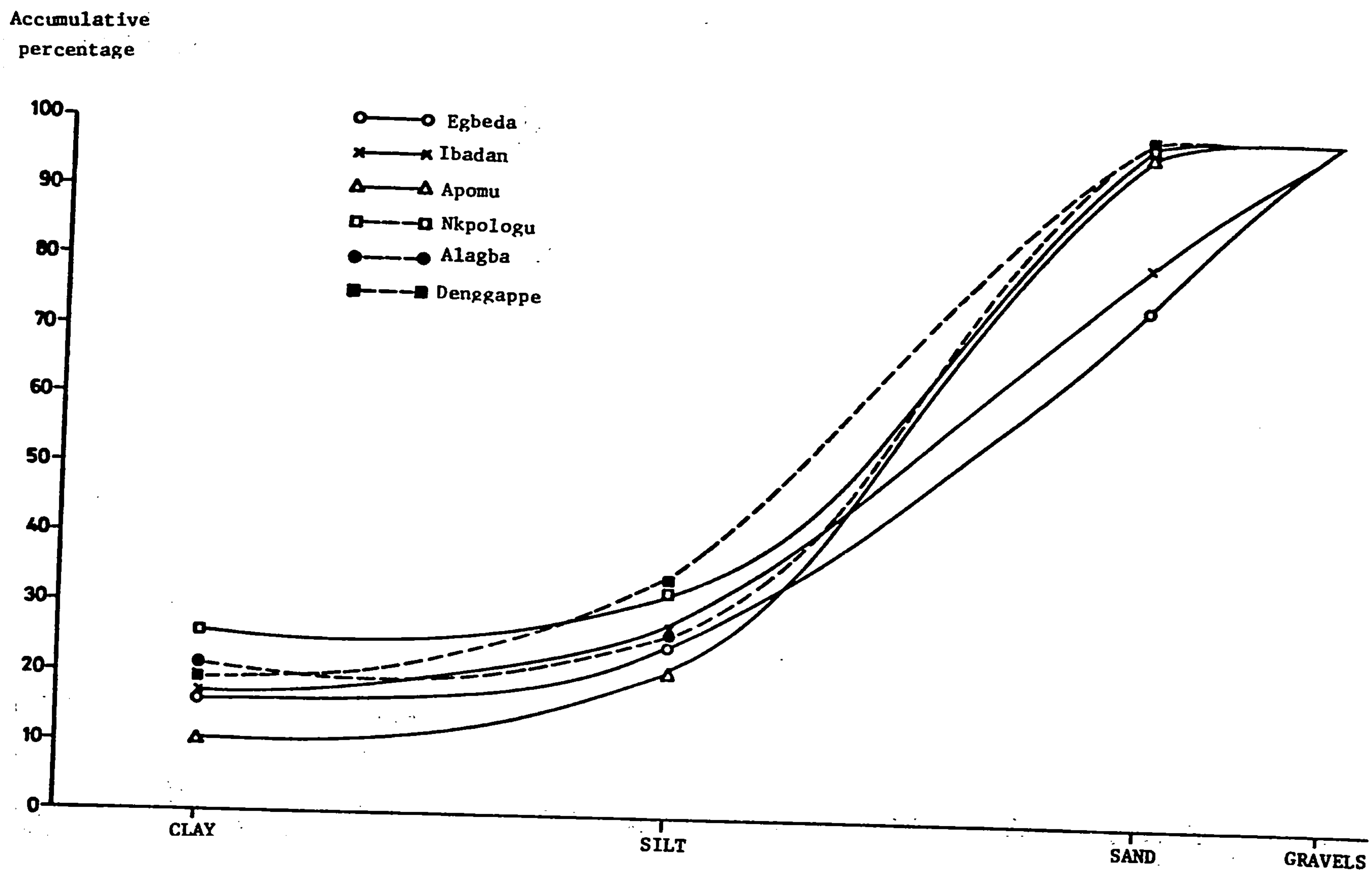
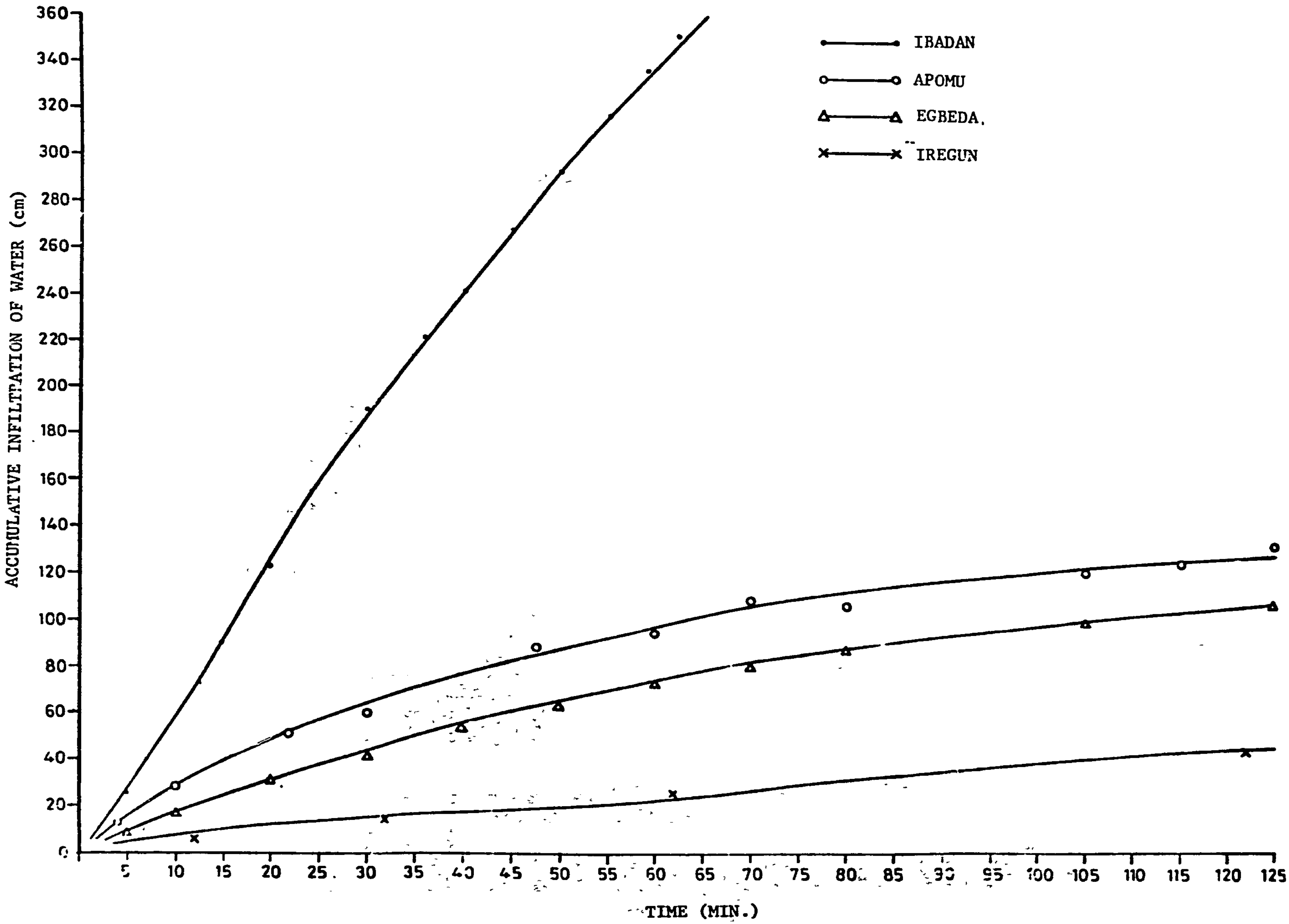


Figure 3. Accumulative infiltration for some Nigerian soils



continuously being degraded because of soil erosion (Cameroun 1965; Guilloteau, 1969; Mitchell, 1957; Ofomata, 1964; Palmer, 1958; Savonnet, 1958), the other believes that shifting cultivation is the only solution to the problem of soil erosion in the tropics (Anthony & Moormann, 1965; Drosdoff, 1967; Dubois & Lecompte, 1949; Kellog, 1963). This controversy exists because, in most of these reports, all the factors involved in soil erosion, e.g. bush fires, soil physical properties, slope, length of period under cultivation, etc. are not taken into consideration.

Soil erosion under shifting cultivation has been attributed by various workers to uncontrolled burning (Gardiner, 1958; Renier, 1957; Saboureau, 1949). The vegetation in Africa is continuously deteriorating,from forest⟶savanna with trees⟶treeless savanna⟶sterile steppes, as a result of excessive burning. The rapidity and degree of deterioration of soil under shifting cultivation also depends on inherent soil productivity and the duration of cropping (Allan, 1965; Fauck, 1953; Stephens, 1969; Udo, 1961). Allan (1965) reported from his investigations in East Africa that whereas it took 17 years of continuous cultivation of a soil with good physical characteristics and gentle slopes for maize yields to fall below the lower economic limit, it took only one to two years on soils of poor physical characteristics and steep slopes (Figure 4).

Kellman (1969) made a comprehensive investigation concerning the length of cropping under shifting cultivation on soil erosion in the Phippines (Tables 1 & 2).

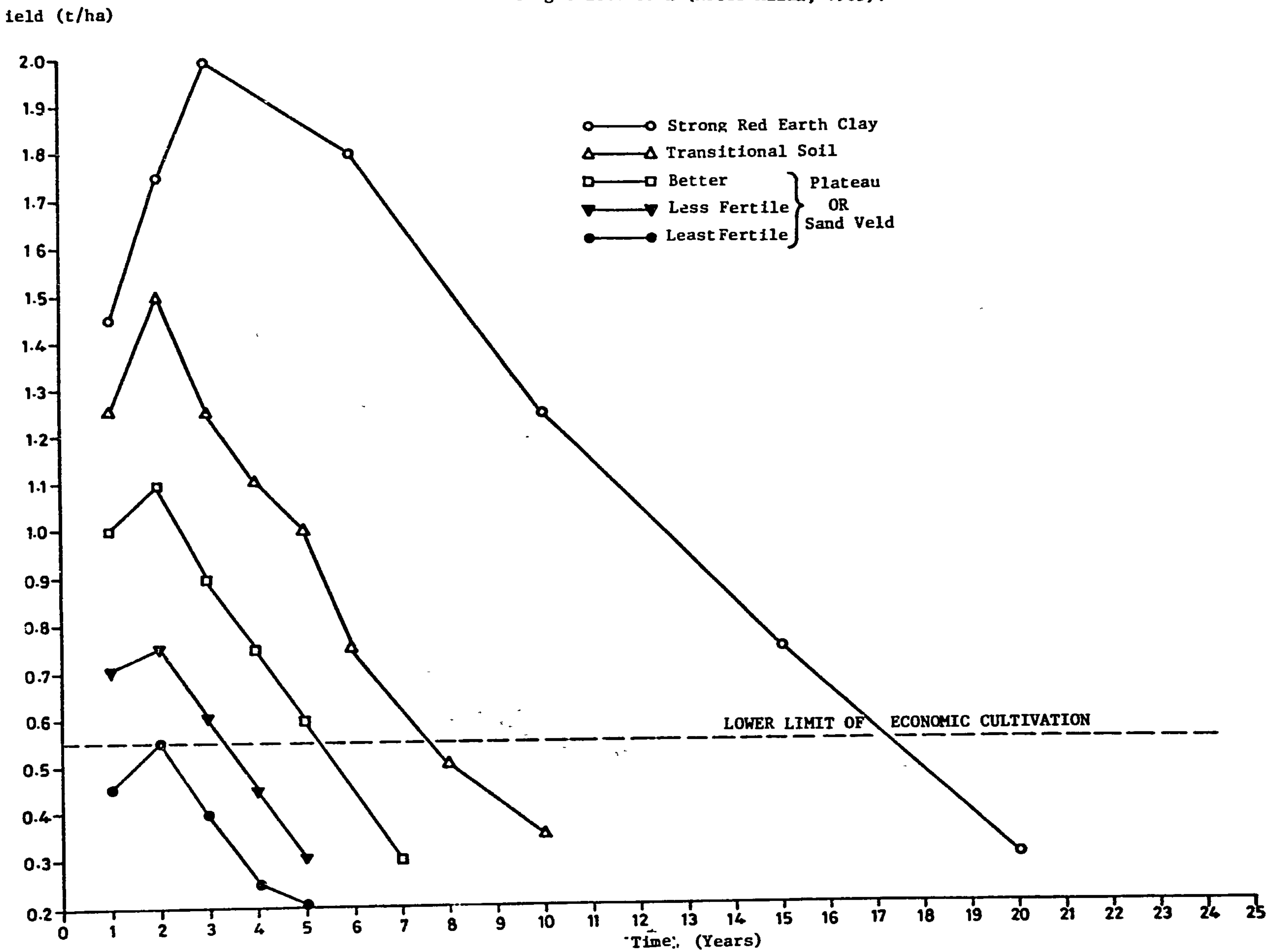
Table 1. Run-off from plots with variable covers (After Kellman, 1969)

Plot	Run-off (%)	
	Cropping period	Un-cropped period
Logged-over forest	-	-
New maize swidden	1.52	0.86
New rice swidden	1.08	0.42
2 year old maize swidden	1.78	0.69 (post cropping 4.08)
12 year old rice swidden	11.64	6.73 (post cropping 14.15)

Table 2. Sediment losses from Swidden plots during cropping period (After Kellman, 1969)

Plot	Sediment loss (g/day)	
	Cropping period	Post-harvesting period
New maize swidden	3.03	0.65
New rice swidden	1.45	0.37
2 year old maize swidden	12.05	9.81
12 year old rice swidden	119.31	6.32

Figure 4. Effect of soil characteristics on yield decline under shifting cultivation (After Allan, 1965).



The run-off losses under rice swidden increased from 1.08 percent in the first year after clearing to 11.64 percent in the 12th consecutive year of cultivation. The run-off losses were even more severe in the post cropping period. Similarly, the soil erosion losses increased from 1.45 g/day in the first year to 119.31 g/day in the 12th year. The estimated annual loss of nitrogen through erosion was 0.575 g/m^2 in the first year of maize and rice. The nitrogen losses increased to 2.205 g/m^2 in the second year under maize and to 23.55 g/m^2 in the 12th year under rice. The soil erosion under a short period of cultivation was not serious.

Soil erosion under shifting agriculture is not, therefore, a serious problem provided that the forest clearing is done on gentle slopes, that there is no extensive damage to forest litter by uncontrolled burning and that a short period of cropping is followed by a long forest fallow. Under the increasing pressure of population on land, however, these conditions may never be realized.

The amount of land under fallow is rapidly declining. A survey of land utilization in Nigeria shows only 44 and 29 percent of land under fallow in the forest and savanna zones respectively (Duckham & Masefield, 1971). To meet the increasing demand for food, the area of land under fallow will decrease under intensive cultivation. The question arises, therefore, whether it is possible to control soil erosion and still have an intensive and permanently viable method of land utilization in the tropics. To answer this question, one has to investigate the changes in soil physical properties as a result of land clearing.

CHANGES IN SOIL PHYSICAL PR PERTIES BY LAND CLEARING

Soil cleared from tropical forest undergoes marked changes in physical and chemical properties. Fauck (1953) reported from Casamance that there was a 30 percent decrease in organic matter content, 70 percent decrease in nitrogen and 60 percent decrease in colloidal humus content of the soil within two years after clearing. Similarly, Cunningham (1963) reported a decrease in soil organic matter, nitrogen and organic phosphorus as a result of changes in soil temperature on clearing. Some of the changes in soil physical properties as a result of clearing are given below.

Soil temperature

The soil thermal régime is significantly altered by land clearing (Figure 5). The diurnal fluctuations in soil temperature, as a result of clearing, can be of the magnitude of 20 to 30°C. Changes in thermal régime can strongly influence the soil flora and fauna. In conjunction with high soil temperature, reduction in organic matter content of the soil renders the soil structurally fragile and highly vulnerable to splash erosion.

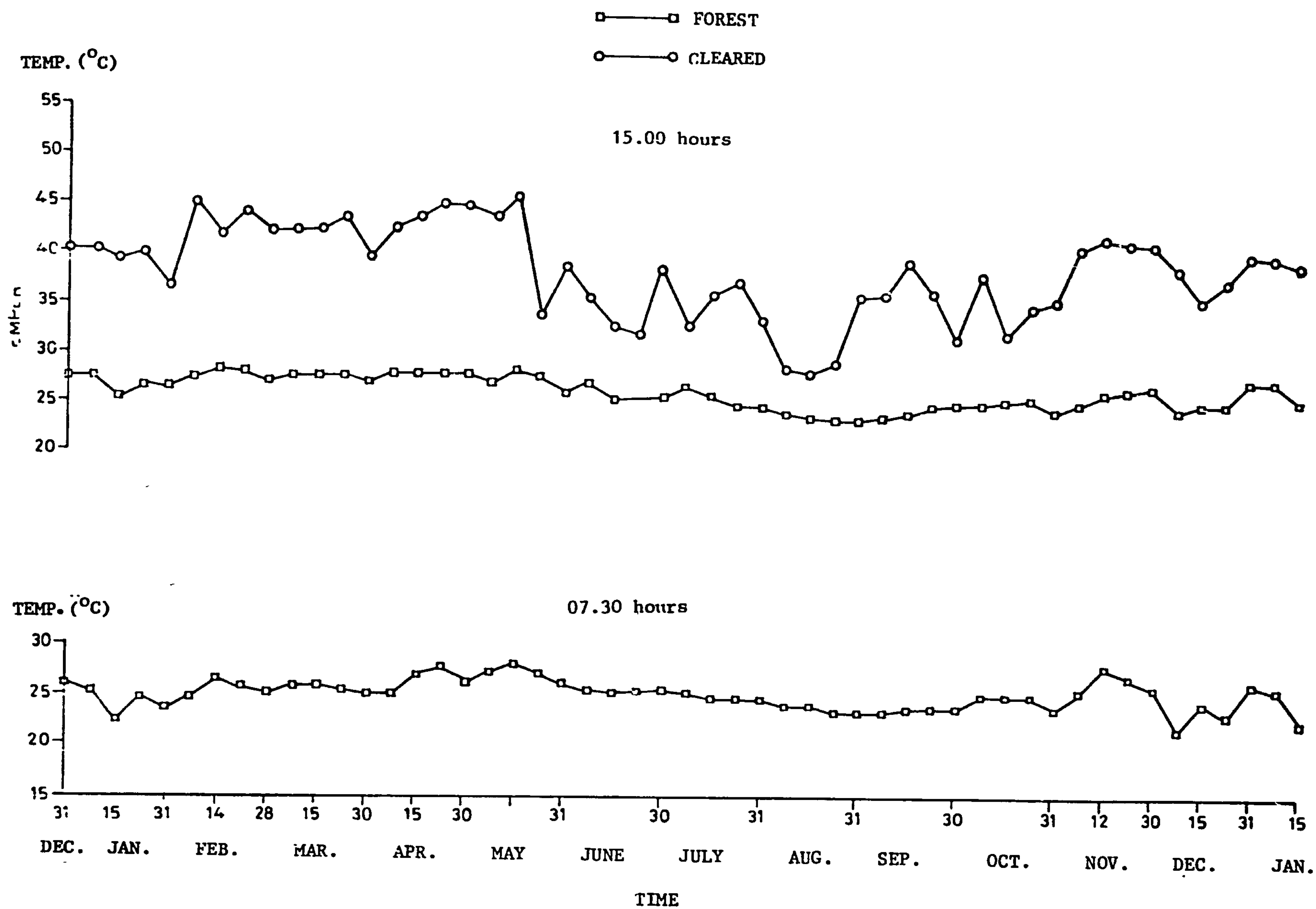
Soil moisture régime

High soil temperature, decrease in the organic matter content and removal of the fine fraction in the surface soil by erosion decreases the already small water holding capacity of the soil. Decrease in the soil biological activity and crust formation in the surface due to rapid desiccation results in the reduction of the macro-pores in the surface horizon. As a result, the water intake rate of the surface horizon is considerably decreased (Figure 6) with a resultant increase in run-off losses. Similar effects of a decrease in the infiltration rate were reported by Wilkinson (1970) for loess plain soils of northern Nigeria.

Soil compaction

Changes in the soil thermal and moisture régime can cause compacting of the surface and subsoil. These man-made soil pans, as noticed in the soils of some of the commercial farms in West Africa, present serious mechanical impedance to root penetration by arable crops. Some of the soils undergo irreversible hardening and thus are rendered permanently unfit for cultivation.

Figure 5. Effect of land clearing on soil thermal régime.



Soil erosion

Removal of the protective cover by land clearing exposes the structurally unstable tropical soils to the beating action of high-intensity tropical rainstorms. Erosion losses, immediately after land clearing, are generally alarming. This was demonstrated by the work of Chaminad (1970) in West Africa and that of Hudson (1971) in South Africa. Hudson (1957) reported that a rainfall of 135 mm in three hours resulted in a soil loss of 11.25 t/ha from soil under maize, whereas the soil loss from plots with a poor cover of vegetation amounted to as much as 100 t/ha. Roose (1967) reported from his work in Senegal that on plots cultivated for 10 years, the surface run-off accounted for 21 percent of the rain water and carried 9.26 t/ha of soil per year. On the average, a layer of soil 0.6 mm deep was removed annually.

Fournier (1967) reported that erosion losses even on a 1.5 percent slope were 1420,433 and 954 t/km^2 under sorghum, groundnuts and rice, respectively. Kowal (1972) reported, from his investigations in northern Nigeria, an average soil loss of 10 t/ha/year. Experiments conducted at IITA indicate a soil loss up to 120 t/ha in the first year after land clearing (Figure 7).

Erosion losses from unprotected cleared lands on most tropical soils are unmistakably large. Let us investigate the use of some soil management practices that may help prevent soil erosion and thus allow for a more intensive land use in the humid tropics.

SOIL MANAGEMENT PRACTICES TO CONTROL EROSION

There are two ways of developing an intensive system of land use in the humid tropics. The first is to improve upon the existing system of shifting cultivation. This will involve a thorough understanding of the system from all aspects. The second is to use a system that has been developed and proven successful somewhere else, e.g. in the temperate countries. The results of experiments with the latter approach at INEAC in Zaire (formerly Belgian Congo) and elsewhere in the tropics have not been encouraging.

Soil water in the tropics, one of the most limiting factors in developing intensive method of land use, can be managed either by minimizing the surface run-off losses by soil management practices or by safely leading the run-off water off the cultivated land by using engineering techniques. In this section the emphasis will be on the cultural practices based on the principle of maintaining the soils at a high infiltration rate and reducing the run-off losses. The maintenance of soil infiltrability in favour of the safe discharge of run-off water under West African conditions seems to be the most desirable.

Corridor system of cultivation

After the unseccussful attempts to modernize agriculture in Zaire by transplanting temperate zone soil management practices to the tropics, the scientists at INEAC improved upon the shifting cultivation technique by successfully developing a corridor system of land rotation (Jurion & Henry, 1969). Each corridor was 100 m wide and was aligned in an east west direction to ensure maximum light for the strip under cultivation. The length of the corridor depended on the nature of the soil and the numbers of farmers involved. The cultivation cycle which followed involved three years of cropping followed by 12 years of forest fallow. This practice, although an improvement over the peasant technique and successful in reducing run-off losses and soil erosion, is still a wasteful use of land and certainly not an intensive method of land utilization.

Attempts were made later to replace the long forest fallow with more effective grasses and legumes and reduce soil erosion as well as the length of fallow period. Dubois & Lecompte (1949) found from their investigations at INEAC that fallows planted with legumes were a failure, but 3-year fallows planted with Pennisetum purpureum were satisfactory. Roche & Joliet (1953) however, observed in Madagascar that a year of leguminous culture during an annual crop rotation system can help the soil to recuperate and to minimize soil erosion. Kannegieter (1969) reported from Ghana the value of Pueraria fallow in reducing erosion losses. Any practice which can reduce the length of fallow period should, in general, be more effective.

Figure 6. Effect of land clearing on soil infiltration rate

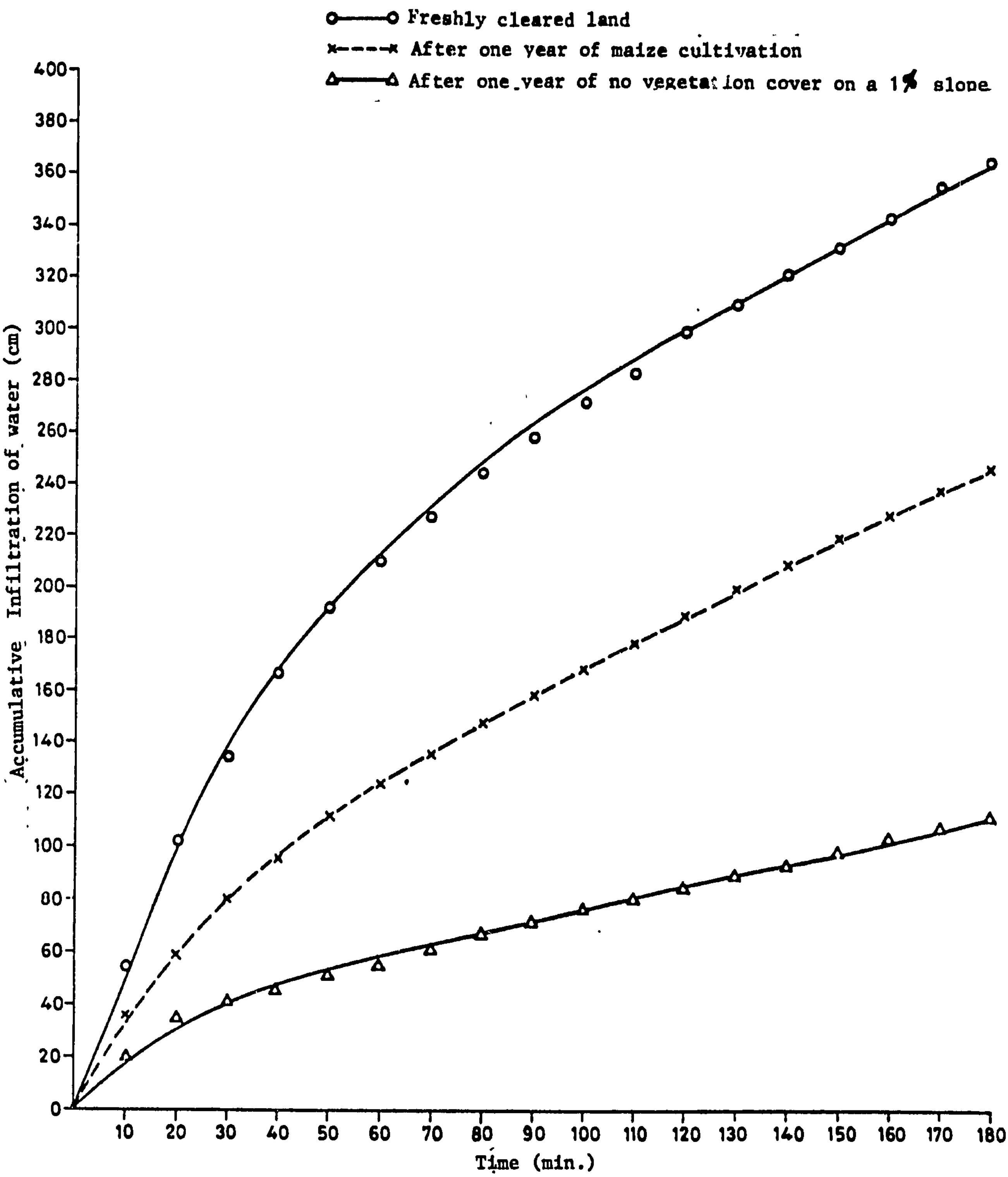


Figure 7. Soil erosion losses from unprotected plots of different slopes.

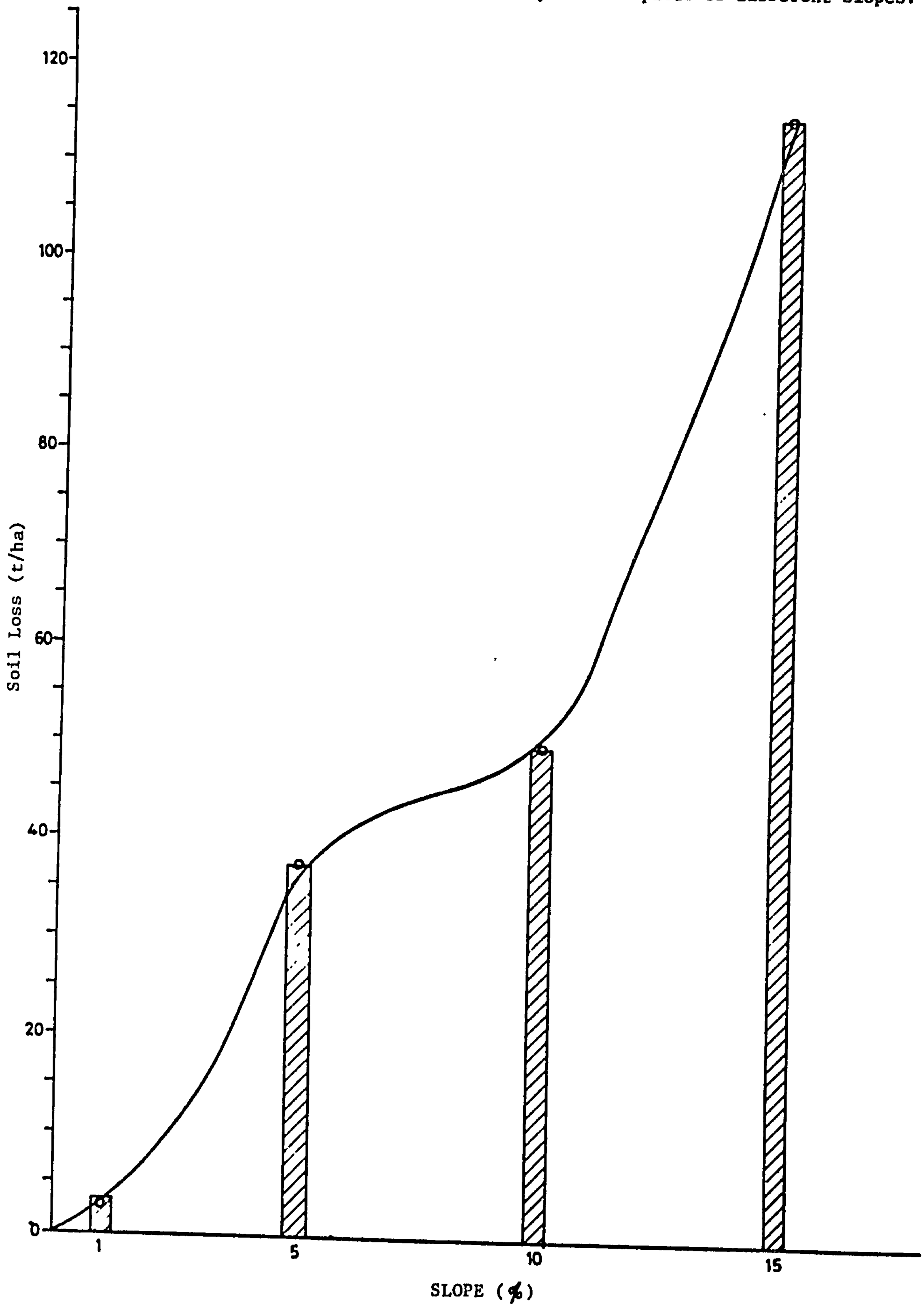
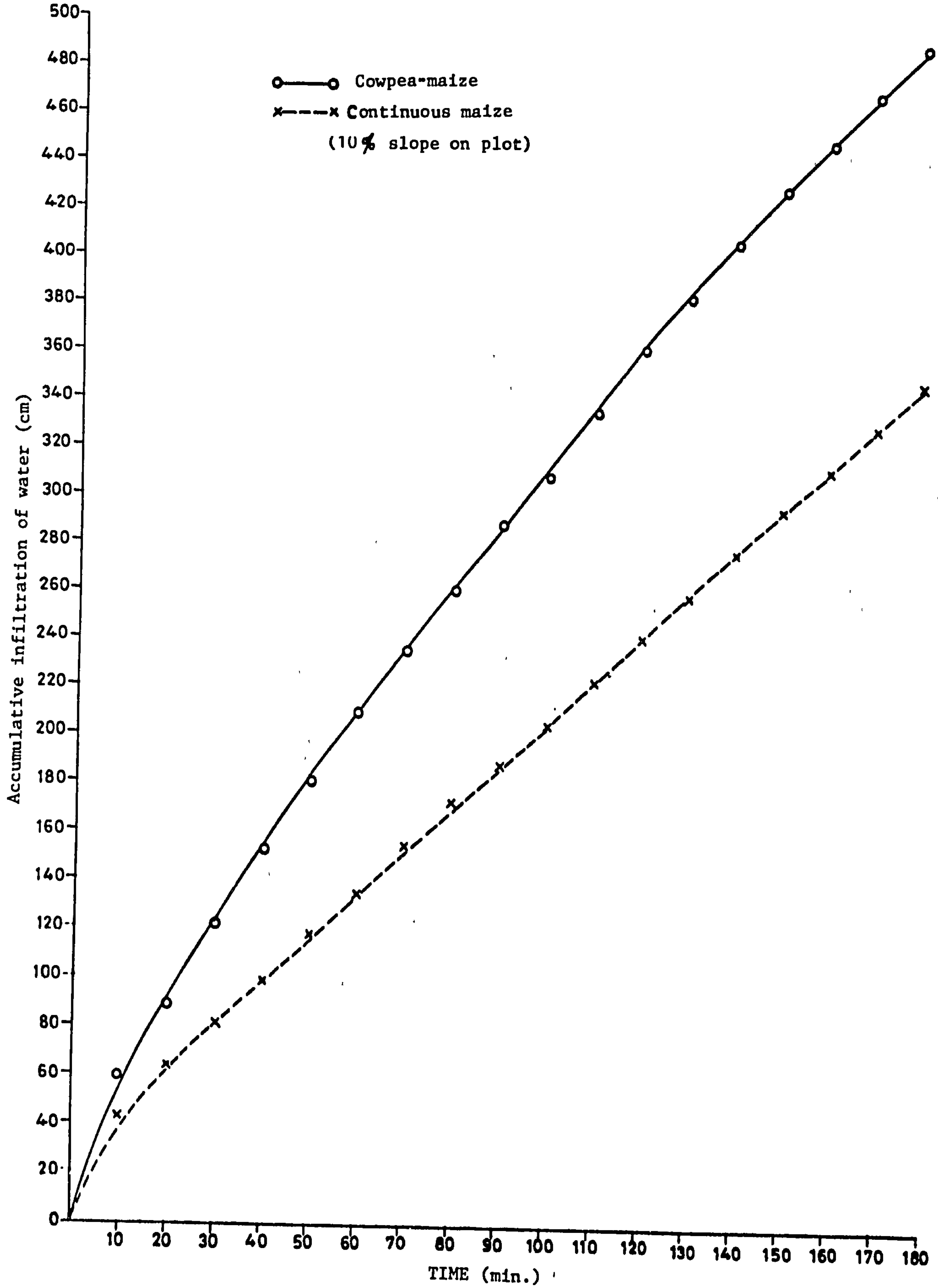


Figure 8. Effect of vegetation cover on infiltration rate



Strip cropping

By this technique a long slope can be divided into a series of nearly horizontal planes with crop grown on some of them to intercept run-off water. In West Africa, this technique has met only with a limited success in reducing run-off and erosion losses. This is because the run-off losses are primarily controlled by the least intercepting row crop which nullifies the effect of intercepting strip. Three times out of five, the run-off losses at Sefa, Senegal, for alternating strips of rice and groundnuts or rice and sorghum, were within the range of the figures measured for the individual crop (Fournier, 1967). On the other hand, the effect of alternating a cultivated strip with an undrained strip under forest fallow were encouraging (Jurion & Henry, 1969). This system of strip cultivation was particularly successful on soils with slopes of less than 15 percent. In addition, contour hedges, at a vertical interval of 1.5 m with a ridge 0.5 m high and 1.5 m broad and planted with *Flemingia rhodocarpa*, proved effective in controlling run-off losses. Similarly, Goujon *et al*. (1968) recommended from experiments in Madagascar that contour benches be planted with grasses to reduce run-off losses. Roose & Bertrand (1971) found that permanent grass strips 2 to 4 m wide were effective in controlling run-off losses. The results of experiments on strip cropping conducted at IITA using alternate strips of maize and cowpeas were not in favour of strip cropping (Table 3).

Mixed cropping and cover crops

Mixed cropping, with the so-called soil depleting and soil protecting crops, has been tried by many researchers. Mixed cropping of maize with mascatle peas proved effective in controlling soil erosion in Madagascar (Fournier, 1967). The effect of intercropping of maize with *Stylosanthes gracilis* was investigated at IITA. *S. gracilis*, though it provided excellent protection against run-off and erosion (Table 4), is an aggressively growing crop and competes strongly with maize for the small quantity of available water in the root zone. The effect of mixed cropping with low growing cover crops, e.g. *Stylosanthes humilis* or *Arachis prostrata*, on erosion control should be investigated.

The results of the experiments conducted at IITA on the effect of different vegetation covers on run-off losses were in the order of cowpea $<$ rice $<$ maize (Table 5). The run-off losses under cowpea occurred only during the initial stages of crop growth. The effect of different vegetation covers on soil infiltrability one year after clearing is shown in Figure 8. The soil structure under leguminous crops is generally good. The usefulness of continuous cover crops such a kudzu, lespedeza, and some grasses, though well known, is economically questionable.

Contour ridging

Contour ridges, particularly tied ridges, have been successfully used as an erosion control measure in many places in West Africa, e.g. Adiopodoume, Bouake, Sefa, Madagascar (Fournier, 1967). In Madagascar, contour trenches were found to be successful in reducing run-off losses even on a soil of 25 percent slope. In South Africa, Hudson (1957) found that contour ridging was a successful practice in reducing run-off losses. He also indicated that the angle of discharge from ridges into drains should be in the direction of water flow. Lawes (1962) found that ridging improved water storage and decreases run-off losses. Kowal (1972) reported from his studies at Samaru, northern Nigeria, that ridges constructed parallel to the slope, on a soil with a one percent gradient, caused more run-off and erosion that a flat piece of land. The concentration of sediments and solutes per unit volume of run-off water was about twice as large as that from flat cultivated land. Ridges also lost about twice as much cohesive material as a flat seed bed. Experiments conducted at IITA

Table 3. Effect of strip cropping with maize and cowpea on run-off losses (September - December, 1970) (Total rainfall = 295 mm)

Slope (%)	Run-off losses (mm)	
	Maize (monoculture)	Maize-cowpea (strip cropping)
1	19	21
5	119	121
10	125	65
15	52	73

Table 4. Effect of mixed cropping of maize with Stylosanthes gracilis on run-off losses following rainfall of 47 mm on 1 June 1972

Slope (%)	Run-off (mm)	
	Maize monoculture	Maize + *S. gracilis* (mixed cropping)
1	112	0.1
5	167	0.9
10	141	1.0
15	151	1.0

Table 5. Effect of crop management on run-off losses (May - August, 1970) (Total rainfall = 417 mm)

Slope (%)	Run-off (mm)		
	Maize	Rice	Cowpea
1	17	13	10
5	121	56	38
10	63	81	51
15	37	59	24

show that though tied contour ridges were successful in reducing run-off and soil losses during rainfall of normal intensity (Table 6), ridges made from coarse textured soils are generally unstable under high intensity storms. Under these conditions, if a ridge gives way and releases the retained water to the one below, more severe gullying of soil can occur, Furthermore, ridges suffer from high soil temperature, low available water and contribute to severe lodging of some crops.

Stubble mulching

The concept of soil depleting and soil conserving crops needs to be revised in the light of present day technology. The soil under improperly managed leguminous crops may deteriorate faster that that under properly managed cereals. Considering the channel system concept of water infiltration, the highest infiltration can be maintained by keeping a continuous stubble cover on the ground. Mulches, in the form of any good cover, not only intercept the rainfall and minimize its direct impact but also decrease the run-off velocity.

Mulches are also known to improve the soil structure by stimulating biological activity. Dubois & Lecompte (1949) reported the beneficial effects of mulches in rejuvenating Zaire (Belgian Congo) soils. Similar effects of mulches in reducing soil and run-off losses were reported from South Africa by Hudson (1957). Table 7 shows the results of experiments at INEAC (Jurion & Henry, 1969) on the effect of mulches with and without fertilizer. Cotton yields decreased from 1032 kg/ha in 1947/48 to 200 kg/ha in 1953/54 on unmulched plots without fertilizer as compared to 1127 kg/ha in 1947/48 to 1117 kg/ha in 1953/54 on mulched plots without fertilizer. Experiments conducted in Northern Nigeria by Lawes (1962) indicated that the relative efficiency of water infiltration under mulched plots was 89 to 98 percent as compared to that of 52 percent for bare, hoed soil. The effect on run-off losses of mulching maize grown on various slopes, as investigated at IITA, showed that mulching was as good as forest fallow in controlling soil erosion and run-off losses (Table 8). Mulching also maintained the structure of the surface soil and preserved its infiltrability. The beneficial effect of mulching on the infiltration rate of soil under maize is shown in Figure 9. Mulching, therefore is a promising method of managing soil and water resources in the tropics under intensive cultivation.

Table 6. Effect of contour ridges on run-off losses (May - August, 1970) (Total rainfall = 417 mm)

Slope (%)	Run-off losses (mm) under maize	
	Flat seed bed	Contour ridges
1	17	11
5	121	31
10	63	35
.15	37	13

Table 7. Effect of mulching on soil protection as measured by the cotton yield (kg/ha) over a 10 year perdio. (After Jurion & Henry, 1969)

Year	Unmulched		Mulched	
	Without Fertilizer	With Fertilizer	Without Fertilizer	With Fertilizer
1947-48	1032	-	1127	-
1953-54	200	440	1117	1434
1955-56	186	797	1464	1977
1956-57	124	706	986	1344

Table 8. Effect of mulching on run-off losses under maize (Sept. - Dec., 1970) compared with forest fallow. (Total rainfall = 295 mm)

Slope (%)	Run-off losses (mm)		
	Unmulched maize	Mulched maize	Forest fallow
1	19	6	5
5	119	23	4
10	125	17	5
15	52	5	6

Reduced tillage

Indiscreet tillage and exposing a structurally unstable soil to high intensity tropical storms can result in crust formation at the soil surface and cause a reduction in infiltration rate, thus increasing run-off and erosion losses. Since the role of tillage as a weed control

Figure 9. Effect of mulching on infiltration rate

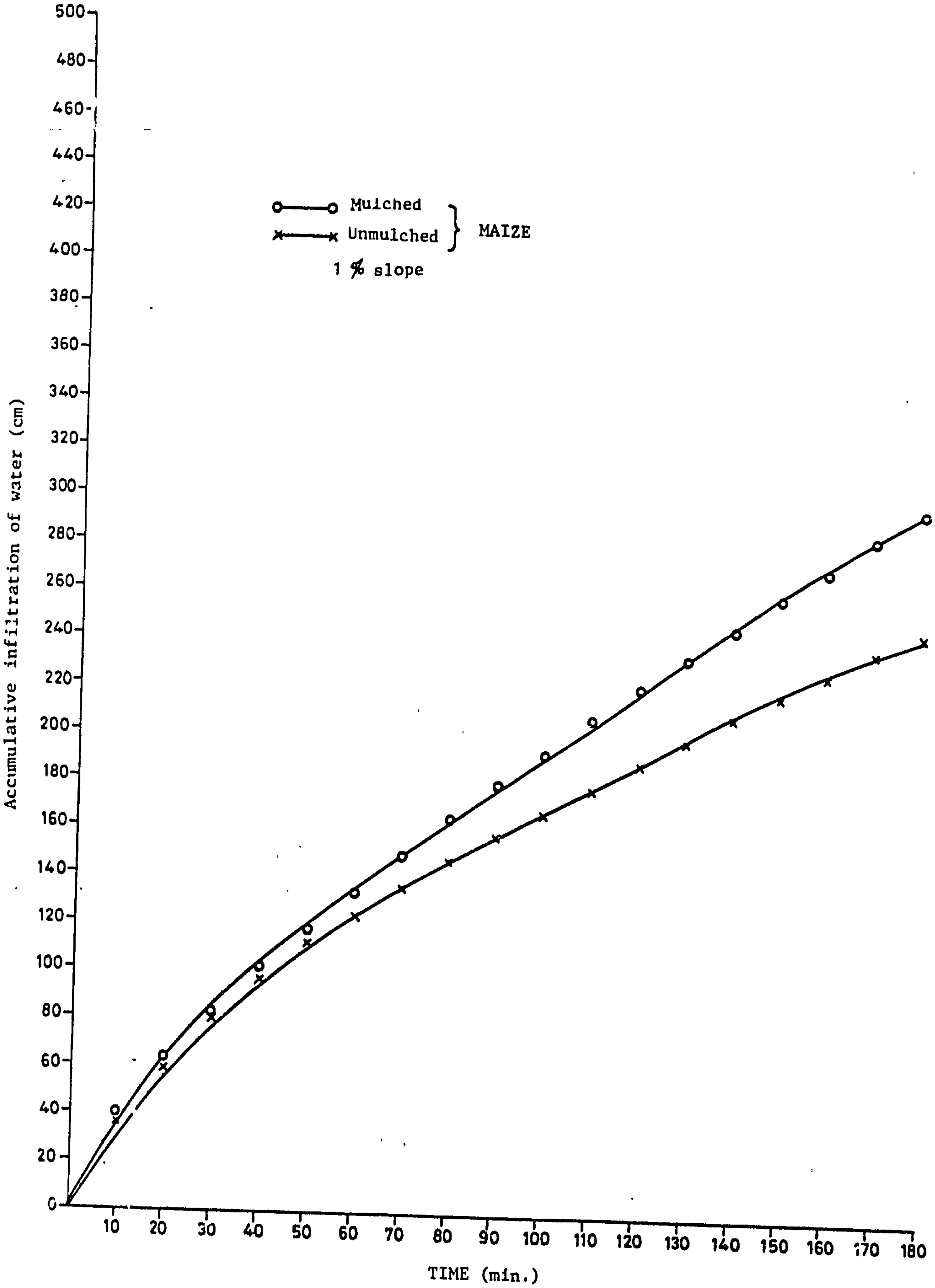


Figure 10. Effect of zero tillage (with crop residues) on run-off and soil loss.

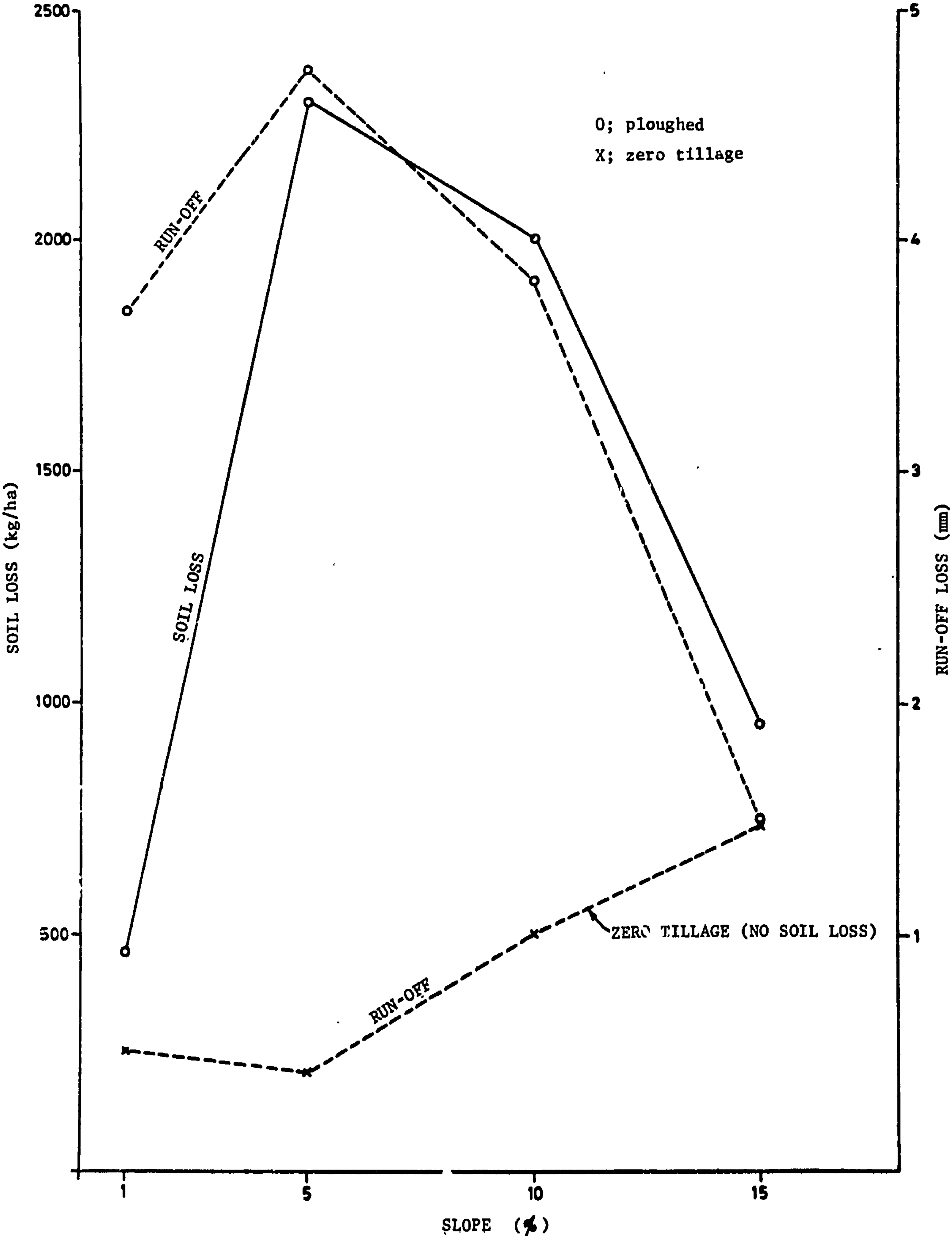


Figure 11. Effect of zero tillage (with crop residues) on infiltration rate

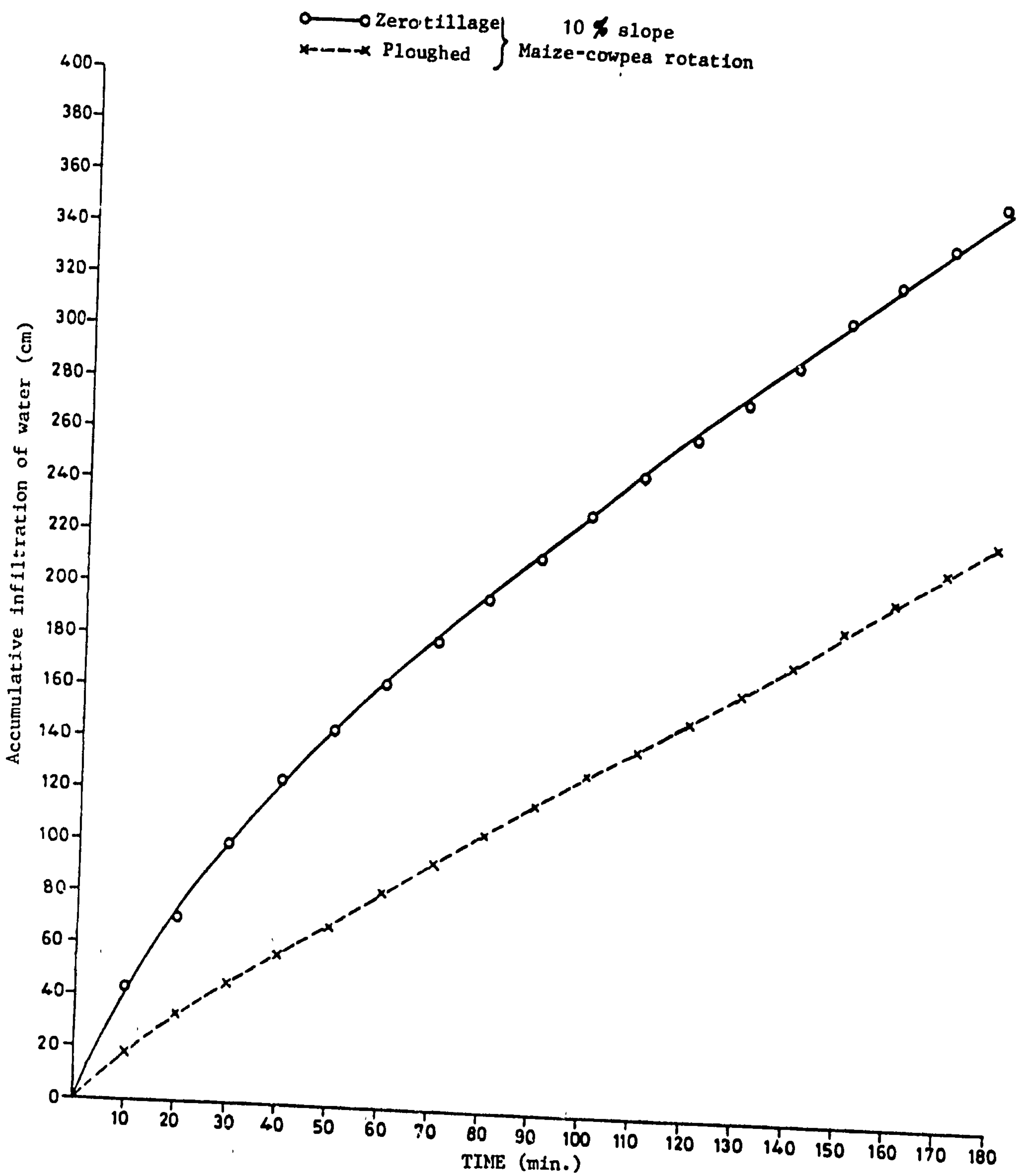
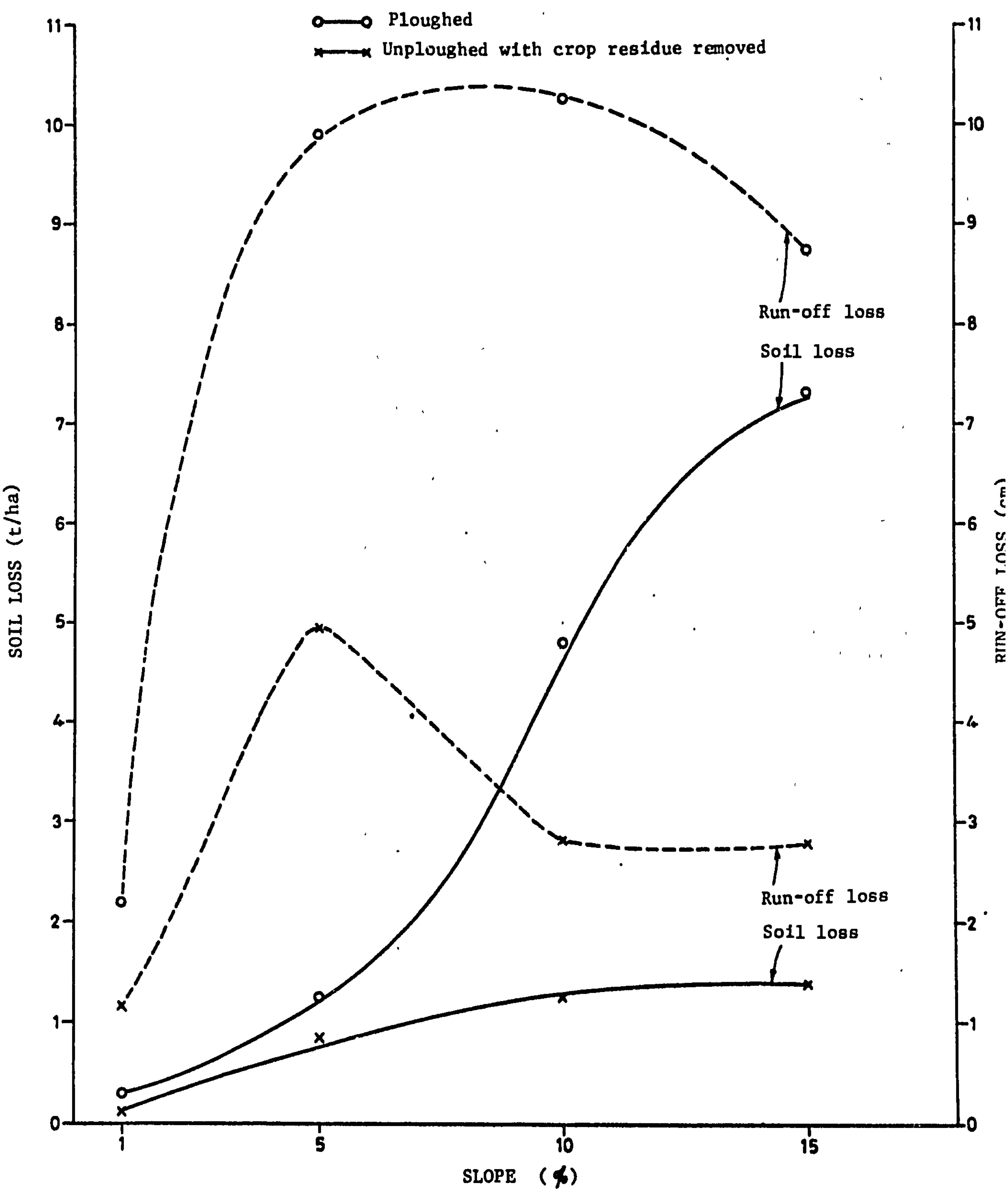


Figure 12. Effect of zero tillage (without crop residues) on run-off and soil loss



measure has diminished since the introduction of herbicides at an economic cost, conventional operations such as ploughing require critical appraisal as regards their effect on soil and water management in the tropics. A system of minimum tillage, also termed 'mulch tillage' or 'trashy farming', ensures enough vegetation cover on the ground with the least amount of soil disturbance.

Though the practice of minimum tillage has been widely practised in most of the temperate countries, it is still in the experimental stages in the tropics, where it is needed rather urgently. Muller & Bilderling (1953) reported, from their work on the corridor system of land utilization in Zaire (Belgian Congo) that yields of upland rice were higher on unploughed than on ploughed land. Ospina Vasquez (1957) found from investigations in Columbia that use of the plough often resulted in heavy erosion. Tillage treatments causing fragmentation of the soil and those that left little crop residue on the soil surface were conductive to relatively heavy losses by soil erosion.

Kannegieter (1969) reported from his work in the forest zone of Ghana that wherever large scale tractor ploughing was introduced,soil erosion and moisture conservation were in dire need of attention. A short term Pueraria fallow combined with zero tillage gave effective soil protection against erosion and improved soil moisture storage for the following maize crop.

The results of the experiments conducted at IITA with zero tillage have been extremely encouraging. Continuously maintained vegetative cover of partially decomposed crop residues not only improved the available water storage capacity of the surface soil but also greatly decreased run-off and soil losses compared with ploughing (Figure 10). The infiltration rate of the soil under zero tillage remained high (Figure 11). Furthermore, owing to the favourable soil temperature and moisture conditions under zero tillage, biological activity, particularly that of earthworms, was extremely high.

Minimum tillage following the removal of crop residues on the soil surface, by burning or grazing, can result in severe losses from soil erosion. The maintenance of an adequate vegetative cover, in the form of either the crop residues or a cover crop such as Pueraria or Stylosanthes, is crucial to control erosion. Some experiments have shown that run-off and erosion losses were higher under zero tillage than under ploughing, but in each case the crop residues had been removed from the zero tilled plots (Charreau, 1969; Charreau & Fauck,1970; Charreau & Nicou, 1971). The experiments conducted with minimum tillage at IITA in the first season after clearing and without crop residues also produced higher run-off and erosion losses (Figure 12).

Ill-considered transfer of technology from temperate countries to the tropics can lead to disastrous consequences. The use of the zero tillage technique, with enough crop residues on the soil surface, offers an attractive compromise between shifting cultivation and permanent land use on the pattern of temperate countries. Minimum tillage techniques, with the use of commercial fertilizer, would help to maintain a high production capacity of the soil and also permit more intensive use of the land. This clearly implies that in most tropical soils the application of the methods of temperate zone large scale mechanized agriculture should be reconsidered in the light of a scientific technology of land use, based on soil conditions in the tropics.

RESEARCH NEEDS

With regard to soil erosion, there are three areas of research that need the prior attention of soil scientists and agronomists:

Erosivity index of the major ecological zones of West Africa

Erosion in the humid tropics is the result of interaction between rainfall intensity and the erodability of the soil. The rainfall erosivity index can be calculated using either the El index developed by Wischmeier et al. (1958) or the KE$>$1 index proposed by Hudson (1971). In order to successfully predict the potential erosion hazard in West Africa, there is an urgent need to calculate the erosivity index for each country. This index can easily be obtained from the records of recording raingauges installed in the major ecological zones in each country. The total annual erovisity can then be drawn on a map as iso-erodent lines. The erosion hazard for any individual locality can also be calculated for different times during the year. This information will be helpful in planning farming operations and in following suitable conservation practices.

Erodability index of West African soils

The structural stability index of the major soil groups of West Africa should be investigated. The structural stability index has been obtained in the past by wet (with and without treating with benzene) and dry sieving techniques. The stability index, however, particularly from the point of view of soil erosion, must be based on the kinetic energy required to disperse or slake a natural ped. A test on this principle of raindrop impact is being developed at IITA from which the soils can be classified in different categories of susceptibility to erosion.

Tillage practices

Research concerning tillage practices under tropical conditions must be given high priority. There is an urgent need to investigate the suitability of minimum tillage to different soils and ecological conditions. The economics of the use of herbicides to control weeds and the effect of various tillage techniques on the physical and biological properties of soils should also be investigated.

CONCLUSIONS

Soil erosion under shifting cultivation is not a serious problem provided that clearing is restricted to gentle slopes, that there is a minimum of burning of the forest litter and that a short period of cultivation is followed by a long period of forest fallow. This system of land use can be satisfactory if the ratio of land to people is high. With increasing pressure of population, it is necessary to increase the length of the period under cultivation and to decrease the length of the fallow period. This action results in serious losses of soil by erosion leading to lower yields and thus lower standards od living.

Indiscriminate transfer of the technology of cultivating soils of temperate countries to the tropics has resulted in the grave acceleration of soil erosion and conversion of forest into grass-savanna and sterile steppes. Mechanized farming, of the type developed and practised in temperate countries, is ill-suited to the highly erodable soils of the tropics.

Soil and water management practices in the tropics must be based on the principle of maintaining the maximum infiltrability of the soil and thus minimizing the run-off losses.

Tillage practices, based on the principles of least disturbance of the ground and maintenance of the maximum amount of vegetative cover, should be developed for the tropics. The practice of minimum tillage, with ample crop residues, left on the soil surface, has great potential to replace the unproductive system of shifting cultivation with a permanently viable and more productive system of land use.

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SOCIO-ECONOMIC ASPECTS OF SHIFTING CULTIVATION

by
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INTRODUCTION

There is no doubt that the Seminar will produce as many definitions of shifting cultivation as there are participants, but for the purpose of this paper, the definition adopted has been that of Allan's (1965) which covers a broad spectrum of cultivation systems. At one extreme, one finds agriculture practised on 'permanent soils' which, when climatic conditions are favourable, can sustain yields - and stable habitations - by the practice of some system ''that is 'shifting' to a degree not much greater than the 'shift' from arable to ley on a well managed English farm''. At the other extreme of the spectrum ''there are weak, leached soils of the ancient plateaux which ... may require twenty five years or even more to regain a brief fertility after two or three years of cultivation''.

Allan clarified his definitions thus: ''It has therefore been proposed to substitute 'land rotation cultivation' for 'shifting cultivation' as a general term, and to restrict the use of the latter for the more extreme variants in which the whole community of cultivators moves''. These definitions are followed hereunder, but whilst Allan distinguished between obligatory and voluntary systems, it would be advantageous to divide the former into two further categories, planned and unplanned. The former covers those systems in which the cultivators show a definite intention to return, as for example by only lopping the branches of the trees, so that they coppice and thus restore fertility as speedily as circumstances allow. The unplanned systems are seen where the land is exhausted beyond the point of no return; there are unfortunately too many examples of this to be found throughout Africa, the existence of which brought into disrepute amongst alien administrators and agriculturists the whole concept of 'shifting cultivation', which we now appreciate was an indigenous system of maintaining fertility in frequently unfavourable conditions.

In considering the economic and social aspects, my personal experience of East, Central and Southern Africa will be drawn upon in the hope that the examples quoted will stimulate discussion concerning conditions found in other parts of Africa. Further, my professional interest will lead to an inevitable emphasis on the social aspects, though it is hoped that the economic aspects will not be neglected.

TANZANIA

In Tanzania the two extremes of Allan's spectrum are typified at one end of the scale by a 'land rotation system' associated with irrigation as practised by the Sonjo, and several at the other end of the scale involving 'bush fallowing' on a rotation of several years.

The Sonjo system, first observed by myself in 1934, was recorded by Griffiths (1940) and fully described by Gray (1963). The social aspect of the system is all important for its maintenance, as the 'land rotation', practised on the rain-plus-supplementary-irrigation fields involves a shift from one block to the other every alternate year. Control of water rests in a hereditary council of 'village elders', whose authority depends on the recognition of their position by all members of the village. If this authority is undermined by 'modern' influences (the concept of individual freedom, so ofter misinterpreted both by religious and political leaders as the abandonment of all forms of indigenous social discipline) the system will speedily break down. If, for instance, one individual defies authority, fails to follow the agreed rotation, and insists on taking water to his plot on the resting land, so much water will be absorbed in transit down an otherwise unused channel that there will be insufficient water to serve everyone.

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The other extreme in Tanzania is found in the bush fallow system practised in the coastal belt (Hartnell & Fuggles-Couchman, 1937) and on the Makonde plateau in the extreme south of the country (Gillman, 1945). Both these accounts by professional and experienced agronomists stress how the system yields crops in unfavourable soil conditions, leads to a restoration of fertility in a minimum period and, importantly, halts erosion and conserves the top soil. No up-to-date report on the present situation in these areas is at hand, but it is suspected that the provision of social services, water supplies, dispensaries etc. may lead to an anchoring of the population, the abandonment of a planned rotation, the exhaustion of the soil to the point of no return, and finally to an unplanned move from the exhausted area. The investment of capital, either individual or group, into an area without ensuring that agriculture is practised on a sustained yield basis, can entail considerable loss, as will be seen later in this paper.

Another social factor - or perhaps one should say a demographic factor arising from social causes - which is affecting the system of land rotation, is the rapid increase of population so widespread throughout Africa. This is not the place to expand on this subject, as the socio-political factors causing this situation are well known: the suppression of the slave trade, the cessation of inter-tribal warfare and raiding, the introduction of modern medical services (particularly such simple prophylactic measures as smallpox vaccination), better nutrition and child care; all these have led to an increase in the birth rate and of infant survival, and to a reduction of the death rate. In many cases the increase in population, which cannot be drawn off into the industrial sector, means there is just not room for people to practise the old rotation system. The period of rest is reduced and land is cultivated before fertility is fully restored. This means earlier abandonment and a premature move to even less recovered land. And so the vicious downward spiral accelerates till the whole area reaches the point of no return and the community becomes a burden on the State, either requiring constant famine relief or assistance in removal to an as yet unruined area, if such is available.

ZAMBIA

In Zambia this danger is particularly significant where the citemene system is widely practised. This system as originally practised is well covered in the literature. Audrey Richards (1939), in her classic work on the Bemba people of Northern Zambia, described the system whereby trees of the Brachystegia woodlands have their branches lopped and dragged from the periphery of the cleared area to the centre where they are systematically spread and then burnt to form a seed bed in which the crop, usually finger millet, is planted. In view of the heat of the fire, no weed growth occurs, so that the axe completely supersedes the hoe.

Further to the south, but still in Zambia, the 'small circle' citimene system is practised by the Lala, the Bisa and other groups. The main difference between this and the Bemba system is that the trees, instead of having their branches lopped, are cut at breast height. The branches are stacked and later, when dry, burnt, thus forming the seed bed for the finger millet crop. A significant feature about all these systems is the fact that the branches are not stacked around the tree stumps, a practice favoured by those further south to bring newly cleared land under the plough. This preservation of the stumps indicates an intention to return and an appreciation of the fact that the quicker the regeneration of the woodland, the speedier the restoration of fertility.

The long period of rotation, 17 years or more, and the amount of ground required to allow for such rotation, necessitated the shifting of the villages from time to time. This was of no social disadvantage, as the village group moved as a whole and so retained its cohesion. Nor was it of economic significance, as the huts were constructed entirely of local material, bush poles and mud for walls, with grass thatched roofs. But the advent of permanent buildings, either private dwellings or public utilities - post offices, dispensaries, court houses and the like - has anchored down the shifting cultivator, with a result that the surrounding area may be cropped to a state of exhaustion beyond redemption. Just how this situation will ultimately be met in the citimene areas remains to be seen. Further south in Botswana, as described below, settlement became permanent much earlier in a country unable to maintain sustained yields under prevailing agricultural practice, with far-reaching social and economic effects.

A large scale development scheme was launched some time ago by the Colonial Government in the Bemba country of the then Northern Rhodesia. One of the objectives was to bring about settled agriculture in place of the shifting citimene system. Much mcney was spent with little positive result. As Dumont (1969) wrote in relation to similar attempts to establish permanent villages in Tanzania ... ''this villagization is also a bringing together of agricultural cultivation, thus fixed permanently in one and the same place. This implies the passage from shifting cultivation to continuous cultivation (my italics). This continuous cultivation of the soil is already used in the fertile and over-populated regions, as on the slopes of Meru and Kilimanjaro. But it is not used at all in many regions of Tanzania, from Lake Victoria to the Southern Highlands, by way of the Coastal zone and the Central region. Even cultivation as intensive as that of tobacco requires a long fallow period; whence the (sensible) adoption of the custom of living well dispersed (author's italics) on the tobacco settlements of the Tabora region, in spite of social difficulties that this causes''.

Dumont thus identified the conflict between the social and economic advantages of close settlement, and the agronomic difficulties which arise unless the change is accomplished by a radical revolution in techniques permitting production on a sustained yield basis in areas of poor soil fertility and erratic rainfall. In referring to the fertile and over-populated regions of Meru and Kilimanjaro, he did not stress the striking contrast between these regions and the infertile steppe and bushlands which comprise the vast majority of Tanzania's land surface. Such facts are well known to those to whom the report was addressed, namely the Government of Tanzania. Whether it is sufficiently appreciated by those who are currently endeavouring to establish Ujamaa villages in the arid and infertile areas of central Tanzania is a matter for concern, for to date no one has succeeded, even after the expenditure of millions of pounds on the disastrous Groundnut Scheme, in establishing static agricultural production on a basis of sustained yield in such conditions. Unless a miracle of technological advance occurs combined with a second sociological miracle which ensures the speedy adoption of the new technology, one fears that a situation will ensue similar to that which has existed in Botswana for about a century, generating the acute social and economic problems described hereunder.

BOTSWANA

The Tswana people are a section of the Sotho speaking people of southern Africa, divided about equally between the Republic of South Africa and Botswana. It is the latter with whom the author is acquainted, but the indigenous settlement pattern is similar throughout. The Tswana live in villages of considerable siz., from 10 000 to 25 000 or more inhabitants and thus present an example unique in the East and the South of the agro-urbanization so characteristic of West Africa. That this is no new feature can be deduced from the existence of the ruins of large stone-built villages scattered throughout the area of Tswana occupation, past and present. It is interesting, but not really relevant to this paper, to speculate, as Wilson (1971) has done, why this settlement pattern was adopted by some of the people of the area, Sotho speakers, and not by others, the Nguni speakers. The fact is that they do, and have done so for several centuries as the evidence of abandoned ruined villages, as well as oral and recorded history, reveals. This evidence also shows that the villages moved from time to time, and whilst the immediate occasion for the move may have been pressure from a hostile tribe, or an internal schism, the root cause was probably the decreasing fertility of the cultivated area round the village; certainly result of the move was to give such land a rest and to open up new areas of cultivation.

Although in some cases such a move meant the abandonment of considerable capital, in the form of stone-built huts, in general the move could be undertaken without undue loss as the houses were constructed of local material, and in any case required reconstruction every few years. But about 100 years ago such movement largely ceased. One of the reasons was that the Tswana had been forced by Boer and Matabele pressure as far West into unfavourable country as they could possibly go, right to the edge of the great Kalahari Desert. Another reason is that missionaries and traders, and indeed the Chiefs themselves, had built permanent structures in the form of churches, stores and private dwellings of permanent materials, which they were unvilling to abandon.

Inevitably the fertility of the land round the villages deteriorated until it was no longer profitable to cutivate it. To compensate for decreased yields, larger areas were cultivated, with the aid of ox-drawn plou_hs. This process was set back by the 1890 rinderpest epidemic, but was resumed as the herds recovered their strength. But this was not sufficient to provide food for an expanding population, so the solution was adopted of taking up land at a distance from the village so great that it was impossible to walk home every evening. 'Lands' houses were in consequence established, where those members of the family concerned with cultivation lived for the whole of the cropping season. A case study of this system was presented in a recent publication arising from a UNDP/FAO Project in Botswana (Fosbrooke et al., 1972).

This then is an example of unplanned obligatory shifting cultivation which has had most serious social and economic repercussions which are complicated by two further socio-economic factors. First, owing to the inability of the land to maintain the population at a reasonable standard of living, and owing to the lack of sufficient local wage employment, a large proportion of the adult sales seek work on the mines and farms of South Africa. This leads to the continued absence of 30 to 40 percent of the adult males. Second, the agricultural situation is complicated by the fact that a considerable proportion of the population possess cattle, a small number owing very large herds. Owing to the absence of sufficient grazing in the vicinity of the village, a large proportion of the livestock is placed in cattle posts and herded by the boys.

Thus, the problem of the split household arising from the system of 'lands' cultivation is aggravated by the fact that a large proportion of the adult males are absent in South Africa, and a considerable number of the boys live on distant cattle posts. The nature of the difficulties is obvious: on the social side there are difficulties of providing social services to the dwellers on the lands; the school children therefore must stay in the villages looked after by a grandmother or an elder sister, neither of whom is likely to have modern knowledge of nutrition. Also, the lack of parental affection and discipline can sow the seeds of future delinquency.

On the economic side, there is the burden of building and maintaining two homesteads. Then there is the expense to the community in providing water supplies to the 'lands' houses, or to the individual of transporting water to the lands. Another expense arises in transporting the harvested crop from the lands to the village. The agro-economic situation is complicated by the fact that much of the decision making is in the hands of the women, i.e. when to plough, how to hire help, what to sell and what to store.

CONCLUSIONS

Consideration of the above material and an analysis of the papers and country reports presented to the Seminar show that there is a necessity to move from shifting to static agriculture. Accepting that, the issue then arises, should the move by evolution or by revolution?

The dangers of change by revolution are both agronomic and socio/political. In the case of the Ujamaa villages of Tanzania there is a danger that a large concentration of population in a relatively unfavourable environment, e.g. the Ugogo country in the central (Dodoma) region of Tanzania, will exhaust the fertility of the peripheral area, so that eventually the village will either have to shift, or adopt the system which has been forced on the people of Botswana, of building houses on distant 'lands' where they take up residence in the cultivation period.

On the social side, there is a grave danger when people are pressed to take a certain course of action, of the project collapsing when the pressure is withdrawn. This frequently happened under the Colonial régime, when contour ridges were constructed by 'tribal turnout'; on the advent of independence these were, in many cases, no longer maintained. It has occurred again, even more recently, when Ujamaa villages have been established by over-enthusiastic political leaders before the participants have been convinced of the advantages of the scheme, and the project has rapidly collapsed.

Thus it is apparent that change must be based on the will of the people, and that this will can only be generated if the people have the knowledge and the urge. The knowledge is frequently lacking, as the process of decreasing fertility is often so insidious as to pass unnoticed unless it is pointed out. Also, having established the fact in peoples' minds that there is a problem, they must be shown that there is a solution to the problem, and that it one that they themselves can achieve by their own efforts.

President Nyerere (1968) had this say on the subject:

''My own experience suggests that our people in the rural areas are prepared to work together for their common good: in many places they have never stopped this traditional custom, and would take quite easily to an extension of it. The problem is not the principle: the problem is that of getting people to adopt practices which retain the central idea at the same time as they allow for development and growth. For we are not just trying to go back into the traditional past: we are tryi , to retain the traditional values of human equality and dignity while taking advantage of modern knowledge about the advantages of scale and improved tools. But inevitably this requires some adaptation in traditional social organizations: ... now we have to do it deliberately, and to do it in such a manner that modern knowledge can be utilized for the common good''.

This then is the case for evolution, the retention of the sound principles of the indigenous system, whilst adapting their application to modern conditions.

One basic principle in the indigenous system was the maintenance of discipline in the relationship between man and land. In one of the cases quoted above, the Sonjo were only able to maintain themselves in the same place for hundreds of years by everyone following the instructions of the elders in the matter of land rotation and water usage. These people, still using the digging stick, are considered 'primitive' or 'undeveloped' by the modern politician, who regards the man with the tractor as the ideal. But who is really more developed, the community which can maintain itself in perpetuity in a harsh environment, or the man who, by undisciplined land use, ruins his farm - a national asset - in less time than he wears out his tractor?

In the light of existing circumstances, i.e. where demographic pressure and other social and economic factors have brought about a situation where the move from shifting to static agriculture is necessary, the first essential is the creation of awareness that such change is necessary. This awareness must not only be engendered in the minds of the farmers themselves, but equally in the minds of the political leaders who guide their destiny. Thus extension must be undertaken on the broadest possible basis. But sound extension involves both research and evaluation. To take one example in the research side, little is known about the reaction of illiterates to visual presentation. Yet there is a widely held belief that the poster, the film and the slide can profitably be used in this field. The necessity for research is emphasized by the rate of illiteracy in most African countries and by the fact that universal primary education is still a distant goal in many places. This means that many of the decision makers on the farms will still be illiterate well into the twenty first century. Is this not a good reason for researching into and then teaching the extension staff the best methods of approaching illiterates ?

Concerning evaluation, this, when undertaken at all, is frequently confined to the study of the relationship between the extension worker and the farmer. It is suggested that a broader approach is required and that constant study should be devoted to the whole process of converting the findings of the research worker in the laboratory and on the experimental plot to action by the farmer in the field. This is not only a matter of communication, i.e. of ensuring that the knowledge flows freely and speedily through the various channels involved. Frequently economic and polititcal decisions are involved; for example, should a subsidy be granted to ensure the adoption of a particularly effective new seed strain, or fertilizer, or weed killer? The side-effects of such action, frequently unanticipated, must be studied by the sociologist and the economist. An obvious example is the case of subsidies for improved bulls, where the farmer pays half the cost and the state the balance. In this, and in many similar cases, only the man with capital can take advantage of the scheme, whilst the small man, whose standard of farming is in more urgent need of advancement, cannot benefit owing to lack of funds.

These then are some examples illustrating the two basic sociological requirements in the move from shifting to static agriculture, aided by constant and broad based research and evaluation.

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ECONOMIC ASPECTS OF SHIFTING CULTIVATION

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INTRODUCTION

Shifting cultivation is a form of land use and a system of agricultural production under which selected and cleared plots of forest or bush are cultivated for a few years after which they are allowed to rest for a lengthy period and revert to some modified form of their original cover.

The term is of a generic nature. It covers a wide variety of practices of land use, crops grown and methods of cultivation, adapted to varying natural conditions, with differing degrees of involvement in the market economy. There are few statements one can make about it that have general application. Shifting cultivation is practised over large areas in Africa, Southeast Asia, the Indian sub-continent and Latin America and provides a livelihood for large populations. Its importance varies from country to country and from region to region. In Southeast Asia alone some 12 million families clear annually 17 million hectares and crop 21 million hectares (Spencer, 1966); the world totals may be several times as large.

There are reasons to believe that shifting cultivation is an early and general system of crop growing, which has its origin perhaps in the Neolithic period, and has provided subsistence for a large number of people for a long time. By using skilful methods in site selection and cultivation it assured an ecological balance in a tropical environment, whether in the forests or in the savannas. It has been a sound system of land use and a lasting system of agriculture until changing conditions, often beyond the control of the shifting cultivators, made the system outdated.

The size alone of the populations dependent for their livelihood on shifting cultivation would warrant a study of their economic performance, especially as the harmful consequences of shifting cultivation under present-day conditions have attracted more attention than the beneficial aspects. Because of changed conditions, the system has outlived its usefulness and it will have to be replaced gradually by some other system. It is, therefore, even more necessary to arrive at a reasonably accurate assessment of the returns obtained from shifting cultivation so that measures to promote a change-over may bring about a change for the better.

Shifting cultivation and shifting cultivators have been studied and described by a number of agronomists, social anthropologists and geographers, sometimes in considerable detail. But the emphasis has almost always been on the agronomic or social aspects. Yet, shifting cultivation is an activity directed to an economic end, no matter how different the farms of shifting cultivators may be from the conventional types to be found in developing, not to mention the developed, countries. Even small farms of the conventional type, producing largely for subsistence, were for long alien ground for agricultural economists who were hard put to analyse their operations and fit them into their conceptual framework. On the homesteads of shifting cultivators, agricultural economists have found themselves lost, while agronomists, anthropologists and sociologists collected much interesting information; unfortunately, they seldom presented a coherent and clear picture of the operation nor of the economics of the homesteads of shifting cultivators.

The purpose of this paper is to discuss the economic aspects of shifting cultivation. It will illustrate the economic approach by discussing several cases from different settings rather than analyse one particular case in depth and will end with a discussion of the defects of the case studies analysed. Hopefully the comments will be of help when making further investigations into shifting cultivation.

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THE HOMESTEADS OF SHIFTING CULTIVATORS

However different their homesteads may be from the conventional homesteads in developing or developed countries, shifting cultivators do operate farms, and in operating them encounter problems similar to those encountered by the ordinary run of farmers. They must select the location of the farm, invest effort and a little capital in establishing the farm, i.e. clearing an area of forest or bush and they must decide what combination of crops would make the best use of their principal resource, family labour, with the minimum of risk, provide the food and some cash that the family needs. Their inputs in terms of labour and seed are measurable.

The main output of the farm (primarily foodcrops for home consumption) has a food value, but a measurable cash income is obtained from the sale of surplus foodcrops, such cash crops as are grown, and from gathered forest products. However, money values play a minor role in this micro-cosmos, and the main purpose of the cultivators is to ensure survival, not profit. In analysing this type of farm, it may be necessary for some purposes to assign values to quantities, but one must be aware of the artificiality of the exercise. We are far from the world in which market value, opportunity costs, shadow prices, interest and profit have a meaning.

The size of the homestead of shifting cultivators is limited by the heavy work of clearing which has to be done by the men in a limited period of time or by the amount of weeding that may be necessary. Generally, somewhat more land is cleared than is necessary to provide a safety margin. The area cleared in a year is rather less than 1.0 ha and seems to vary within fairly narrow limits. The cultivated area is larger than the annually cleared area as land is usually cultivated for two years or more, and amounts to about 2.0 ha for the homestead, corresponding to 0.4 ha per person in the family.

The short period of cultivation is determined partly by a decline in yields owing to the depletion of the fertility of the soil and partly by the shifting cultivators inability to cope with the weeds.

Shifting cultivators are very careful in choosing the location of the land to be cultivated. In selecting the site they have to rely on their knowledge of the local vegetation as an indicator of the fertility of the soil. A location will be chosen which will allow the growing of a variety of crops to ensure as varied and continuous food supply over the year as conditions permit. Compactness of the farm is sacrificed to these considerations.

In selecting a site shifting cultivators consider not only the physical characteristics of the site, types of soil, terrain and vegetation, but also its distance from their hut and the distribution and activities of the local social groups in their own community and their own affiliations in the neighbourhood. Apart from religious taboos, several restrictions may limit their choice.

It is difficult to obtain the data necessary for an economic appraisal of the operation of the farms of shifting cultivators. Even when the farm is compact and there is only one plot of land, the farmer does not know the area involved and the shape of the plot makes it difficult to measure. When the farm is composed of several non-contiguous plots, the difficulty is very much greater. Furthermore, the cleared land is covered with trunks of trees and stumps. The net area is a fraction of the cleared area and is difficult to calculate; an aerial photograph would be needed.

Individual plots may be assigned to different members of the household, as in the case of the Zande where the women possess complete sets of fields of specific types, in the same way in which they possess complete sets of specific types of pots, mats, tools and buildings. Certain crops may be men's crops while others are women's crops. A farm is thus composed of micro-units.

In farming the individual plots, crops are not grown separately but in association with others (inter-cropping). Thus, the area under a particular crop and the yield per unit area are difficult to establish. Only the quantity of seed planted and the yield to seed ratio can be determined with reasonable accuracy. Several varieties of the same crop are grown. Planting is usually phased and there is not one but several harvests of the same field. The reason is the need for evening out labour requirements and reducing risks.

Crops are grown in succession on the individual plots to ensure a continuous plant cover. However, the way in which individual plots are used is not haphazard but follows a definite system. There is order in the apparent chaos which strikes the observer used to well laid out fields, which are clean cultivated with crops planted in rows at proper spacing.

Apart from seed, production input is almost exclusively human labour, much of which is required for clearing the land. However, cultivation, weeding and harvesting, as well as processing and transport, also require substantial labour input which is both seasonal in nature and requires differing skills and abilities. There is usually a very distinct division of labour among various members of the household.

The labour input required for land clearing has been measured in different areas and for different types of vegetation. It was found to vary considerably from 325 to 408 h/ha (virgin forest) to 179-262 h/ha (secondary forest) in Borneo for hill rice; from 486 to 1450 h/ha (for careful clearing with two burnings) in the rain forests of the Congo; 924 to 1105 h/ha on the savanna, and 822 h/ha on Pennisetum grassland in the same area. In Guatemala, clearing lands for maize required only 427 man-hours per hectare. The skill with which various individuals perform the same operations also varies a great deal.

Because crops are grown in association and because of the division of labour under which the plots growing mixtures of crops are assigned to different members of the household, the labour spent on the cultivation of an individual crop is difficult to determine; several crops would be weeded at the same time. The organization of work is also different. An individual tends to perform two major tasks a day but when so doing, he may perform a number of minor tasks. The amount of effort required for different tasks varies and so determines the length of the working day.

As crops are grown throughout the year, an accurate record of the time spent on farm work would require continuous observation through the year.

The scale of cultivation is determined not by the total amount of labour theoretically available over a year but by the labour available for meeting peak requirements. This principle applies to shifting cultivators, who rely only on hand labour and the labour of their household, even more than to small settled farmers using animal power, as these can usually employ additional hired labour. Labour requirements of the shifting cultivator are, however, evened out by his growing many different crops and several cultivars of each, and phasing their planting even at the expense of yield.

The processing of crops is a time consuming task for the households of shifting cultivators, and where the weight of freshly harvested produce is heavy in relation to the final product, the processing is done in the fields. Bitter cassava is brought from the field to a stream or water hole, fermented under water, mashed into pulp after fermentation and spread out to dry. The dried cassava lumps are pounded in a mortar to convert it into flour. Grain is threshed by hand and ground by hand; rice is pounded in a mortar, and groundnuts are shelled by hand.

Transport of the crops takes up much time as there are neither roads nor carts. According to Jurion and Henry (1967) a family of four. planting annually 0.5 ha of maize, rice, groundnuts and bananas with an average distant of 1.5 km between the hut and plot, spends annually 120-140 man-days on transport (assuming a load of 35-45 kg and 4-5 journeys per man-day).

The utilization of available labour (probably about 40-50 percent) is low by the standards of farms in developed countries and certainly by those of farms using paid labour, but is not much worse than that found in developing countries on small family farms in permanently settled areas.

Assessment of the economic performance and true farm income of shifting cultivators is complicated because of the methods used in growing and harvesting the crop. The observer of local life has little opportunity of measuring the variety and quantity of food and other products gathered from surrounding land. The case of the Pilipppine Pinatubo Negritos observed by Fox (see Spencer, 1966) may have been extreme; however, his conclusion was that about 50 percent of their subsistence was derived from sweet potatoes and about 14 percent from maize but hunting, fishing and gathering wild produce were still of critical importance, some 450 plants entering into Pinatubo usage. The Negrito only recently began to grow plants and were not yet established crop producers.

Most of the crops grown on the homestead are consumed by the household; many have no market value at all. A small part of the crop may be sold when there is a surplus, together with any cash crops grown and forestry products collected for sale. The proceeds of sales are significant and of interest, small though the cash income may be. Calculation of the value of farm consumption, on the basis of the volume of major crops and using the nearest approximation to farm gate prices, gives a meaningless figure for the shifting cultivator. It grossly underestimates the farm income as it takes into account neither the collected food nor the benefits and amenities that are at the disposal of the homestead for no more than the cost of effort, although in total they account for a substantial part of the farm income. Furthermore, by itself a farm income figure means little; other income figures in the same country are necessary to give it meaning. For international comparison farm incomes are of limited value; for this purpose, instead of calculating the money equivalent it might be safest to convert all food into a wheat equivalent, making a liberal allowance for gathered foods and hunting and fishing catches.

CASE STUDIES

After the discussion of the various aspects of shifting cultivators from the point of view of farm management and economic performance in general terms, we propose to discuss a few case studies. Some studies describe the operation of the homesteads in varying degrees of detail without, however, summarizing their economic performance in the form of farm budgets. Others give less detailed background information but present farm budgets of varying quality.

(a) Ivory Coast

Bergeroo-Campagne (1956) studied shifting cultivators of a tribe, the N'Dranovas of the Baoule people in the village of Oko, in the Ivory Coast. The area of the village was 1 744 ha of which 288 ha were occupied by communal grazing land and the village itself, while 4 ha were cemeteries. The remainder of the land was cultivated under a shifting cultivators system. The population density was 28 persons per square kilometre or 33 persons per square kilometre of land of agricultural value. Four hundred and sixty six people lived in the village and formed six clans ranging in size from 24 to 217 persons. Far from being in an isolated area, the village was well served with all-weather roads which could carry trucks of up to 7 tons. There were weekly markets nearby and the principal market town had a railway connection. The cash crops were tobacco, swamp rice, coffee, cacao, coca (cultivated by men) and maize (cultivated by women). The people eat no rice and little maize.

A clan is composed of several families which include the man, his wife or wives and their children and the brothers and sisters of the wives. The right of use of the land is invested in the clan which is presided over by a hereditary chief. With the exception of swamp rice, the clan cultivates jointly the land of which it has the usage. Yams, rice, coffee, cacao and tobacco are the men's crops, while manioc, maize, cotton, groundnut, pepper, gombo and tomato are the women's crops, The women dispose freely of their crops and of the proceeds of the sale (for the purchase of clothes, household utensils, etc.). The crops of the men belong to the clan. The needs of the clan and the seed for the next neason are set aside and the remainder is sold. The clan of the chief guards the proceeds of the sale; he cannot spend it but invests in gold as soos as possible.

The clans cooperate in clearing the forest, in hunting, in fishing and eventually in other tasks. They help each other with loans without interest in case of need, but there is no cooperation in storing or marketing the produce.

The total area cultivated by the village was 78.85 ha. In individual clans: the cultivated area per worker varied from 0.21 to 0.58 and the cultivated area per head of population varied from 0.14 to 0.31. The principal crops, their yields and the amount of labour required for raising them were as follows:

Crop	Yield (kg/ha)	Labour (man-days per hectare)
Yam	4 000	150
Maize	350	90
Tobacco	250	Not available
Cotton	200	1 350

The clans owned cattle, sheep, goats, chickens and guinea fowl. Forestry products are used for food and the preparation of palm wine for medicine. Firewood is also sold.

The study gave an estimate of the family budget of one of the six clans which every year cultivated 30 ha of yam, succeeded by about 24 ha of maize and 7.5 ha of tobacco (the clan did not grow cotton or swamp rice). Annual production amounted to 180 t of yam, 8.4 t of maize and 3,75 t of dried tobacco leaves.

Perhaps one fourth of the yam harvest and the whole of maize and tobacco would be sold. The clan had 215 members of whom 86 were small children. In addition to covering its food requirements, the clan received 800 000 francs from the sales, a sum which could be reduced to 325 000 francs were the yam harvest to be poor. These sums do not include proceeds from the sale of minor products. In comparing the proceeds of these sales with those of cacao and coffee elsewhere, Bergeroo-Campagne was evidently in error in that neither his labour requirements nor yields were realistic, but he added that the clan was able to hoard part of their income.

(b) Philippines - Study No.1

Conklin (1957) in his study of Hanunoo 1/ agriculture in the Philippines found that the system required a little more than 2 ha of cultivable land to maintain its average 12 years cycle. Sixteen universally grown crops and at least 20 other basic crop types were represented in every swidden. The annual minimum labour requirements varied from 2 865 to 3 180 man-hours per hectare depending on whether the vegetation to be cleared was climax forest or woody or bamboo secondary growth. There was wide variation in grain production per hectare on the swiddens (the Yagaw range was from 1 800 to 6 500 l/ha).

In general terms, for each hectare of average swidden (secondary growth) cultivated, 3 000 man-hours of labour produced among other crops 4 000 l of unhusked rice, corresponding to 1.32 l per manhour. Eighty five percent of swidden rice was used for home consumption or saved for seed. Crops other than rice, grown mostly on the same swidden, provided more than 80 percent of the starch staples used annually. About 10 percent of the annual diet consisted of non-starch staples also derived from the same swidden. As non-food plants (tobacco, cotton) were also cropped, the man-hours devoted to rice production were but a

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1/ The Hanunoo are an ethnic group inhabiting Mindoro Island. Yagaw is the name of a geographical area in the hills of eastern Mindoro inhabited by 34 families who formed 33 households and lived in 7 settlements. Swidden is a revived English dialect word and means 'burned clearing'.

small fraction of the total direct labour input. If these factors are taken into account, the adjusted yield of rice per man-hour rises from 1.32 to over 4 1 (2.5 k). This rough estimate, Conklin concluded, compared favourably with labour costs, for rice production under the best conditions elsewhere in the tropics.

Yagaw swiddens usually produced enough food for immediate consumption and seed for future planting. When the reserve supply ran low, rarely for long, semi-domesticated starch staple crops would be used. Between 10 and 15 percent of the annual yield of rice and some other crops were used in trade with other Hanunoo (for other plant products, local manufactures, salt or beads), with the Buhid (for plant products, pots, medicines) and with lowlanders (for salt, beads, metal objects, and other 'imported' goods, such as scented hair oil and flashlights). No Yagaw crops were raised purely for export or sold only for cash.

Conklin added that swidden unit annual cash incomes averaged less than 10 pesos (US$ 5.00 in 1957), the actual range being from 2 to 30 pesos. Capital investment mainly took the form of perennial tree crops, swidden annuals, beads, cattle, and imperishable artifacts (roughly in order of decreasing economic value). In lowland terms, the existing tree crop groves (excluding banana stands) in Yagaw were worth considerably more than 5 000 pesos (US$ 2 500 in 1957). It is of interest to note that according to Conklin (writing in 1957) the national average rice yield per hectare remained practically at its 1918 level and was about half that of the Hanunoo swidden yield.

(c) Philippines - Study No. 2

Ozbilen (1971) made a survey of 347 kainginero (shifting cultivator) families in the Anbuklao Pilot Forest, Philippines. The average number of persons per family was 6.2, corresponding to 2.6 man equivalents. The average size of farm was 4.18 ha of which about 0.7 ha of land was cleared annually. However, only 1.32 ha of the total area was under crops (annual and permanent) with 0.92 ha used for temporary grazing and 1.91 ha left idle for cultivation in the future. Of the cultivated land, 0.13 ha was under semi-permanent or tree crops (mainly banana, coffee and avocado), 0.94 ha was under root crops (mainly sweet potato), 0.16 ha was under rice and 0.09 ha was under vegetables (mainly Irish potatoes and cabbage). Rice and vegetables were double cropped. The yield of potatoes was 3.2 t/ha; of sweet potato 7 t/ha of harvested area or 5.6 t if reduced to the total area under the crop, rice gave 1.1 t for the first crop and 970 k for the second crop. The family had an average 2.5 head of cattle, 0.6 water buffalo, 2.0 hogs, 0.8 goat and 8.1 chickens.

The total labour requirements of the average farm were 325 man-days per year, of which 153 man-days were needed for field crops, 12 man-days for the orchard, 60 man-days for livestock, 28 man-days for land clearing and terrace making and 72 man-days for other farm work. Clearing and burning 1 ha of forest land took about 74 man-days; more than 50 man-days were needed for cutting and felling only. This work has to be done at the beginning of the dry season in about 30 days or so. Clearing 0.7 ha fully occupies a kainginero's time. In addition, the average family spent 37 days on work off the farm. Counting 25 working days per month, average gainful employment thus accounted for 46 percent of their available time.

Tables 1 and 2 show analyses of the economic performance of the average farm.

The important question is what was the true reward of the labours of a kainginero family in a year. The farm household is a production and consuming unit. The food consumed by the family and other benefits accrued are part of the reward and are their income in kind. The crop given to the labourers is a cost, as are cash wages. The cash that remains from the sale of the crops after meeting farm cash expenses is the cash income of the farm. Division of the total income into returns to labour, land and capital, or making a distribution between 'farm labour income' and 'farm labour earnings' is arbitrary.

Accepting the valuation of the crops and livestock consumed as complete and correct, the family had an income in kind of 613.20 pesos* or, including the use of dwelling 646.82 pesos. In addition they had a cash income from the sale of farm products amounting to 263.31 pesos. Deducting their cash farming expenses, 146.09 pesos, we arrive at a cash income from farming

* US$ = 6.42 Philippines pesos (1971)

of 117.22 pesos which brings the total farm income to 764.04 pesos. To this one would have to add the net increase in inventory 34.72. As the family spent 325 days in farm work, they earned 2.35 pesos per day. Their total income, including earnings off the farm amounted to 911.42 pesos of which 264.60 pesos was cash income and 646.82 pesos income in kind.

(d) Venezuela

Watters (1971) found that in Venezuela a shifting cultivator had a family of about six with a labour force equivalent of two men. One man could, working with traditional methods, handle a maximum of 3 to 4.5 ha per year. Cropping was primarily for subsistence, and the chief crops were invariably maize and black beans. Intercropping was common, with a variety of annual and semi-permanent crops. In the final stages of cultivation, semi-permanent crops such as plantain and banana often took over from the annual crops. Yields per unit area cropped were low, generally below, and sometimes well below, the national average of Venezuela. There was little specialization of labour; members of the family undertook all tasks in the agricultural cycle.

Capital input was virtually nil and even minor improvements representing fixed capital in terms of labour expended (e.g. drainage ditches, etc.) were very rare. Cash cropping usually represented a natural extension of the subsistence system, with a small surplus being sold. Some cultivators were wholly shifting cultivators, in that all their agricultural production came from shifting fields, but most were 'partial' shifting cultivators; part of their agricultural production or income was derived from some other source, such as wage labour (which amounted usually to about 10-15 percent of the saleable agricultural output) or from some permanent or semi-permanent crop, such as coffee or banana. Cash crops were a small addition to the principal crops on shifting fields. Part of the crop was consumed by one or two household cows, pigs or goats and by poultry. Where primary forest was near at hand, hunting and fishing supplemented the shifting cultivators' economy.

Table 1. Total Farm Receipts and Expenses (pesos) of a shifting cultivator in the Anbuklas Pilot Forest (Philippines)

Receipts		Expenses		
Cash items		Cash items		
Crops sold	190.85	Livestock bought		18.66
Livestock sold	72.46	Hired labour		38.45
		Materials and tools		66.49
		Others		22.49
		Interest on loan	6.25	
		Land tax	3.74	
		Miscellaneous	12.50	
Non-cash items		Non-cash items		
Value of crop given to labourers	4.32	Value of crop given to labourers		4.32
Net increase in inventory	34.72	Value of unpaid family labour		153.50
Total farm receipts (cash and non-cash)	302.25	Total expenses		303.91
Non-farm cash income	147.38			
Total cash income	410.69	Total cash expenses		146.09
Balance				264.60

Table 2. Farm Business Analysis of a Shifting Cultivator's Farm in the Anbuklao Pilot Forest (Philippines)

	Pesos	Pesos	Pesos
Farm income			-1.56
Farm receipts		302.25	
Less; Farm expenses		303.91	
Operator's Farm Labour Income			-390.75
Farm income		-1.56	
Less: Interest on average investment		-389.19	
Operator's Farm Labour Earnings			256.07
Operator's farm labour income		-390.75	
Plus: Farm priviledges		646.82	
Use of dwelling	33.62		
Crops consumed by family	558.05		
Livestock consumed by family	55.15		
Family Farm Labour Earnings			407.57
Operator's farm labour earnings		254.07	
Plus: Value of unpaid family labour		153.50	
Family Income from All Sources			944.14
Family farm labour earnings		407.57	
Plus: Other income		536.57	
Non-farm labour income	147.38		
Interest on investment	389.19		

The total labour input for all agricultural activities varied from 32 to 86 man-days per hectare, depending on the growth of the secondary of the secondary forest to the cleared and the steepness of the terrain. This represented a cost of 200 to 530 bolivares* per hectare, calculated at an average of 6 bolivares per day (although average wage rates, excluding food, varied from 4 to 10 bolivares a day).

In another study 1/ quoted by Watters (1971) it was found that the average sized farm had a total labour input of 155 man-days. As the average family had the labour equivalent of two adult men. it was concluded that only 26 percent of available labour was required for shifting cultivation. The breakdown by operations, was as follows:

Operation		Labour input (man-days per acre)
Underbrushing		5
Felling		5
Firebreaks		1
Cleaning up		1
Planting		2
Weeding		3
Harvesting		3
Various		3
	Total	23

In appraising the income level of shifting cultivators Watters (1971) refered to a survey 2/carried out in 1957 in the Venezuelan Guyana which covered 154 families and found that their income was 496 bolivares (US$ 110 in 1957) per head or 2 775 bolivares per family. Another study 3/ referred to by Watters found that 46 percent of the sample families earned a gross income of less than 800 bolivares a year (i.e. 133 bolivares, or US$ 30 per head in a family of six). The average income of the sample of Petricek's survey gave 1 860 bolivares in farm earnings plus 700 bolivares in off-farm earnings, giving a total of 2 560 bolivares (US$ 570 per family or US$ 95 per head).

According to Watters' own calculations the median gross per head income varied between US$ 25 and US$ 157, or between US$ 44 and US$ 201 if the approximate value of subsistence production is added (our italics). For an appraisal of these figures one has to bear in mind that according to a national sample survey 4/ of earnings and family budgets carried out in 1964 (quoted by Watters) in the rural areas of Venezuela, 53 percent of the families surveyed had an income of less than 300 bolivares (US$ 66,67). We can add that a large proportion of people surveyed were small, and not so small, farmers of the ordinary type and some were agricultural labourers; shifting cultivators, if covered at all by the survey, accounted for a very small proportion of the sample. In comparison with the level of rural incomes in Venezuela, the figures given by Petricek, Hill & Hill, Watters himself do not show that shifting cultivators lived in more abject poverty than the rest of the rural poor.

1/ Petricek, R.J., Shifting Cultivation in Venezuela, unpublished thesis.

2/ Consejo de Bienestar Rural, Reconocimiento agropecuario y forestal del oriente de la Guyana Venezuelana, Caracas, 1954. (Author, A.L. Jolly).

3/ Hill, G.W. and Hill, R.O. La vida rural en Venezuela, Caracas, 1958. p.5-11.

4/ Oficina Central de Coordinación y Planificación de la Presidencia de la Republica et alia, Primera encuesta nacional de ingresos y gastos familiares en Venezuela, Caracas, 1964.

* US$ = 4.50 bolivares in 1964.

Watters drew up two farm budgets, one for a shifting cultivator in the mountains (Table 3) and another for a shifting cultivator in the tropical lowlands.

Table 3. Estimated Net Income (bolivares) of a Typical Andean 3 ha Farm under Shifting Cultivation

Income from crop sales		Expenditure	
Maize (2 ha)		Labour	
Two thirds of maize crop sold: 1 070 at 30 centavos.	320	50 man-days per hectare for 3 ha at 8 bolivares per day	1 200
Black beans (1 ha) 3.5 cargas at 80 bolivares	280	Tools (including depreciation)	50
Other income: wage labour	300	Seed	120
Value of subsistence production			
One third of maize crop 530 kg at 30 centavos	160		
Other subsistence crops	350		
TOTAL	1 410	TOTAL	1 370
		Balance	40

Table 4. Estimated Net Income (bolivares) of a Typical 3 ha Farm under Shifting Cultivation in Tierra Caliente, Venezuela

Income from crop sales		Expenditure	
Bananas (2 ha)		Labour	
300 bunches per ha at 2.5 bolivares	1 500	70 man-days per ha at 8 bolivares	1 680
Maize (1 ha)		Banana clearing, picking	420
Two thirds of production: 600 kg at 30 centavos	180	Tools, including depreciation	50
Other income: wage labour	400	Seed	120
Value of subsistence production			
Maize, one third of production: 300 k at 30 centavos	90		
Other subsistence crops	500		
TOTAL	2 670	TOTAL	2 270
		Balance	400

In the first budget the value of farm production appears to be 1 110 bolivares, one half of which was sold, which indicates a high degree of commercialization; also, it can be suspected, that the value of subsistence production was underestimated. True costs amounted to 170 bolivares, as family labour in our view is not a cost. The cost of seed, 120 bolivares, appears to be high in comparison with the value of the crops (760 bolivares). Whatever the true figure, the fact is that according to Watters' own figures the family had a farm income of 990 bolivares, to which one would have to add the value of farm privileges, say 40 bolivares, for the hut, etc. The family spent 50 man-days obtaining that income, therefore with their labour they earned 22-60 bolivares per day, when the current agricultural wage was 8 bolivares per day. At that rate a rural labourer had to work for 141 days to earn a sum equivalent to the farm income of the shifting cultivator. As the shifting cultivator earned an extra 300 bolivares by working off the farm, his lot compared favourably with that of an agricultural labourer. In fact, a realistic estimate of the value of farm consumption would raise his farm income considerably above the figure of Watters. Mutatis mutandis, the same is true of the budget of shifting cultivators in the lowlands.

(e) Congo

Ruthenberg (1971) calculated the economic returns of shifting cultivation in the Congo Kinshasa (Table 5) on the basis of data given in a study by Tondeur (1956).

Table 5. Economic Return of Shifting Cultivation in the Congo-Kinshasa (model calculation per ha, 1956) 1/

	Harvest (q)	Price (US $ per q)	Value (US $)
Product			
Rice	8	3.15	25.20
Manioc (dry)	50	1.26	63.00
Bananas	100	0.42	42.00
Gross return 2/			130.20
Purchased inputs 3/			
Expenditure on tools			1.00
Income of holding 2/			129.20
Productivity			
Labour expenditure			Work-days 4/
Clearing and burning, 160 work-days/ha 5/			80
Seeding and planting			30
Rice harvest, including transport to the hut (800 kg, 500 m) 6/			45
Preparation of produce			5
Transport to market (400 kg, 5 km)			7
Manioc harvest, 15 t, including transport to the hut			50
Preparation of produce and drying			120
Transport to market (5 t, 5 km)			42
Banana harvest, 10 t, including transport to the hut			16
Transport to market (5 t, 5 km)			83
Total labour expenditure			478
Gross return (US $ per work-day)			0.27
Gross return (US $ per ha cultivated)			130.20
Gross return (US $ per ha of the total area of land)			13.02

Source: Ruthenberg (1971)

1/ Two years of cultivation, 18 fallow years, 0.5 ha annual clearance, 1 ha annual cultivation. Area requirement of the holding: 10 ha.

2/ Excluding the return from hunting, collecting and fishing. Domestic consumption (4 q rice, 50 q bananas) is included.

3/ Excluding farm-produced seeds and planting material.

4/ Tondeur did not supply the number of working hours per day.

5/ The labour expenditure of 160 days per ha. is very high indeed. The labour expenditure on harvest given by Tondeur corresponds with that of other data.

6/ Transport of carrying.

Ruthenberg noted that in addition to the products listed, other produce, often in considerable quantities, is obtained from the garden that is developed near the hut and from collecting, fishing and hunting.

As the calculation takes no account of other than the three main crops, it underestimates the total production of the homestead. It also underestimates costs because farm produced seeds and planting material are real costs. The true value of production and also the income of the holding must, therefore, be considerably higher than US$ 130.20 per hectare and US$ 129.20 per hectare respectively. For want of information on wage rates, it is difficult to say what a gross return of US$ 0.27 per work-day or US$ 130.20 per hectare means. Owing to the very high labour input, 75 percent of which is devoted to harvest, transport and processing and the return per work-day is low, while the return per hectare of cultivated land or even the total area, US$ 130.20 and US$ 13.02 respectively, appears to be high.

(f) Tanzania

Baum (1968) studied land use in the Kiberege strip in the Kilombero Valley in Tanzania where in some areas, notably on the slopes of the escarpment and the round hills, in the valley and on the flood plains, shifting cultivation is practised. Fifty five smallholdings were studied. An average household in the Kiberege strip was composed of 5.5 persons who cultivated an area of 5.22 acres* per household, 2.27 acres per available man-equivalent and 0.98 acre per household member. Labour capacity amounted to 2.3 man-equivalents. The sample holdings were hardly centrally managed farms; practically every household worked his own plots and had control over the returns of these plots. All household members, however, carried out certain tasks jointly. Certain jobs are done only by men, others only by women. Individual families are not economically isolated. Relatives and neighbours help each other. Certain jobs, such as clearing, are still performed jointly. The neighbours normally assist in cases of crop failure and high labour demand.

The farms are composed of a garden plot which is used for several years in succession where vegetables, peppers, surgarcane, banana and papaya are grown and outlying fields where shifting and semi-permanent cultivation is practised and rice, maize and occasionally cotton are grown. For additional earnings the people collect building material, fuel, wild honey, etc. they also used to collect rubber. Hunting and fishing are practised to some extent. There are opportunities for off-farm employment.

On the escarpment the growers of hill rice practise a crop-forest sequence. Two or three years of rice growing are followed by 10 to 25 years of fallow. The people also grow some maize, tobacco, sesame, etc. A cropping - grass fallow is practised on the fertile plains of the valley which are flooded from time to time and are used for rice growing. On these plains, weeding limits the intensity of land use; where land is abundant, 2-3 years of rice growing is followed by 2-3 years of grass fallow. After 15 years or so the farmers move to a second and then to a third area before returning to the original area.Where there is not enough land they move back and forth from one area to another.

The characteristics of shifting cultivation and semi-permanent farming in the Kiberege strip are shown in Table 6.

Baum (1968) also drew up farm budgets for the hill rice holdings and for the valley rice holdings in the Miombo forest and plains. (see Table 7).

It is not clear to what extent these farm budgets take account of the lesser crops and the products collected. Gross returns are probably underestimated . Farm expenditure seems to include only the items bought. But the use of farm produced seed is as much a cost as bought seed. Whatever the true figures for gross returns and family incomes may be, the family income of the mountain rice holdings (580 shillings) was slightly higher than that of the rice-cotton holdings (562 shillings), although it was inferior to the family income of the valley rice holdings (466 shillings) and the rice sugar holdings (1070 shillings).

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* acre = 0.4 ha

Interesting as these figures are as indicators of the productivity of shifting cultivation in comparison with other types of farming in one country, they give no information on the extent to which the shifting cultivators succeeded in meeting their food requirements, on the proportion of crops sold nor on the cash incomes received; they are also practically useless for international comparisons.

(g) Sarawak

Freeman (1955) studied the shifting cultivation of hill rice by the Iban in Rumah Nyala in Sarawak. The people live in family groups (bilek). The average size of the family is about 5 or 6 members. The bilek families are grouped together in communities which vary in size from 4 to 50 families, the average size being about 14 families.

Table 6. Characteristics of Shifting Cultivation and Semi-Permanent Farming in the Kiberege Strip (Tanzania)

	Shifting cultivation on the escarpment	Semi-permanent cultivation in the valley
No. of holdings	6	14
R value 1/	0.15	0.55
Crop area per man-equivalent (acre)	1.5	2.3
Rice yield, lb/acre	1 500	1 060
Labour input in man-days per acre 2/	110	100
Labour input as a percentage of the total		
Land cultivation	31	19
Planting	19	16
Weeding	20	32
Harvesting	30	37

1/ $R = \frac{\text{years of cultivation}}{\text{years of cultivation} + \text{fallow years}}$

2/ Data from 4 and 8 holdings only. The number of hours worked per day is different for the individual jobs. Thus, clearing takes an average of 6 hours and weeding and harvesting 4 hours.

Table 7. Land Use and Farm Returns for various Types of Holdings in Tanzania (after Baum, 1968)

	Mountain rice holdings	Valley rice holdings in Miombo forest	Valley rice holdings on the plains
No. of holdings	6	5	14
ME	1.9	2.12	2.67
Crop area (acres)	2.75	9.10	5.38
Acre/ME	1.50	4.30	2.00
Per cent of the total crop acreage			
Rice	70	47	68
Cotton	5	11	5
Maize	-	37	14
Sugar cane	-	-	-
Garden, etc. 1/	25	5	13
Gross returns (sh)	580/-	1 060/-	893/-
Farm expenditure	-	63/-	105/-
Family income (sh)	580/-	997/-	788/-
Coefficient of variation 2/	37	49	70
Gross returns (sh/acre)	212/-	115/-	155/-
Family income (sh/ME)	306/-	466/-	296/-
Coefficient of variation	38	46	54

ME denotes man-equivalent

1/ In two holdings 0.25 acre of tobacco was planted.

2/ Coefficient of variation = average variation in percentage of mean value.

All the bilek families have equal rights of access to land. The apportionment of virgin land is decided in a general palaver in which all the senior male members participate. In selecting virgin forest for felling, each bilek family acts largely on its own initiative, but usually a small group of families operate in the same immediate area. While virgin forest was in virtually unrestricted supply, they used to attach little value to secondary jungle. The ground cycle of cultivation is 15 to 25 years.

The Ibans grow several varieties of rice and take great interest in new or uncommon varieties. The seed is carefully selected and about twice the quantity required is reserved. A wide range of catch crops is grown with rice. Weeding which is the work of women, is a limiting factor of cultivation. The largest area a woman can cope with is about 2.0 acres. Reaping, again, is women's work. The rice is threshed by treading the panicles; the trodden panicles are thrown on to a grille to separate the grain from the straw.

The time expended in the various activities is shown in Table 8.

Table 8. Time Expended by Ibans in growing Hill Rice (man-days per acre)

Activity	Division of labour	Virgin jungle	Secondary jungle
Slashing	Men & women	6	5 - 6
Felling	Men	12 - 14	4 - 5
Secondary clearing	Men	2 - 5	2 - 5
Dibbling	Men	4	4
Sowing	Women	5	5
Wedding	Women	12 - 16	15 - 20
Reaping	Women	14 - 20	14 - 20
Transporting the padi	Men	1	1
Minimum total		56	50
Maximum total		71	66

Freeman also calculated the area felled and under padi per head of population and worker and arrived at the figures shown in Table 9.

Table 9. Area (acre), per Head of Population and per Worker, of Land Felled and Planted with Hill Rice by Ibans in Sarawak (after Freeman, 1955)

	Felled area	Area under padi
Average area per head of population 140 men, women and children	0.8	0.6
Average area per worker, a total of 85 persons	1.3	1.0
Average area per male worker participating in felling, 50 men and boys	2.2	
Average area per female worker, 49 women	-	
Average area per weeder, 49 women plus 11 men who assisted	-	1.8

With favourable weather conditions, particularly when working land of good quality, Iban farmers are sometimes able to achieve yields of 30 - 40 bushels per acre. Under below average conditions, yields of 13 to 16 bushels per acre are typical.

The interesting data in Table 10 which summarizes the economics of four families are the area under padi, especially in relation to the size of the labour team and the number of persons in each household; the yield per acre in relation to the quality of seed sown, and production as a percentage of normal requirements.

The value of the crop and the return per man-day expressed in local money means little, without having some criterion of appraisal. As the bilek families grow crops other than rice and collect some of the food they eat, the total value of the crop given in the Table understates the economic performance of the families.

SUMMARY AND CONCLUSIONS

In summing up the significant points of this paper, especially the implications for any future action regarding shifting cultivation, it must again be stressed that the technical, social and economic factors involved are very closely interwoven. Also, in attempting an economic appraisal, it must be remembered that the shifting cultivator is more concerned with producing an adequate food supply for his family, rather than with any particular enterprise or degree of economic efficiency, rate of return in monetary terms and/or the measurement of other economic performance indicators. This does not imply that economic considerations are not relevant. Even without assigning money values to inputs and outputs, the problem of allocating available resources so as best to achieve the production targets in mind is an economic one.

The information on the economic performance of shifting cultivators in countries as varied as Venezuela, the Philippines, the Ivory Coast, Tanzania, Congo-Kinshasa and Sarawak, shows that in normal years they are generally able to cover their food requirements adequately and in good years they may have a surplus which is usually invested in objects of value. These can be exchanged, or sold for food in years when production is insufficient. By the standards of developed countries they live under primitive conditions and appear to be very poor. However, comparing their standard of living with that of some of their compatriots they are not so badly off and have a better life than many of the urban poor. Within this context the following conclusions are drawn:

Table 10. Summary of the Economics of Four Bilek Families of Rumah Nyala (Sarawak) during the 1949/50 season (values in Sarawak $*)

	Bilek No. 5 pun bilek: Kamba 1/	Bilek No. 22 pun bilek: Kubu	Bilek No. 20 pun bilek: Sulan	Bilek No. Ia pun bilek: Bangi, and Rebut
Number in bilek family	8	6	5	5
Number in labour team (15 yrs and over)	4	4	4	3
Area of farm in acres (i.e. area under padi)	6.5	5.44	4.75	5
Acreage per head of family (i.e. under padi)	0.8	0.9	0.9	1.0
Total yield of paddy (gantang 2/)	710	639	620	960
Yield of padi per acre (gantang)	109.2	117.5	130.5	192.0
Yield of padi, per head (gantang)	88.7	106.5	124.0	192.0
Ratio of grain harvested to seed sown (5.7 gantang/acre)	19.1	20.6	22.9	33.7
Yield as a percentage of normal requirements (i.e. 114 gantang padi per head per annum)	77.8%	93.4%	108.7%	168.4%
Total value of crop (reckoned at rate of $2 per gantang of hulled rice)	$754	$680	$658	$1 020
Amount produced per head of labour team	$188.50	$170	$164.50	$340
Return per man-day (reckoning 60 man-days per acre)	$1.93	$2.09	$2.30	$3.40

* £ sterling = Sarawak $8.57 in 1950

1/ Two adult males, who were absent on journeys, are omitted

2/ 1 gantang = 1 Imp. gallon = 4.55 l

i. Given the conditions under which shifting cultivators work and the means at their disposal, their economic performance is surprisingly high. It could be improved, but only within narrow limits. The rise in population and the demand for greater output emphasize the deficiencies of this type of cultivation both in terms of land use and production.

ii. Given the characteristics of this type of farming, even a detailed description of the habitat and farming methods of shifting cultivators may not furnish all the information necessary for an economic appraisal of their farming. Conversely, neither economic analyses nor farm budgets are sufficient for a true understanding of the situation without detailed background information regarding the habitat and farming methods of the shifting cultivators.

iii. In studying shifting cultivation the customary method of a farm survey, using a detailed questionnaire and one or more interviews in depth, breaks down. Concepts used in developed economies are alien to shifting cultivators; they would not be able to answer questions which to them make no sense. Drafting a realistic questionnaire would have to be based on a good knowledge of their way of thinking and operation. Even then, it would be impossible to obtain answers to some of the most important questions because, even if the shifting cultivators knew the answers, their distrust or beliefs might prevent them from giving the information to strangers.

iv. Contrary to popular belief, the small farms of shifting cultivators are complex enterprises, often composed of several micro-units of nearly equal complexity. A study of the farming of shifting cultivators would have to cover each micro-unit, and because of almost continuous cropping it would be necessary if not actually to live with the people under study at least to pay them very frequent visits throughout the year.

v. In order to obtain the information needed for an economic appraisal, close liaison would be needed between agricultural economists, anthropologists and agronomists.

vi. Farm income is composed of income in kind (the food produced and consumed on the homestead, collected products and the amenities) and cash income from the sale of products and possibly of labour in the form of external work. As it is impossible to attempt to estimate the quantities of the scores of varieties of products produced, there is an inherent danger of over simplification through the selection of a few crops of commercial value.

vii. In order to express total family production and consumption in one meaningful figure, it is common practice to calculate the value, in terms of farm gate prices in local currency, of the principal crops of commercial value. The lack of a criterion of values poses an immediate problem in that the earnings of some well-defined social group of the country are seldom given. The problem is compounded by annual differences in local prices and variations in international rates of exchange. An alternative method which appears promising, although to our knowledge has seldom, if ever, been used in studies of shifting cultivation, would be to convert the output into grain equivalents. This method has been used, e.g. by Clark and Haswell (1964), for measuring productivity in their study of subsistence agriculture.

viii. The farming costs incurred by shifting cultivators are mainly seed and labour; most tools are home made and only a few are acquired by barter or purchase. It is not difficult to fix a unit cost of seed, but it may be very difficult to estimate the quantity used. In costing labour, it is relatively easy to measure total time but difficult to establish time spent on individual crops.

ix. In this case it is not appropriate to use opportunity costs which implies that family labour input has a value assigned to it based on current wage rates. Therefore, the only meaningful figure for assessing economic performance is the value of the farm income (as defined in (vi) above). Once the time spent on raising crops is measured and output is expressed in one figure, one can calculate the return to labour.

x. To try to calculate interest on the capital of shifting cultivators is as absurd as to try to calculate 'rent' on the holding.

xi. Another figure of interest which should be calculated is the proportion of the crops sold relative to that consumed on the homestead and the cash income and its source.

Shifting cultivators, who for centuries had been following a sound and successful system of agriculture well adapted to the existing conditions, can be forgiven if they could not foresee the consequences of their increase in numbers and the reduction of their living space caused by the inroads of civilization. They were incapable of solving by themselves the problem posed by the declining yields that were the result of the shortening of the fallow periods that circumstances forced upon them. They did not receive much help from governments who had no valid answer to the problem of permanent land use in the tropics other than plantation crops.

Instead of financing sufficient research into the possibilities of sound semi-permanent and permanent use of tropical lands, governments generally resorted to the force of law. It was frequently ineffectual in the given setting to prohibit the use of land by shifting cultivators whose practices had become destructive under the changed circumstances. This futile policy is now giving way to a better understanding of the situation. As one student (E.R. Leach, quoted by Freeman, 1955) of the problem expressed it: ''In the past, critics have been quick enough to note the wastefulness of shifting cultivation; what they often failed to recognize is that, given expropriate demographic conditions, agricultural methods such as these do provide an effective means of livelihood. The problem which faces the administrator and his agronomist is not so much that of 'abolishing shifting cultivation' as of creating social conditions in which there is an incentive to utilise resources efficiently without detriment to the basic fertility of the soil. The answers to such a problem cannot be discovered ready-made by interpolating facts derived from European experience into an Asian tropical context. To understand what constitutes economic motivation in any system of production we need to study the social context in which that system operates.''

FAO recognizes the magnitude of this problem. In a paper to the Committee on Agriculture (COAG), March 1972, entitled 'Improving Productivity in Less Favourable Environments' (COAG/72/8), the humid tropics (where shifting cultivation is chiefly practiced) were identified as one of the principal areas which should receive extra attention. After considerable discussion, low-rainfall areas were given first priority by the Committee and a study (Improving Productivity in Low Rainfall Areas) is now under way.

ACKNOWLEDGEMENT

The author wishes to thank Mr. M. Lunan of FAO for his helpful comments.

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AGRICULTURAL ASPECTS OF SHIFTING CULTIVATION*

by
H. Ruthenberg**

DEFINITION

Shifting cultivation is the name we use for agricultural systems which involve an alternation between cropping for a few years on selected and cleared plots and a lengthy period when the soil is rested. Cultivation consequently shifts within an area that is otherwise covered by natural vegetation. The intensity of shifting cultivation varies widely. A relatively simple and appropriate criterion of land use intensity is the relation between the period of cultivation and the period of fallow. Joosten (1962) proposed, and we follow his example, to measure land use intensity through the value R 1/. The value of R tells us the percentage of the land that is cultivated annually (see Table 1).

If the time between the cultivation periods is long, or if only a small part of the total and temporarily cultivated area is used annaully, R will be small. If, for example, two years of cultivation are followed by 18 years of fallow, R amounts to 10. The shorter the time between the cultivation periods, or the greater the annually cultivated area in relation to the total area, the more sedentary does farming become in character. In the course of this development, short fallow systems replace long fallow systems. If the value of R is more than 30, i.e. if 30 percent of the arable and temporily used land is cultivated annually, we no longer speak of 'shifting cultivation' but of 'semi-permanent farming'.

CLASSIFICATION OF SHIFTING SYSTEMS

The forms assumed by shifting cultivation are more varied than in almost any other land use system. It is therefore useful to consider it in relation to several criteria, and a distinction is here made between vegetation systems, migration systems, rotation systems, clearance systems, cropping systems and tool systems.

Vegetation systems

We may distinguish on the basis of vegetation between the shifting cultivation of the forest, of the bush savannas, and of the grassland areas. Shifting cultivation in the rain-forests is typical of rainfed farming in humid areas of low population density. Rotations with bush-fallowing predominate in the African savannas. Alternation between cultivation and wild grass vegetation is found in some tropical high-altitude areas, in semi-dry climates and not least where the reduction of the fallow period has led to the growth, while the ground is resting of largely useless grasses (frequently *Imperata* spp.) instead of bush or forest.

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* This paper is based on: Ruthenberg H. (1971) Farming Systems in the Tropics. Oxford: Clarendon, Press.

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1/ R = the number of years of cultivation multiplied by 100 and divided by the cycle of land utilization. The length of the cycle results from the number of years of cropping plus the number of fallow years.

Migration systems

The continual movement of cropping results, in most systems with shifting cultivation, in a slow migration of the population. The cultivated plots move slowly away from the previous clearing and the vicinity of the hut. At the same time the cost of transporting the harvest increases, especially where root crops are grown. Beyond a certain distance, it becomes advantageous to build a new hut near the field instead of carrying the harvest such a long way.

Allan (1965) described the process in Central Africa as follows;

''A village or other group within such a concentration will use up the accessible land in its neighbourhood before the area first cultivated has had time to regenerate and a move must then be made to regenerated land ...... A series of pictures or serial photographs made at suitable intervals would show a gradual movement of the larger community across the countryside in a manner suggestive of the progress of an amoeba on a microscope slide''.

ROTATION SYSTEMS

Shifting farming is practised not only by migrating cultivators but also by sedentary cultivators. In each case, however, cropping and fallowing alternate, and this alternation can have an irregular or regular character. In the case of a regular sequence, a definite number of fallow years follow a definite number of years of cultivation

The rotation systems in rainforest agriculture are mostly simple. Two to four years of cultivation are followed by one to three decades of fallowing. Miracle (1967) termed such patterns 'classical long fallow systems'. In the savannas of Africa, on the other hand, we often find complicated rotation systems in which the following fallow periods alternate in a single cycle of land use:

(a) short-term fallow periods of 1-2 years;
(b) medium-term fallow periods of 3-5 years; and
(c) long-term fallow periods of 6 years or more.

Clearance systems

Shifting systems may be classified according to the clearance system and degree of completeness of the removal of the vegetation (Spencer, 1966). Occasionally the farmers restrict themselves to ringing trees or creating clearings by felling some trees. If fire does not consume the trunks and the larger branches, these are left lying on the ground and cultivation is carried on among the debris. In other cases, however, the vegetation is thoroughly burnt off. Differences in clearing technique appear to be fairly well explained by variations in ecological conditions. The simplest and least intensive techniques are found in the humid forest belt. The number of operations and amount of labour required are greater in the savanna areas (Miracle, 1967).

Cropping systems

Shifting cultivation is almost exclusively carried on as farming with annual and biennial crops. In humid climates we find mainly rice economies or root crop economies, where the emphasis is on manioc, sweet potatoes, yams and taro. Widespread, and extending into the drier climates of the savanna, are maize and millet economies. In between are numerous mixed economies which are based on root crops as well as grain crops.

Tool systems

Shifting cultivation in the rainforest is still occasionnaly practised without agricultural implements; after burning off, seed is sown in the ashes. The axe and the matchete are the shifting cultivator's main tools. Hoe systems predominate in the savannas, particularly where the cultivation period stretches over several years, since in these circumstances soil cultivation and weeding by hoe are necessary. The plough system can only be employed in shifting cultivation where an unused grass vegetation grows in the fallow period.

CHARACTERISTICS OF CROPPING

The various shifting systems are characterized by some common features with important economic implications.

Spatial organization of cropping

The farmer with a stationary home and land that is permanently cropped tries to create favourable growing conditions for his crops; that is, he tries to control nature. Shifting cultivators, on the other hand, are usually highly knowledgeable about how to adapt their cropping practices to the environment in which they are working. Four aspects of adaptation are important:

(a) the choice of the plot of land to be cultivated. The main determining factors are: soil fertility, the effort of clearing the vegetation, the amount of weed growth, the danger of vermin, and location in relation to the road and a source of water. On fertile soils a smaller plot can better cover food needs than on poor soils. Fertile soils, however, are by no means always preferred. Expenditure of labour per unit of production is a much more decisive factor. If one can clear and cultivate with the same effort three times as much poor land and obtain only half the yield per unit, then there is still a net gain (Allan, 1965).

(b) the choice of crops;

(c) the organization of cropping in the form of mixed cropping, phased planting and crop rotations; and

(d) the arrangement of short-term, medium-term and long-term fallows.

A decisive factor in operating these principles is usually the very precise knowledge of soils and plants possessed by shifting cultivators.

Cropping principles

The adaptability of shifting systems is closely related to three principles of cultivation which are linked in various ways:

- Mixed cropping, i.e. the simultaneous cropping of two or more useful plants on the same plot, is not organized with the help of a formal principle, but is based on the best possible adaptation to the natural conditions.

Mixed cropping has a number of advantages:

(a) It reduces susceptibility to disease and pests, and therefore reduces the yield risk.

(b) It allows the adaptation of planting to changing soil conditions.

(c) It allows cultivation to be adapted to the light and shade requirements of individual crops. Both vertical and horizontal variations of cultivation are facilitated. Thus, for example, medium-height manioc plants grow under bananas, and on the ground pumpkins or beans are found.

(d) In smallholder farming a varied food supply is usually sought. Over and above this, the household tries to assure a continuous supply of fresh food, since there are insufficient storage facilities and the storage losses are high. Both aims naturally lead to phased planting and mixed cropping.

(e) A further advantage of mixed cropping, which it shares with phased planting, is the soil cover provided. Where there is a vertical arrangement, the rain, for example, falls from the bananas on to the manioc and then on to the beans, and only then does it reach the soil.

By virtue of these advantages, mixed cropping often produces higher total returns per hectare and per year in quantity of product than monocropping.

- Phased planting. It follows necessarily from mixed cropping, i.e. from the simultaneous cultivation of crops with differing growth periods, that crops cover the soil for varying lengths of time. The systematic arrangement of planting dates means that cultivation is phased. The result of this again is a continuous sequence of growing and harvesting. A number of benefits arise from phased planting:

(a) The phasing of labour operations allows the work to be distributed over a longer period.

(b) The combination of periodic planting and weeding may be labour-saving.

(c) Planting is not necessarily dependent on renewed soil cultivation.

(d) The risk of failure is distributed. The effects of weather variations are counter-balanced and pest damage is reduced.

(e) The phasing of harvests ensures a regular supply of food for the household and minimizes the storage losses. Over a period of several months, a single plot may produce a steady stream of harvestable food in the form, for example, of maize, beans, peas and sweet potatoes.

(f) The ground is covered by growing plants for almost the whole year. Consequently, the soil is protected from water and wind erosion.

- Rotations. Shifting cultivation with short-term cycles is rarely connected with crop rotations. Usually one crop or a given mixture of crops is grown for several years. However, when shifting cultivation is carried on with cultivation periods lasting for several years, or even a decade, crop rotations are evolved - a logical continuation of the tendencies which can already be seen in phased cropping. De Schlippe (1956) termed the change in the composition of mixed cropping a 'pseudo-rotation', but as a rule it is a matter of carefully considered cropping sequences that can justifiably be termed 'rotations'.

The diversity in spatial cropping pattern, mixed cropping, phased planting and crop rotations is mainly due to the shifting cultivator's effort to adapt to given conditions of soil fertility. This diversity, however, is very difficult to reconcile with yield increasing innovations, and the rationalization of labour use. Shifting systems are clearly elastic in changing cropping pattern, but they are very inelastic in increasing total output. They are suited to a static situation but not to a dynamic one.

Characteristics of the fertilizer economy

The various features of the organization of cropping which are applied by shifting cultivators aim primarily at the best use of the existing soil fertility. The basic feature of shifting cultivation is the cost-free, effortless regeneration of soil productivity during the fallow period, especially when the fallow consists of forest or bush vegetation. The damper and warmer the climate, and the poorer the soils, the more rapidly the organic substances break down, and the more rapidly the crop yields tend to sink. If further utilization of the plot no longer promises to be rewarding, the shifting cultivator allows it to lie fallow for a fairly long period, in the course of which the soil fertility regenerates. Shifting cultivation thus allows soils poor in nutrients to produce regularly relatively high and certain yields in a climate in which arable farming is always a difficult struggle against nature. This is usually achieved without manure, terracing or any other means of maintaining fertility that involve a high expenditure of labour. If the fallow periods are long enough, this type of land use system represents a balanced exploitation of the resources available to farming.

Provided the fallow periods are long enough, a slash and burn system proves to be in no way harmful to the soil. In fact, the yields after a fallow period with secondary forest are sometimes higher than those after the first clearing. The smallness of the plots, the considerable shading of the soil during the cultivation period that arises from mixed cropping and phased planting, the presence of tree stumps in the field, and other factors, mean in addition that balanced shifting cultivation involves little risk of erosion damage. Another advantage of field shifting is the fact that losses through plant diseases remain comparatively slight.

Characteristics of the labour economy

Shifting cultivation is a system of production, almost without need of capital, based on labour and the periodic consumption of soil fertility. Practically the whole input consists of manual work. The operation of shifting cultivators can conveniently be classified as follows:

(a) Clearance of wild vegetation

From the standpoint of the labour economy, clearance is the most strenuous activity. Clearing is frequently, but by no means always, carried out within a system of fire-farming. Table 2 shows that the input into clearance varies widely (179-450 hours per hectare) according to the vegetation and the thoroughness of the clearing.

(b) Land preparation and planting

Immediately after burning, planting can often be carried out without cultivating the soil. However, most shifting cultivators do in fact disturb, loosen and move surface soil as part of the operation of planting. In the savanna, or on grass-land, or where cultivation lasts for several years, the soil has to be thoroughly loosened, because it is usually much harder, but on the whole the shifting cultivator needs less soil preparation than semi-permanent or permanent cultivators.

(c) Weeding

The fallow suppresses the growth of weeds, and after fire clearance the soil is often weed-free. Many shifting systems manage, therefore, with little weeding. Only as the period of cultivation increases does the effort spent on hoeing and weeding increase.

(d) Harvest, transport of harvest and processing

Together with clearing, harvesting is the most labour-demanding task. This applies particularly to root economies, in which the transportation of harvested produce - there are usually no roads or carts - and the processing of the crop tend to be time-consuming, as for example with manioc.

In addition, various other activities have to be considered which are more time consuming than in other types of farming, because of the shifting pattern of land use. Huts have to be moved and built. Water carrying often takes much of the wives' time. Visiting local markets is also very time consuming. Work in the fields usually absorbs not more than half the working time. It is important in this connection to realize that the seasonality of labour demand in shifting systems is usually less pronounced than in more intensive arable systems. Clearing, harvesting and processing are the major time-consuming activities, and there is more latitude for doing these chores than there is with cultivation or weeding.

In the traditional forms of shifting cultivation, the execution of the labour operations is usually governed by the customs of labour division. A number of main types of labour division can be recognized:

(a) Division of labour with respect to different tasks

A clear division of tasks between men and women is usually found wherever forest and bush vegetation must be cleared. In fire-farming in the forest, clearing is the man's job, while planting, weeding - if done at all - and harvesting are carried out by the women.

(b) Division of labour with respect to plots

Short-term cycles of cropping and fallowing give rise to a fallow vegetation consisting of grass and bush. The input for clearing is comparatively low. Consequently, work is divided between men and women in terms of areas. Both men and women tend to cultivate their own plots. They usually help each other as much as is necessary. The men do most of the heavy work (clearing) and the women perform the weeding and harvesting.

(c) Division of labour with respect of specific crops

When larger plots are planted with cash crops, then the women are usually responsible for cultivating the food crops, whereas the men farm the plot with cash crops. Housework and collecting firewood are almost always women's and children's tasks, while the men are responsible for cutting the wood used for building and erecting the houses.

Although the implements of shifting cultivators as a rule are limited to hand tools unassisted by domestic animals, the productivity of labour is by no means lower than in more intensive forms of traditional land use. Conklin's (1957) data from shifting cultivation with rice in the Philippines indicates that the labour input per quintal of rice compares favourably with the labour cost figures for rice production in irrigated paddies. Information collected by Baum (1968) in the Kilombero Valley, Tanzania, indicates that shifting cultivators need 30 percent less labour per unit of rice than semi-permanent cultivators. There is, however, a chance in the timing of labour demand. Shifting cultivators put most of the effort into land clearance and cultivation, while semi-permanent cultivators devote most of their time to weeding.

WEAKNESSES OF THE SYSTEM

Considering the main characteristics of shifting systems it can certainly be said that this is a sound way of land use under the condition of

- low population density, i.e. sufficient fallowing, and
- in a situation where agricultural innovations, as developed in industrial societies, are not yet applicable.

Shifting systems provide subsistence and usually some cash income. Yields are comparatively reliable. The productivity of labour is probably not as low as with permanent rainfed farming in overpopulated tropical lowlands. The problem with most shifting systems of our time is that the two above conditions no longer hold. Today we usually face shifting systems with less and less fallowing.

In temperate and subtropical climates, in the tropical high altitudes, and in the drier savannas of the tropics, the gradual intensification in land use has led to a transition from shifting cultivation to semi-permanent cultivation and finally to permanent cultivation. The warmer and damper, i.e. the more tropical, the climate, the greater the difficulties that this development encounters. The weakness of tropical shifting cultivation, particularly in the rainforest, lies in the fact that the productivity of labour and soil can hardly be increased within the system. The introduction of cash crops such as cotton, groundnuts, tobacco or sesame leads to increased income. The yields per hectare can be raised by means of denser planting, timely weeding and plant protection. By relieving families of the arduous work required for such tasks as shelling groundnuts, peeling and drying manioc, local centres for processing free labour for work in the fields. The same applies to the introduction of the bicycle, which makes the transport of the harvest considerably easier and quicker. But all measures which increase the cropped area or the yield per hectare shorten the fallow period or make the regrowth of a fallow vegetation more difficult. The fertility of the soil in the tropics, is, however, closely related to its status in nutrients and organic matter, and thus to the length of the fallow period and the vigour of the fallow vegetation.

In the forest regions and in the tsetse-infested savannas, there is a lack of livestock to provide animal manure. The use of mineral fertilizers is usually not worthwile, because of unfavourable cost-return ratios which can hardly be avoided in shifting systems. Shifting cultivation is limited to the hoe; ploughs cannot be used unless roots and tree stumps are cleared, and that would prevent the growth of the desired fallow vegetation. In shifting cultivation roadways are almost unknown; there are only footpaths. But frequent changes of field would necessitate an exceptionally large network of roadways in the absence of which carts cannot be introduced. The harvest must for the most part be carried on foot or transported by bicycle, and those people who have animal manure must carry it to the field in baskets.

The shifting of fields leads to the change of hut sites. Those people whose fields and huts are moved at intervals have little inclination to invest work in permanent improvement of the land, and a countryside with shifting cultivation is therefore distinguishable by the lack of permanent improvements, such as irrigation, drainage and tree plantations. In general, the family units are scattered. The lack of stationary housing and the long distances between fields create difficulties in storing food, collecting surplus produce and in the division of labour between farming and non-agricultural pursuits. Shifting cultivation is thus a hindrance to the development of villages and towns, central political organizations and advanced societies. The land use system moulds the economic attitude of the farmers who practise it. Shifting cultivators are in the habit of regarding the soil as a free gift of nature, not as capital which has to be maintained. Where soil fertility decreases and land is in the process of being eroded, shifting cultivators are much more inclined to 'mine' the land and to look for virgin territory than to invest labour in soil conservation.

With increasing population and larger production for sale, a number of distinct stages of development can be distinguished:

(a) The oldest form is probably the shifting of cultivation and of the farming group in one direction within a primary vegetation.

(b) According to the growing number of other claimants to land, the groups share the total area among themselves, and then each family shifts in a circle in the area allotted, which is covered by secondary vegetation, and moves on after one or several decades. Relatively intensive cultivation is temporarily practised near the dwelling ($\underline{R}$ = 30-50).

(c) With a further increase in population, instead of circular shifting with long-term intervals of fallow and cropping, there often occurs the shifting of fields within a fairly limited area, with the tendency to stationary housing where possible along a road. On the permanent site the hut position is sometimes changed.

(d) A continuous increase in population and the development of cash cropping involve an intensification of shifting cultivation by shortening the fallow ($\underline{R}$ rises to 30-60). At this stage the pattern of land utilization has changed to such an extent that the system is best regarded as semi-permanent farming and no longer as shifting cultivation.

Naturally, the crop yields of shifting systems vary greatly according to climate and soil type. In any case, however, the shortening of the fallow or the lengthening of the cultivation period beyond a certain point disturbs the equilibrium of the land use system. Shifting cultivation, which can be called 'balanced exploitation' where the fallow period is sufficiently long, turns into 'unbalanced' exploitation and 'soil mining'.

The increase in cultivation involves more thorough clearing, more intense hoeing and, at the same time, the death of roots and tree stumps. The fallow ground does not produce bush quickly enough, especially on soils of low fertility, after the years of cultivation, so that only weeds, grass, bamboo or wild banana establish themselves. Bush regeneration is made difficult, and the clearing of bamboo and many types of grass (especially, Imperata cylindrica) involves a high labour input. Almost everywhere in areas with shifting cultivation, in the dry season the burning of vast bush and forest areas takes place, partly from habit, partly to make hunting easier, and partly to get early fresh grass for the cattle before the beginning of the next rainy season. Regular grass fires also help to prevent the growth of forest and bush.

The interaction between grass and fire transforms the countryside of unbalanced shifting systems from a natural forest or bush vegetation into a grass savanna created by man. Grasses in the tropics, however, do not have the same ability as bushes or trees to remobilize nutrients and to accumulate organic matter. Trees and shrubs alone have the depth of rooting, the capacity to make good use of a large part of the rainfall throughout the whole year, and the ability to retain, in their own structure or in their leaf litter, a substantial portion of the nutrient material available.

The development problem in this context is that soil mining, i.e. the production in 'unbalanced' shifting systems, is often economic in terms of the individual family. With increasing population densities, no access to unclaimed land, and little non-agricultural employment, little else can be done within the framework of rainfed arable farming but to extend cropping at the expense of fallows. Lower yields per hectare which result from this are usually more than offset by the larger area, i.e. capital in the form of soil fertility is consumed in order to sustain a growing rural population and to allow for some cash cropping. The end of all this is a rural poorhouse with degraded soils and an impoverished population as we find it in extensive parts of India and an increasing number of areas in Africa.

DEVELOPMENT PATHS OF SHIFTING SYSTEMS

Shifting cultivation is obviously not essential in the tropics, but is rather an expression of a certain stage in population density and price relations. Its improvement or replacement by some land use systems more open to innovations is, however, by no means easy in the light of our present knowledge.

Improved shifting systems

(i) Shifting systems with planted fallow vegetation

Experiments to replace wild vegetation in the form of forest or bush, by planting quick-growing tree or shrub legumes, have as yet not been able to make much headway.

(ii) Shifting systems in forestry reserves

Foresters in several countries successfully combine shifting cultivation with planned reafforestation. The cultivators are allowed to cut down, burn and farm a certain area of unimproved forest allotted to them, on condition that the land is vacated after two to three years of cropping and that the forest trees (mahogany, teak, pines, etc.) which are planted in the second year are properly weeded. Then they receive a new plot. The only, but considerable, disadvantage in this process is that relatively few shifting cultivators can be absorbed. The felling cycle of timber is much longer than the usual fallow of 15 years, reaching 80 years with teak and mahogany and about 30 years with pines. The above method is thus well adapted to forest areas with little population pressure, but it is unsuitable for more densely populated areas that are inhabited by shifting cultivators.

(iii) The 'couloir' system

A large-scale experiment to regulate and improve shifting systems took place under the Belgian Colonial Administration in the Congo. In 1960, about two million hectares belonging to 200 000 shifting cultivators were cultivated under the 'couloir' system. The system consisted of a sufficiently large and fertile area being selected, declared a 'paysannat' in agreement with the population, and divided into straight strips. The individual families each received a strip of forest of 8-12 ha, of which 1-2 ha were cleared and cultivated whilst the remainder was fallow.

A rotation of cultivation years and fallow years was established on the plot. The plots cleared by each family were adjacent to each other, so that normally a cleared corridor ran through the forest. As clearance continued, this corridor shifted in one direction and left behind incipient secondary forest.

The 'couloir' system brings some increase in productivity per hectare and per man-unit, but it remains in principle a land use system which demands a great deal of land, the labour productivity remains at a low level, and it is a system which the participants often feel to be too rigid. It is also expensive in terms of public expenditure.

Summarizing, it can be said that efforts to improve shifting systems, i.e. to increase the productivity of land and labour within the framework of alternating crops with bush fallowing is rarely worthwile in terms of the cultivators, who are expected to practise the improved systems. Research and development efforts in this direction seem to be a waste of resources. Much more relevant is the gradual changing over to other systems.

The change from shifting systems to more intensive types of farming

(i) Change from shifting to permanent rainfed farming

The obvious development of shifting systems lies in a progressive shortening of the fallow, which leads finally to permanent agriculture after a period of semi-permanent agriculture or unregulated ley systems. In tropical high-altitude areas, especially on fertile soils and in the dry savannas, the development toward permanent farming has taken place to a considerable degree in a relatively short period. In the low altitude savanna and rain-forest climates, on the other hand, the introduction of systems with permanent arable farming presents a difficult problem from the standpoint of agronomy and farm economy.

Recent experience shows that permanent rainfed cultivation in the tropical lowlands is possible with heavy applications of mineral fertilizer and the maintenance of sufficient organic matter in the soil. Apparently, the needs are those of proper permanent farming in temperate zones, but at a much higher level of intensity. The problem is that this level of intensity is scarcely practicable under the input-output conditions of most cultivators. They prove mostly to be too complicated or too unrewarding to be adopted on a reasonably large scale by indigenous farmers.

(ii) Change from shifting to regulated ley farming

Another possibility of evolution is the replacement of the bush fallow that occupies the land for several years by plants which (1) are themselves usable, (2) regenerate the soil productivity, and (3) allow the use of the plough. The obvious way to achieve this is the transition to the ley system. However, the economic conditions for ley systems demanding much fertilizer are found only rarely. Much effort has been devoted towards the introduction of ley systems in Africa and only little has been achieved.

(iii) Change from shifting cultivation to perennial crops

The humid tropics are by nature forested, and the natural environment is relatively well-suited to perennial crops like bananas and to tree crops, a fact which is widely recognized and used by the shifting cultivators. The slowing down of the shifting cycle leads to stationary housing with more or less permanently cultivated gardens. Permanent banana groves develop, offering soil protection as well as high yields of calories per hectare. Wherever remunerative markets are available, shifting cultivators tend to plant tree crops such as rubber, coconut and cocoa in their plots, since these are less choked by weeds and demand less of the soil than annual crops. The cultivation years are thus not followed by regeneration of fallow vegetation, but by a stand of tree crops whose effects on the soil resemble those of forest and bush vegetation. Evolution of this kind has taken place on a large scale. Nowadays in tropical Africa thousands of hectares which were previously utilized by shifting cultivators support cocoa, oil palm and coffee. The evolution from shifting systems to perennial crops

Table 1

Length of the Crop and Fallow Periods under Shifting Cultivation

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

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

[a]Semi-permanent cultivation in our terminology

Source: NYE and GREENLAND (1960)

is obviously suitable for the natural conditions of the wet tropics in particular. Over and above this, it is a change which is relatively simple and cheap.

(iv) From shifting cultivation to irrigation farming, in particular to paddy rice

The experience of tropical Asia shows that the best system of arable cropping in a warm, damp climate lies in concentrating production in the relatively fertile, irrigated valley bottoms, i.e. by replacing shifting cultivation over large areas by irrigation farming, especially with rice, in small, intensively cultivated plots. The transition from the shifting system to the paddy rice system can be observed in large areas of the tropics (Madagascar, East Africa, Ceylon, Indonesia). It depends, as a rule, on the initiative of the indigenous population, and obviously represents an evolution which is ideally adapted to the special environmental conditions of agricultural production in the tropical lowlands.

Table 2

Labour Input (man-hours per hectare) into Land Clearing in Shifting Systems

	Borneo [a] Virgin forest	Borneo [a] Secondary forest	Guatemala [b] Milpa	Congo [c,d] Rainforest	Congo [d] Savanna	Congo [d] Pennisetum grassland
Slashing and felling	293-326	147-180	276	312-492	222	42
Burning and clearing	32-82	32-82	151	174-958	702-883 [e]	780 [e]

[a] Clearing for hill rice

[b] Clearing for maize

[c] Man-days for supervised work, assuming 6 hours per man-day

[d] Careful clearing with two burnings

[e] Including hoe cultivation: 450 hours per hectare.

Source: Borneo - FREEMAN (1955).
Guatemala - TAX (1963).
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SHIFTING CULTIVATION IN DEVELOPING AGRICULTURE

by

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INTRODUCTION

The motivation for the development of agriculture in general is the same as that for the improvement of shifting cultivation: to meet the food requirements of exponentially growing populations and to increase agricultural productivity for the betterment of the socio-economic status of rural populations as well as of the national economy.

The change to a more intensive farming system calls for careful and thorough planning and preparations and greatly increased services rendered to the farmer.

It is against such background that this paper is presented.

REASONS FOR IMPROVEMENT OF SHIFTING CULTIVATION

The urgency of the problems and the extent to which change is desirable vary in both complexity and degree. For example, there is less urgency in the forest zone where prevailing favourable climatic conditions are less destructive to soils, and again where land may also be available to a greater extent than in other climatic zones.

In certain parts of the Savanna zone on the other hand, either there are no fallow periods or they are so brief that they have little or no effect on the regeneration of soils. Consequently, action might first be required in the savanna zone, possibly leaving more time for the appropriate preparatory work in the forest zone.

(a) Demographic pressure

Demographic pressure combined with a reduced availability of suitable land is one of the main reasons causing the collapse of the system.

As a simplified example, let it be assumed that the average basic food requirement of a population is in the order of 300 kg of cereals per head per year. With an assumed average yield of 1 000 kg of cereals per hectare, it could be concluded that the food supply, excluding losses in storage, becomes critical when the population density exceeds three persons per hectare of food crops. The consequences are that either additional land has to be cultivated or yields per area unit have to be increased.

(b) Effect on Evironment

Besides providing industrial raw materials, a source of employment and an export commodity, forests are one of the climatic buffers on which mankind depends, and changes in the forest biomass have a significant effect on the environment, especially on climate.

With shifting cultivation being practised on an increasingly large scale forests are being felled to furnish new areas for the production of food for rapidly increasing populations.

In Latin America, between 5 and 10 million hectares of forest are felled annually for agriculture. In the Far East as a whole, it is thought that there are about 24.5 million shifting cultivators who annually fell up to about 8.5 million hectares of forest, and the total area under shifting cultivation is at least 103 million hectares.

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In Africa the opinion has been expressed that south of the Sahara, the original area of closed tropical forests has shrunk by at least 100 million hectares because of shifting cultivations. For example, in the Ivory Coast, forest inventories were made in 1956 and 1966. In the intervening period, 2 800 000 hectares, or 30 percent of the area covered by forests in 1956, were cleared by itinerant cultivators.

It is conceivable that these conditions could have influenced the onset of the drought which countries in the Sahelian zone have experienced during the last four years.

(c) Socio-Economic effects

In numerous developing countries some sectors of the national economy develop faster than the agricultural sector, and are thus, or appear to be, more attractive to the rural population. The economic gap between that portion of the population and the other social strata widens continuously, and rather frequently the peasant farmer is unable to profit from the increased purchasing power of his fellow countrymen because of the limits set by his farming system. Importation of foodstuffs is the consequence, so using capital which would be used more economically in the importation of investment goods.

An increase in the purchasing power of the rural sector would lead to a larger home market for local industries, the creation of jobs for artisans, and generally an improvement of rural living conditions, e.g. electricity and water supply, thus reducing the rural exodus which still exceeds the labour requirement of new industries and aggravates the problem of urban unemployment.

ELEMENTS FOR THE IMPROVEMENT OF SHIFTING CULTIVATION

(a) Research and Extension

In order to establish a sound basis for further improvement or replacement of the system, the social aspects of the problem should be kept in mind. To find, *a priori*, the best technical solution is certainly necessary and of great value, but as it is extremely difficult, if not impossible, to turn a traditional farmer nearly overnight into a modern farm manager, it might be wise to foresee a transition period including appropriate transitional methods. During this period the task would be not to impose the best technical solution on the people but to have at hand the best technical solution which is acceptable to the people. As mentioned earlier, the problems, although having certain features in common, differ in kind and degree of urgency between the forest and the savanna zone.

In the savanna zone it appears that in spite of considerable efforts to demonstrate sole cropping, the farmers largely continue to adhere to their traditional inter-cropping system. Concerning research in this field, Parish (1972) mentioned that "scientists have naturally tended to avoid becoming involved with work on inter-cropping because of its complicating effects on the problem they wish to study, be it soil fertility and fertilizer response, or some other aspects of crop production; for example, a study of the effects of fertilizer on yields in some of the complex cropping situations which exist would be most tedious and expensive, and understandably therefore almost all fertilizer research work in Africa has been carried out on pure stands".

Another aspect of the problem was pointed out by the Agricultural Economics Department of the Agricultural Research Institute, Samaru, after having studied small farmers inputs and outputs in three villages near Zaria. In the conclusions the following statements were made:

"There are valid reasons of technological, sociological and economic nature for the farmer's reluctance to change to a sole cropping system"

"This reluctance highlights one of the fundamental problems of extension workers. Unfortunately, most farmers remain unconvinced of the value of recommendations demonstrated by such individuals. Until these workers can suggest changes that have a convincing return, and yet do not involve big changes in farming methods, it is unlikely they will ever be truly effective in their work. It is suggested that once the farmer has adopted an innovation that does not conflict too much with his present traditional outlook, e.g. improvement of his returns from inter-cropping, it will then be easier for the extension worker to suggest more radical changes, e.g. sole cropping.''

The problem of inter-cropping versus sole cropping should also be seen from the point of view of soil conservation. Whereas inter-cropping as it is practised provides a cover for most of the soil surface, sole cropping, especially with cereals, leaves the ground open to the effects of heavy rainfall. Mulching in the savanna zone is dependant on availability of appropriate materials and possibly also on transport.

Farmyard manure and household refuse are are already used in the savanna zone. An improvement in both the quality and quantity of these manures would, together with other inputs, be an asset for the maintenance and increase of soil fertility and, consequently, would result in higher yields. Mixed farming, therefore, is recognized as an effective system to achieve this target. Although the availability of additional land may be limited, the system allows for higher production per unit area, thus leaving land for growing fodder for the animals. The spread of mixed farming migh be hampered by the traditional division of the population into herdsmen (often nomadic or semi-nomadic) and sedentary farmers who have little or no connexion with cattle. The introduction and extension of the use of draught oxen was an excellent way of making non-herdsmen familiar with cattle and also contributed to the economic resolution of the problem of transport over short distances. In certain cases it might be useful to revive this activity.

To effect a lasting improvement or change in the system, land classification and land-use planning would first have to receive more detailed attention as also would the application and economics of agricultural inputs such as improved seed, fertilizers and plant protection materials.

Whereas the behaviour of chemical fertilizers in tropical and sub-tropical soils has so far been relatively well covered by research, the role of calcium as a nutritional element and as a soil amendment appears to require more investigation before it can safely be recommended.

Appropriate soil conservation measures have to be found and/or introduced into the system, and in the field of agricultural engineering certain equipment may have to be designed or adapted to the new system and requirements, e.g. a seed drill for upland rice and a device for the placement of fertilizers, possibly both manually operated at least in the forest zone.

(b) Education and Training

The improvement or change of a farm system necessitates intensive educational and training activities. Agricultural education and training at all levels must provide excellent practical knowledge so that all those involved can see the problems from the right angle and have realistic innovations to offer the farmers.

In this connexion it might be worthwile to mention as an example the positive experience gained in some French speaking countries of Africa with an enterprise entitled ''Rural Animation'', of which the basic principles were:

(i) Closest possible coordination of all services involved in rural development;

(ii) Motivation of the rural population towards innovations and self-help action, e.g. use of improved seeds and fertilizers (in connexion, of course, with the appropriate demonstration and extension work), formation of cooperatives, organization of sound agricultural credit, construction of schools, etc.

Another positive experience was the ''Young Farmers Centres for Professional Perfection''. The characteristics of these Centres are that young farmers are familiarized with the recommended system and practices throughout an entire agricultural season. The course consists basically of practical training only and the participants live in an environment which corresponds as much as possible to that of their homes. At the end of the course, they receive, on credit, the equipment necessary to apply the improved practices on their farms.

(c) Agricultural Inputs and Marketing

Increased agricultural inputs are necessary to increase crop production. Their acceptance by the farmer is to a great extent conditioned by the economics of their application or, in other words, by their value: cost ratio. FAO generally considers that a value: cost ratio of 2 provides enough incentive for a farmer to use inputs, although others advocate a ratio of 3 which makes the decision still easier for the farmer. To avoid misunderstanding it should be mentioned in this connexion that the value: cost ratio alone could be misleading, and that especially in the case of fertilizers the institution responsible for the formulation of recommendations should be constantly aware of the marginal rate of return which, logically, should not be below 0 percent.

To motivate the farmer to adopt innovations, appropriate incentives such as acceptable value: cost ratios should be provided. Whereas it is the task of research and extension to find out the effect on productivity of the various inputs and to provide for their most appropriate application, it is an option of policy either to keep input prices on a relatively low level (with consequently relatively low prices for staple food crops which correspond to the purchasing power of the majority of the population) or to grant less or no subsidies which results in higher costs of production.

Unless inputs are available at the right time in the quantity and quality required, efforts to introduce and extend their use will be of little value and may even have an adverse effect on the farming community. Such a difficulty may be due to late ordering which in turn may be caused by inefficient agents. A uniform price throughout a country helps to avoid speculation and reduces the risk of local artificial shortages.

Increased crop production requires also improvement of the output marketing system and an adequate marketing and transport infrastructure.

(d) Farmers Institutions

The merits of sound 'farmers' 'institutions' such as farmers· associations or agricultural cooperatives are well known. Where the motivation for these orginates from within the community among groups of small farmers producing staple foods, their success is generally assured. However, when imposed on the farmers from above, or outside, success is less certain. Some countries have recognized this and have made an entirely new start by working up from small groups of individuals.

It has also been found that the existence of both farmers institutions and private traders leads to sound competition to the advantage of farmers. Farmers institutions will be considerably stengthened when the farm income and rural development offer enough incentive for school leavers to stay on the farms.

(e) Agricultural Credit

The extension of sound credit to small farmers is one of the basic pre-conditions for agricultural development. In many cases earlier errors in this field may have to be corrected, and it might be best to start from small groups providing mutual responsibility and security.

In an early stage, credit should be extended in kind. It is the task of the agricultural extensionist to assist the farmer in making the best possible use of this credit, but it is not the extensionist's task to act as a debt collector.

As already mentioned, the system requires increased services to the farmers. In some countries, the extension of bank services to rural areas through mobile units has proved to be very useful and effective.

IMPROVEMENT OF SHIFTING CULTIVATION - PHASES OF A PROGRAMME

Planning of a comprehensive programme aimed at improvement or replacement of shifting cultivation in its various forms can be divided into the following phases:

(a) Preliminary Study

Before launching the programme it would first be necessary to define the problems by:

(i) a description of present conditions and their rationale;

(ii) a definition, and eventually classification of the various forms of the system;

(iii) an inventory of the actions already taken and a compilation of their results.

(b) Inventory Phase

This phase should consist of drawing up a comprehensive inventory, especially on problem areas which might have been defined by the first phase.

The inventory would cover the main elements connected with farming systems such as soil, water and forestry resources, land appraisal, population, livestock, quantitative data about agriculture as presently practised, family budgets, nutritional levels, etc.

Hence, statistical studies would be of prime importance. At the same time, the sociological aspects should be studied, including land tenure and subjective incentives for a change of the system.

(c) Research Phase

The knowledge obtained from the aforementioned phases will allow a plan for basic and applied research to be drawn up.

This research will originally be carried out at experiment stations, and later on, in fields strategically located in the areas under study.

(d) Pre-Extension and Training Phase

During this phase, the results of research programmes should be tested in pilot schemes, not only to confirm the technical aspects but also to determine people's reaction to the proposed solutions.

This phase would also be appropriate for training of the field staff to be entrusted later with the extension of the improved or new methods.

(e) Extension Phase

Once the pre-conditions have been met and preparations terminated in all fields of intervention, the extension phase could be started, bearing in mind that the results will be a function of the quality and quantity both of spiritual and material inputs invested in the action.

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CHANGES OF FARMING SYSTEMS IN AREAS OF SHIFTING CULTIVATION

by

C.L. Pierson*

When considering changes in farming systems in areas of shifting cultivation, it should be kept in mind that each traditional system of cultivation is specific with regard to ecological constraints and to social structures prevailing in that particular area. Thus, changes which are now taking place under the pressure of both the move towards a market economy and the population growth are very much hampered by the weight of these factors, the relative importance of which gives its specificity to each system.

In Africa, but for the citimene system in Zambia which can be considered as rather close to a genuine shifting cultivation system, most of the traditional patterns of land use are more the 'bush fallow' system than shifting agriculture. In fact, the only typical shifting cultivation systems are peculiar to some place in southern Asia, mainly in mountainous areas where opium producers have shown themselves as the most efficient forest destroyers to be found.

However all previous attempts to classify the various systems have been shown to be relevant only for limited areas, especially because in many parts of the Continent, for historical reasons, one can find various ethnic groups all closely integrated, though each one still has its own way of life. The case of the population along the Senegal River can be mentioned as an example of the complexity of such a classification: fishermen have a limited right to crop, farmers cultivate well-defined areas, sedentary and semi-sedentary Fulanis also farm, and finally the nomads are the owners of some lands farmed by other groups.

This example leads to the conclusion that shifting cultivation is less a primitive device than a remarkable adaptation of a non-mechanized agricultural society to the constraints of the environment in order to meet its daily needs.

This conclusion is corroborated by the remarkable practical knowledge shown by the farmers in selecting the areas to be cleared on the basis of the natural vegetation, in the elasticity of their rotations in regard to the soils, in their astonishing awareness of the succession or association of the weeds, bushes or trees, as indicators of the decrease or the regeneration of fertility.

Hitherto in Africa, under the pressure of population growth, greater output in agriculture has been mainly achieved by increasing the cultivated areas instead of by increasing the productivity, as shown in Table 1 for two of the staple crops.

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Table 1 - Annual Rate of Increase (%) for Sorghum and Millet

	1948-52/1964-68	1952-56/1964-68
North America		
Production	9.3	10.8
Area	3.4	3.0
Yield	5.6	7.6
Latin America		
Production	10.4	11.9
Area	6.8	7.3
Yield	3.4	4.3
Europe		
Production	5.0	5.8
Area	0.1	0.4
Yield	4.8	5.3
Africa		
Production	2.3	2.5
Area	1.2	1.4
Yield	1.1	1.1

One of the conclusions to be drawn from Table 1 is that food production per head is likely to be static or declining in most countries as one of the consequences of social, cultural, economic and sometimes technical changes which are endangering the whole pattern of shifting cultivation. Unfortunately, only seldom has action been taken to tackle the problems posed by the increasing hunger for new lands.

Most current development programmes place more emphasis on 'capital intensive transformation' than on 'improvement' of existing production systems. Thus, investments are mainly concentrated on areas which were traditionally considered as 'uncultivable'.

It is well established that 'transformation' can be productive of much more rapid and spectacular results because it is on the one hand unhampered by the complexity of traditional agriculture and on the other hand enhanced by the fact that as it usually deals mainly with cash crops it benefits from a matchless incentive: money. But this also implies that the old systems under which productivity is steadily declining under the pressures of an irreversible evolution, will have to continue to supply the bulk of the nation's food supply.

There is little doubt that the increasing popularity of permanent or semi-permanent crops as a major source of cash has been contributing to the settlement of agriculture. But until now the traditional farmers still devote most of their labour to the food crops which remain for them the best insurance for survival. As these food crops are still considered subsistence crops the modernization of this area still remains very difficult because of its inability to bear the costs of increased input, because of the lack of adequate marketing structures and last, but not least, because of very low yield and low labour productivity.

Several attempts have been made to settle and modernize agriculture, few of which have been encouraging.

Most attempts were oriented toward a structuring of the traditional local system to keep the shifting within narrow geographical boundaries, but often overlooking the diversity of African soils, the still controversial use of intercropping and the fantastic hunger for land which resulted from the population explosion.

Other attempts were based on the extension of permanent cash crops which finally led to competition between cash crops and food crops. The result has always been the same, in the long run the food crops suffered.

Disappointed by these poor accomplishments, but at the same time keeping in mind some scattered attempts which showed more encouraging results, one wonders if an exhaustive evaluation might not be made by an integrated and multidisciplinary team to investigate all the contributing factors inherent in the previous failures and successes.

Are we sure that all our proposals which were technically encouraging in research centres were really suitable for the traditional farmer in his environment, taken as a whole with its traditional, social, financial and mechanical limitations? Should we not keep in mind that an African farmer is not a producer of coffee, maize or pigs, but all these at the same time? The traditional farmer has hitherto shown an integrated approach towards his environment in view to exploiting it with the minimum labour cost, and obtaining the optimum return. Perhaps the best illustration of this is the fact that in West Africa, the best farmers are the nomad cattle breeders. As soon as they settle they integrate animal breeding and cropping through an intensive use of manure and a ready adaptation of ox-drawn implements for soil preparation and transport.

In Dahomey and Togo, a fast and wide-spreading evolution is taking place through this kind of integration in which animals are no longer kept solely as a source of milk and meat and a sign of wealth, but also as the main provider of energy in many of the production activities. Other important steps have been reached by the increasing interest shown by farmers for lay farming and rapid turnover of their animals to supply the growing market of meat.

This encouraging development could give rise to optimism that this kind of evolution of the production system could also take place elsewhere, however, we should not be too optimistic. Many problems are still unsolved, and we cannot yet think of duplicating indiscriminately such a programme of development. It has taken place in an area where land is still available and where climatic conditions are suitable for only one crop a year and intercropping is uncommon.

In some areas of the Cameroons, under intense demographic pressure, some farmers are trying to adopt a completely different system of cultivation, switching from a genuine shifting cultivation with a factor equal to or above 10 to a semi-permanent system with a factor below 2 or 3. These farmers establish contour strips of grass to control water erosion; they use leguminous crops for fodder fresh or dry, in combination with the grasses from the contour strips. The trend now is to try to introduce oxen as a possible source of manure and energy as well as a source of complementary revenue by fattening. Nothing is yet known about how the soils are going to respond to this drastic change nor about the kind of tillage which would be suitable.

When examining the various cultivation systems, one can see that they vary from one region to another and that the land use factor (ratio of fallow period to cropping period) are related to the ecological conditions and the kind of crop. It seems that nothing has been done to investigate the precise changes in the soil and the relative importance of the factors involved.

It appears also that the traditional techniques of soil preparation have been hastily dismissed as irrelevant. These techniques vary from one soil to another and from one crop to another. The depth and the frequency of ploughing can vary considerably and often the tools are well adapted to a specific operation or crop. These conditions are not, of course, general throughout Africa, but one might expect to find them prevalent in areas where population density has limited the farmers to a land use factor below 3, i.e. where cultivation is permanent or semi-permanent.

In many areas of Africa, water is the most important limiting factor, one should therefore investigate in further depth the various aspects of water balance in cultivated fields in relation to soil preparation, weeding and burying of organic matter from hay or fallow. Of course plant water requirements are known but what about the supply and availability of this water in the cultivated fields? Have we never seen crops cultivated with traditional techniques peforming better than in research centres with regard to drought resistance, even though the varieties used were the same?

There is no doubt that we have the devices and the means to overcome all these adverse factors. Unfortunately for the farmers, we too often talk in terms of increasing the inputs (intensification of mechanization, fertilizers, irrigation, pesticides). We ought to bear in mind that relative to the size of the individual estate all these inputs are comparatively immoderate and that the possible return, though reasonable, will remain very small, unattractive and even risky.

Now that concrete, though incomplete, proposals are being made to steer African farming away from traditional cultivation methods and towards capital intensive food crop systems, it is probably appropriate to examine proposals for improving existing methods and thus reach by progressive means a level of productivity which will not irreversibly upset the food production capacity of Africa.

Two proposals can now be made to all scientists dealing with the inescapable but still unsolved problem of shifting cultivation.

First, examine the suitability of the recommendations to the farmers. At best the proposals will contribute only to a slow process towards improving the current system but at least they will involve the farmers more deeply in the possible changes.

At present technical advice is mainly transmitted to farmers through demonstration plots in farmer's fields but most of the operations are conducted by extension workers. It might be worthwhile to have the farmer himself, under technical supervision, doing all the operations with all the limitations that it implies. By so doing experiments will become a community effort and through their complete involvement the farmer and his fellow men will more readily understand and absorb.

This kind of demonstration on farms should be organized on an extensive scale so that the effects would be widespread. An essential preliminary condition is that those in charge of the programme should be thoroughly familiar with traditional techniques in order to know what to retain, what to improve and what to discard.

Second, investigate the pattern of shifting cultivation as an entity, covering the whole cycle of a shift and not piecemeal. It is unsatisfactory to tackle each aspect (soil, crops, tillage, weeding and social) individually. Studies should be undertaken in diverse environments to give us the most comprehensive knowledge. In this way it should be possible to learn the full technical reasons that may justify the traditional shifting and cropping methods.

FOOD PRODUCTION AND FORESTRY IN THE HIGH FOREST ZONE OF NIGERIA

by

R.G. Lowe*

The Forestry Services are the largest estate owners in the country. In the southern states they clear annually about 20 000 acre (8 000 ha) of forest, a substantial proportion of which which is employed in the production of food crops at the same time as the new timber crop is established. This uses the residual fertility from the natural forest which would otherwise be lost, and the farming operations assist the growth of the young trees. In the southeast state the farming operations are carried out directly by the Forest Department, though in other states it is more usual to obtain the cooperation of peasant farmers. These are prepared to carry out a large proportion of the task of removing the original forest cover without payment, in exchange for permission to farm the land they have cleared for 2 or 3 years. Forestry is already responsible for the production of about ₦ 1 million of food crops annually, which could rise to well over ₦ 10 million during this decade (at present values). The area of land cleared annually for timber crops should rise to 150 000 acre (60 000 ha) during the present decade, if projected wood requirements are to be met.

The peasant farmer and his wife can clear and maintain about 1 acre (0.4 ha) of new land each year.At Awi the South Eastern State Forest Department earns ₦ 44 per acre (₦ 109 per ha) from maize and cassava. Farmers on the more fertile soil at Gambari could almost double this to ₦ 100 per acre (₦ 250 per ha). By concentrating on producing yams, earnings can be raised to between ₦ 300 and ₦ 600 per acre (₦ 750 to ₦ 1 500 per ha) per annum. This compares with a basic Government labourers wage of about ₦ 270 per annum. The area of forest that a man can clear and maintain is the single most important limiting factor on his earnings. Without using costly machinery for land clearance, at between ₦ 100 and ₦ 200 per acre (₦ 250 to ₦ 500 per hectare), limited improvement is possible. In the high forest area there is no intermediate technology between the hoe and the heavy crawler tractor. This is unlike the savanna zones where oxdrawn equipment and light tractors can provide intermediate stages in mechanization.

Timber crops, like other permanent crops such as cocoa or oil palm, are capable of yielding more profit than shifting cultivation alone with annual foodcrops, as the approximate figures in Table 1 show. In fact the average taungya farmer earns less, making a net loss on the cost of his labour (Andrews, verbal communication). The consequence is that farming for food crops is unattractive in the high forest zone, except for subsistence and as a prècursor for tree crops. Where farming is combined with the establishment of tree crops, the use of hand labour for clearing the land is considerably cheaper than the use of machinery.

So far as peasant farming in the high forest area is concerned we are already seeing the beginning of the end. The portents are already clear in agricultural stagnation, a population of farmers which does not enlarge and of which the average age increases. Rural school leavers would prefer to work as paid labourers on a regular wage with adequate domestic and health facilities, than to suffer the uncertainties of self employment and continued parental authority, even with a slightly higher gross income. The peasant farmer will never produce enough cheap food to supply Nigeria's enlarging urban population. He is concerned mainly with producing enough food for his family's subsistence, selling any surplus, and not with food production by cash cropping. Assistance to them should be recognized for what it is : a political necessity.

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The only effective alternative with a long term future is adequately capitalized and efficient agriculture. Government would be required to mobilize the capital and to organize the supply of land; the plantations could be run by competent management companies. Such a development would supply employment for agricultural graduates to use their expertise directly; it could supply the cheap food which the country needs and bring to the rural areas an improved quality of life which might encourage the country dweller to stay where he is most needed.

Table 1 - Approximate net present worth of timber crops (Naira per acre)

Crop	Rotation (years)	Yield (cu.ft./acre		Discounted net income from 60 years to beginning ₦			
		Main crop	Thinnings		6 %	8 %	10 %
Gmelina pulpwood	7	3 000	-	Final	500	350	250
Gmelina timber	15	3 000	2 000	Final Intermediate	350 70	220 60	130 50
Terminalia timber	30	4 000	-	Final	150	55	-7
Teak timber (taungya)	60	3 000	3 000	Final Intermediate	90 260	10 180	-15 +125
Peasant farming (maize & yams)	2 + 5 = 7	₦ 300 per acre			170	120	80
Note: For peasant farming labour has been charged at ₦ 250 per acre							
Mahogany/Nauclea timber + poles (taungya)	70	3 000	4 500	Final Intermediate	15 75	0 50	-5 +15

SOME OBSERVATIONS ON BASIC AND APPLIED RESEARCH IN SHIFTING CULTIVATION

by

P.M. Ahn *

INTRODUCTION

Previous papers presented at this seminar dealt with problems of nomenclature and definition, with types of shifting cultivation, particularly in Africa, with the soil and the water aspects of the topic and with the reasons for shifting cultivation as far as they are at present understood. To some extent these papers themselves suggest areas where our knowledge is inadequate and where further research is required. To this extent they overlap with the present contribution.

The papers presented serve to emphasize the great variety of practices included under the general term 'shifting cultivation' and the variety of physical and human environments in which these practices are found. They suggest therefore the great and sometimes bewildering complexity of the soil and water aspects involved in any fundamental research on shifting cultivation. It is this many-sided, complex aspect of the subject that it is wished to emphasize first.

Scope of the subject

When a farmer clears natural vegetation and grows a crop he raises in the mind of the scientifi investigator questions which involve, to varying extents, almost every known aspect of soil science. These aspects include our present knowledge of tropical soils and their characteristic of soil fertility and plant nutrition, of soil microbiology, of soil physics and our knowledge of the dynamics of soil change during the cultivation period. It would, in short, be difficult to demonstrate that any important general aspect of soil science did not have a bearing on shifting cultivation. Nevertheless, 'fundamental research in shifting cultivation' is here taken to mean mainly fundamental research on shifting cultivation itself, including changes that take place during clearing, cropping and fallow.

When we turn to applied research, it is not easy or necessarily advisable to limit the discussion to shifting cultivation per se. Obviously the relevant applied research includes research on other systems which we hope might replace or modify existing shifting cultivation systems.

The relative urgency of different lines of research

An essential first step is to summarize what we already know and then, just as important, to try to indicate major gaps in our knowledge. Do these gaps really matter? Some researchers appear motivated by curiosity, sometimes referred to as 'scientific curiosity' . This curiosit has sometimes resulted in discoveries of the greatest importance, and of course any additional knowledge might have practical consequences. But this is nevertheless a 'hit and miss' appro and today we live in an age where results are more likely to be obtained by teams of workers (often from different but related disciplines) acting on an agreed but flexible programme rather than by isolated individuals motivated primarily by curiosity, scientific or otherwise. As in many other areas of human endeavour, we need: -

(a) to define our objectives as precisely as possible, or at least to define our questions as precisely as possible, and to put them in some order of priority, and

(b) to work out the most efficient means of achieving the objectives, or of answering the questions defined in (a).

Obvious as these general statements are, they are frequently ignored.

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Two contrasting approaches to change

To many investigators, it appears that there are two distinct and contrasting approaches to the question of changing shifting cultivation. The first approach seeks to modify shifting cultivation practices slowly, step by step. The second approach seeks to introduce alternative systems of commercial agriculture which seek to make use of all relevant aspects of modern science and technology from the start.

The step by step approach, which the author calls the ''hasten slowly'' (festina lente) approach, recognizes the fact that shifting cultivation is a system which has undoubted advantages and which works fairly well when the ratio of people to land is still moderate. Moreover, it is a system which will certainly persist for a long time to come in many areas. As yet, there does not appear to be any alternative system of continuous arable mechanized cultivation which has proved workable and economic in most of the areas where shifting cultivation is important. Advocates of the 'hasten slowly' approach therefore recommend progressive modification of the system designed to retain its advantages and to minimize its disadvantages. In particular, they direct attention to raising yields and to lengthening the cropping period in relation to fallow. These modifications are considered more likely to be successful if we know more about current methods and have a greater scientific appreciation of what is actually happening during the three important phases of clearing and burning, cropping, and fallow.

The alternative approach, in its more extreme form, considers that shifting cultivation suffers from overriding disadvantages, particularly from the fact that it is wasteful of land and gives low yields, and that it is an archaic system that must by swept aside by new systems which make use of modern technology. These views were expressed more frequently 30 years ago than they are today, since many of the attempts at sudden change have failed, sometimes spectacularly. Nevertheless, the argument persists that once a farmer goes in for commercial agriculture (as distinct from subsistence farming as a way of life) the use of one single improvement, such as the introduction of hybrid seed or higher yielding varieties, inevitably entails, if it is to be fully effective, introducing at the same time the whole apparatus of modern commercial agriculture, including better management, the use of fertilizers, insecticides, weedicides and other products of modern chemical technology, and at least some measure of mechanization in some cases and perhaps irrigation.

Differences between the two approaches may not be as great as may appear at first. Both approaches agree that change is necessary, and both approaches are in fact limited in practice by (a) our knowledge of the technical answers needed to improve on existing practices and (b) by economic and social factors which delay a change-over to a commercial economy as against a more or less subsistence one. In any case, it is as well to remind ourselves again of the very great variety of soils and environments in which shifting cultivation is practized. Different approaches and different combinations of methods will certainly be needed to meet local needs and to make the best use of local opportunities

THE MAIN AREAS OF RESEARCH

In the following paragraph research topics are discussed under a number of overlapping headings:

A. The physical environment: the need to characterize local climate and soils, and to relate agriculture to its ecological zone.

B. Information on current practices: detailed local information on existing methods, criteria used in selecting land and in abandoning it, and local attitudes to innovation and change.

C. Fundamental research on soil and other aspects of shifting cultivation: this can usefully be considered under Nye & Greenland's (1960) divisions of

   i. What happens during clearing and burning;
   ii. Changes during the cropping period and reasons for loss of productivity;
   iii. Changes that occur during fallow, particularly ways in which soil productivity is restored.

D. Research on improvements and alternatives: including (a) knowledge of practices which successfully increase yields, lengthen cropping periods or otherwise modify existing shifting cultivation, (b) information on attempts at continuous cropping and on alternative systems of agriculture.

In discussing the above, emphasis will be placed on the extent of present knowledge, on relative priorities, on the need to relate all work to the particular environment (physical, economic and social) in which it is carried out, and, last but no means least, on the practical difficulties research has encountered in the past and is likely to continue to encounter.

A. The Physical Environment

i. Climate and Vegetation

Ecologically the farmer is clearing the natural vegetation and substituting for it other plants, more useful to him, adapted to the environment. To some extent natural vegetation gives an indication of agricultural possibilities. Both systems of shifting cultivation and the crops grown change with climate. Even within areas of similar climate, shifting cultivatio methods may be locally modified to adapt them to soil conditions, or they may be different because different groups of cultivators are involved.

The most important climate data required are rainfall distribution and reliability. Other data required include temperature, hours of sunshine, humidity, potential evapo-transpiration and other generally less important factors such as winds. It is also important to realize the possible effects of microclimates- for example, differences of air and ground temperatures and of humidity between (for example) a patch of forest and an open farm patch without shade trees next to it. Such information is available only very occasionally. The following tabulated data give some microclimatic differences between adjacent forest and cleared patches at Kade, southern Ghana, as recorded by university students from the Dept. of Botany on a field exercise:

		High forest	Adjacent cleared plot
Relative humidity,	14.30 hours	91 %	62 %
	17.30 hours	100 %	89 %
Soil temperature at	15.00 hours (°C)		
	Surface litter	28.0	40.3
	At 7.5 cm	25.0	30.0
	At 36.0 cm	24.8	28.0

If climatic data are to be relied on and subjected to statistical analysis, then it is necessary to record them over a period of years (at least 10, preferably 30). A statistical analysis of the data can then indicate the probability of any particular climatic event taking place, and these calculations are used particularly in regard to probable dates of the onset of rains and probability that a certain minimum fall of rain will be received over a growing season of a stated number of months. It might, for example, be calculated that at a certain locality there are three chances out of four that rains will start in April and that there will be three months with at least 125 mm per month. A farmer using this information would then expect to have less rain, and possibly a crop failure, one year in four on the average.

Considerable emphasis has been placed on rainfall probabilities in East Africa, particularly by EAAFRO in its programme of work on the theme ''making the best use of low or erratic rainfalls''. In brief, the EAAFRO approach (as described by Russell, 1968b) demands (a) a knowledge of how much rain can be expected statistically at a location, and (b) a knowledge of the rainfall requirements during the growing season of specific crops and crop varieties in order to marry the crop to the possible rainfall. In practice this approach is limited in almost all areas of shifting cultivation by our lack of detailed, reliable knowledge of rainfall probabilities, and also by how surprisingly little we know about crop water requirements at different stages of growth. When rainfalls and rainfall probabilities are known, then it might be possible to assess the relative advantages, for example, of a five month maize with high yields which can be expected to succeed two years out of three, or a local four month maize with low yields which can be expected to give some yield every year.

The shifting cultivator has evolved his own insurance methods to deal with unrealiable rainfalls, but the insurance premium he pays for this reduction of risk is often a drop in yields. In the Baoule - V of the central Ivory Coast, for example, the author has observed yams, the staple crop, being planted on a wide range of soils, from upland to valley bottom: in a dry year the farmer gets his harvest from the valley bottom soils but the upland yams die of drought; in a wet year the valley bottom yams die of suffocation, and rot, but the upland soils give a crop.

In upgrading shifting agriculture, increasing use must be made of climatic statistics and probabilities. The response to fertilizers on farmers' plots, depends on adequate rainfall: lower rains than usual might result in yields being decreased by the fertilizer, as happened to tobacco farmers at Ejura, in Ghana, who subsequently became discouraged. Again, a fertilizer might give a response in the major rains but fail to give any response on the same soils and with the same crops during the minor wet season.

It is probably true that in the areas of the world where shifting cultivation is practised the major limiting factor is simply water. Even in some of the wetter forested areas, there are periods of the year when water is in short supply, and it has been found that irrigation may be economic for such crops as banana and oil palm. In drier areas rainfall failures lead to crop failures and sometimes to famine. With so much emphasis on fertilizers, improved seed and other improvements it is as well to remember that everything else depends on water, which usually means the natural rainfall.

A greater knowledge of climates and microclimates is necessary therefore not only to assess the extent to which existing methods of cultivation are adapted to the local environment, but as a guide to what crops and crop practices can be successfully introduced.

Practical difficulties at present include the paucity of long established climatic recording stations, the wide range of annual fluctuations often encountered, the lack of information on microclimates and the local effects of aspect, relief etc., and the difficulty and danger of interpolating statistics for areas away from stations.

ii. Soils

Soils are an integral part of the environment which reflect the local geology and relief, climate and vegetation. The soil scientist knows that the soils under forest cannot be the same as those under savanna, that soils of wet areas are different from those of dry areas and that soils over sandstone are always very different from those over, for example, basalt. The answer of the soil scientist and agronomist faced with this infinite variety of soils is the process known as soil correlation. Soil correlation is essentially an attempt to compare and consider together sufficiently similar soils in the hope that what we have found out about one soil can usefully be applied to comparable ones.

The process of relating agricultural practices and trial results to specific soils or specific soil characteristics can only continue when there is also sufficient basic soil information to allow comparisons to be made. Unfortunately it is surprising how few papers publishing the results of agronomic work give even abbreviated information on the soil. For example, a recent paper on the role of organic manures in maintaining soil fertility under continuous cultivation in Northern Nigeria (Heathcote, 1970) gave almost no information on soil characteristics, not even soil texture, and this is not an unusual example. Drosdoff (1972) summarising current work on micronutrients wrote:

''There are many difficulties ... One is the general lack of specific information on the characteristics of the soils under study. In many instances no information at all is given on the kind of the soil, merely the location. In other cases a series of local names is given without any additional information ... generally the information is limited and difficult to interpret.''

This lack of soil data relating to agronomic work may result in part from increasing specialization: a spectographer working in the laboratory on trace elements or an agronomist carrying out field trials may not be technically qualified to sample, describe, analyse and classify the soil, so that he pays little attention to these aspects. What is needed in such cases is interdisciplinary team work, the team to include soil scientists capable of giving the information wanted. The author's personal experience is that surprisingly few agronomists, and even many soil scientists, have little idea how to sample a soil correctly, and thus ignore the old adage that 'the analysis is no better than the sample.' Correct soil sampling is essential if laboratory results are to have any value. For profile pits this means a very careful division into natural horizons. For bulk sampling this means taking frequent cores of uniform thickness to a stated depth, and the important factor is the number of samples taken, which is often inadequate. The greatest practical difficulty is the heterogeneity of the soil, particularly variations over very short distances. Soil heterogeneity is a topic of the greatest practical importance and is considered in more detail below.

The local cultivator has often surprisingly detailed knowledge of local soil characteristics and adapts and modifies his methods accordingly. Far too little attention has been given to examining and using this local knowledge. Local farmers are often guided by the associated natural vegetation (both trees and grasses). They often distinguish soils mainly on the basis of texture and drainage, the main division being between extremely heavy soils, such as black clays, which are too heavy to work with local hand tools and are left uncultivated, medium textured soils, and extremely light sandy soils. Colour is sometimes used as a guide. Drainage characteristics serve to distinguish soils of valley bottoms subject to waterlogging from upland soils. Often a variety of local names are given to soils, with var ing degrees of consistency. What is of interest is the extent to which local clearing, cropping and fallow practices vary on different soils, the reasons for these differences, and their validity.

What soils information is necessary when studying shifting cultivation and agricultural trials? Ideally a full profile description and set of routine analyses should be included, but here, as elsewhere, a compromise may be necessary and it is important to specify priorities. Essential are the pH (the single most important laboratory determination and the cheapest), texture, drainage, and an indication of broad parent material (e.g. recent alluvium, acid crystalline rocks etc.), and the organic matter content. The latter reflects the vegetation zone and the history of cultivation.

Very desirable, but less essential, are structure and consistency, the nature of the clay mineral, the cation exchange capacity and the exchangeable bases. Total phosphorus is difficult to interpret; available phosphorus by a stated extractant may be helpful, particularly in trials involving P applications, but correlations with responses in the field have sometimes been very poor. A knowledge of the weatherable mineral content of the sand and silt fractions serves to indicate what reserves, if any, are in the soil apart from those in the organic matter, thus separating soils with long-term powers of recuperation from those which consist of little except resistant residues once the humus has gone. More detailed information on physical properties, particularly 'true' and 'natural' textures (discussed further below) might help in predicting physical deterioration during prolonged cropping.

Nowadays there is an increasing tendency to classify the soil according to both local systems and the U.S. Seventh Approximation. This helps in soil correlation. However, it should be remembered that the U.S. classification is not designed to group soils according to their agricultural vocation, and that it ignores or does not emphasize many aspects of practical importance. Classifying the soil is therefore no substitute for giving basic information on it in the text. Perhaps the main benefit of the U.S. 7th Approximation so far is that it has forced us to look at the soil very carefully and to take note of features which formerly were given inadequate attention.

About half of the land between the tropics of Cancer and Capricorn lies in Africa. A soils feature of widespread occurrence in tropical Africa is the soil catena. A soil catena is simply a fairly regular sequence of soils related to relief. Differences between soils are partly due to (1) differences of site and drainage, giving a drainage sequence from well drained at the summit to poorly drained soils in flat valley bottoms, and (2) differences of local parent material, since upland soils are often sedentary while those on lower slopes and in valley bottoms may be developed in local colluvium and in alluvium.

From the point of view of research on shifting cultivation, two aspects of soil catenas are worthy of emphasis. The first is that catenas, rather than individual soils, are often used as the soil mapping unit, particularly at medium scales such as 1:250 000 or 1:100 000: it often needs a relatively large scale (such as 1:10 000) to show individual soil series and these maps are expensive and only rarely available. The second consideration is that the catena as a whole should be considered in agronomic and land use planning: the shifting cultivator often has patches in different parts of the catena which he uses in different ways. He may put rice, maize and chewing cane on poorly drained sites and other crops on the uplands. Rational agriculture would also consider the catena as a whole, with different crops in the valley bottoms, on steep slopes and on well drained gentle slopes. It has been suggested that grass in valley bottoms should be cut for use as mulch for the slopes, so 'moving soil fertility up the slope' .

iii. The use of ''Ecological Zones'' in Agriculture

The use and definition of natural ecological zones is a convenient way of grouping and handling a wealth of related information on climate, vegetation and soils. If climate maps, vegetation maps and soils maps are compared - particularly small-scale maps showing fairly large areas - there is often a broad degree of similarity or correlation between them. These correlations are particularly well developed in West Africa where there are successive belts of decreasing rainfall more or less parallel to the coast which correlate with vegetation belts. Since climate and vegetation both strongly influence soils, it is not surprising that we can recognize soil belts which correspond broadly to the climate and vegetation belts, even though local variety is produced by differences in relief and geology.

In comparing agricultural systems it is very desirable to relate them to these natural ecological zones. Trial results at one site are more likely to be relevant to another site within the same zone than to one outside it, and there is a strong case for correlating information on this basis. In West Africa though fertilizer responses may appear varied and haphazard at first, they can in a broad way be related to ecological zones, with nitrogen being generally required in the savanna areas but only seldom in the forest zone, while potassium responses, with some exceptions, show the opposite trend, i.e. they are frequent on forest soils but relatively uncommon in the savanna (Nye & Greenland, 1960; Ahn, 1968 b).

The division into savanna and forest is the first and perhaps most important one in many parts of Africa. Differences between the two zones include differences of climate (particularly length of dry season), natural vegetation, relief and soils, and hence differences in agricultural possibilities. In West Africa in particular, savanna soils are generally shallower than forest soils, often less weathered, usually less leached and of higher pH, and are often associated with more gentle relief. They are nearly always much lower in organic matter than forest soils due to the sparser vegetation and the prevalence of annual burning over wide areas. Forest soils are often deeper than savanna soils, and more productive because of higher organic matter contents and because of the better rainfall distribution.

However, this broad division into forest and savanna, important as it is, is not enough. Within these two major divisions important subdivisions related to differences in rainfall and vegetation, and in some important cases to altitude, must be recognized and related to agricultural opportunities.

Within the savanna areas of West Africa there are several broad zones of decreasing rainfall (associated with sparser vegetation containing fewer broad leaved trees) between the forest to the south and the Sahara to the north, though they may merge into each other rather gradually and their boundaries be the subject of dispute among ecologists.

Within the West African forest zone there are important differences of rainfall. Although the forest may look fairly uniform to the untrained eye there are differences of species and of structure which reflect the broad soil and climate differences, and these in turn lead to very great differences in agricultural opportunities and in existing agricultural methods and sequences.

In the broad area of forest between Ghana and the Ivory Coast, the author distinguishes at least four major agricultural zones which he relates to differences in rainfall, natural vegetation and soils. In the very wet areas, with rainfalls over about 70 inches (1750 mm) there is an excess of rainfall over potential evapotranspiration, particularly in the very wet months of May and June), which leads to through leaching, to removal of exchangeable bases (particularly Ca and Mg) and the formation of very acid topsoils, usually within the pH range 4.0-5.0. These infertile soils are associated with rain forest vegetation which has far fewer large trees than the more extensive semi-deciduous forest of the less wet forest zone. Agricultural possibilities are related to the acid soils and high rainfalls: whereas shifting cultivation in the semi-deciduous forest may start with cocoyams and plantains and end with cassava after three or four years of production, in the acid rain forest areas neither cocoyams nor plantains do well and the cultivation may simply be a single crop of cassava or in some areas, a crop of a hill rice followed by cassava, so that the cropping period may be half as long, or less, than on the semi-deciduous forest areas, with a much smaller range of crops. In such areas of high rainfall and poor fragile soils, ecological considerations strongly suggest that tree crops are better suited to the environment than annuals. Fortunately both oil palm and rubber grow well in these areas, since they require heavy rainfalls and are adapted to poor soils, oil palm because of its extensive rooting system and rubber because of its low demands.

In the less wet semi-deciduous forest zone, rainfalls are more moderate, there is little excess of rainfall over potential evapotranspiration and little leaching. The topsoil reaction of typical soils is usually in the range 6.0-7.0 and they are relatively saturated with exchangeable cations. The broad semi-deciduous forest areas can be usefully divided into three. (1) In the south the wetter semi-deciduous forest areas show characteristics which approach those of the wetter areas: lower pH values and lower topsoil saturation, less productive and versatile soils, with rubber a commercial possibility but cocoa less promising than in the main semi-deciduous forest areas. (2) The central semi-deciduous forest zone, a broad area with a rainfall of about 55-65 inches (1375-1625 mm) includes some of the most productive soils in West Africa and forms what the author terms the 'belt of maximum cocoa success' . Here shifting cultivation often continues for four or more years: in many areas it starts with cocoyam and plantain, and the number of years these continue to produce is a fair indication of fertility.Often it is three or four. Finally maize and cassava may conclude the cropping period. (3) To the north of this productive zone is a drier area, characterized by its own type of forest (the Antiaris-Chlorophora association) where the chemical fertility of the soils is usually at least as high as in the belt of maximum cocoa success but where yields and the survival of cocoa are both affected by dry season water shortages.

The example of this subdivision of part of the West African forest zone has been given to illustrate the fact that it is possible and practicable to delineate ecological/agricultural zones and to make useful generalizations about soils, climate and cropping possibilities within them. Studies of existing cultivation methods, and results of trials and research lead to improved and modified methods that can usefully be related to these zones. It is most unlikely, for example, that the same fertilizer mixture or crop rotations could be recommended for all the four zones enumerated above. Conversely, methods found workable in the very wet rain forest zone, for example, might well be found equally adapted to the rain forest areas of southwest Nigeria and to the extensive rain forest areas of the southwest Ivory Coast and of Liberia. Thus the agricultural belts of West Africa stretch eastwest across political divisions, a fact which should encourage scientific cooperation with ones neighbours.

In East Africa areas of high and low 'potential'' are related to differences of rainfall, but rainfall itself is often associated with altitude. Altitude and temperature changes produce a vertical zonation even in areas of similar rainfall. Temperature affects (among other things) the length of the growing season: maize which may take 4-5 months to mature at low altitudes may take up to one year at 8 000-9 000 ft (2 400 - 2 700 m), while in the Bogota area in South America the author has seen maize at 12 000 ft (3 600 m) requiring 15 months to mature.

From the soil point of view soils at high altitude in the tropics differ very fundamentally from those at low altitude in that lower temperatures reduce the rate of humus mineralization so that, from the point of view of shifting cultivation, the overriding fact is perhaps that organic matter levels decline much more slowly. In the highlands of Kenya there is very little shifting cultivation. Continuous cultivation presents fewer problems than in the lowland tropics, and methods of maintaining organic matter and yields worked out in temperate areas can often be applied successfully.

B. Information on current practices

The literature on current practices of shifting cultivation is now very extensive 1/ though still often lacking in details such as exact information on crop spacing and on yields, and even on the usual size of farm patches about which there has been much dispute. In Ghana, the Soil and Land Use Survey systematically collected information on land-use as well as soils, particularly on detailed sample strips (usually one mile (1.6 km) long and a quarter of a mile (0.4 km) wide, mapped on a scale of 1:10 000) which showed soils, vegetation, relief and farm boundaries (Ahn, 1961; 1972). Aerial photographs often give important information on the size and frequency of cultivated patches but have to be tied in with observations on the ground, particularly in savanna areas where patches may look fresh from the air several years after they have been abandoned.

The following information on current practices appears desirable:

- Environmental information (climate, soils, agricultural zone) as discussed in the preceding section.

- Population densities; ratio of land cultivated to land in fallow.

- Criteria used for selection of land to be cleared.

- Methods of clearing and planting; on flat, ridges, mounds etc. Crop sequences, including times of planting, spacing, details of mixed cropping. Harvesting and yields. Division of labour between men and women and other social considerations.

- Length of cropping period and reasons given by the farmer for moving on.

- Extent to which local methods vary with the soil and the site; local knowledge of soils.

- Attitude of cultivators to innovations; extent to which crops are sold or used for subsistence; storage methods; transport and markets; other economic considerations affecting growing and marketing.

The ratio of cultivated land to fallow can be expressed in various ways, such as the 'land-use factor'(L) of Allan (1965) obtained by the formula: $L = (C + F)/C$, in which C = length of cropping period and F = length of fallow period.

1/ Among major reference works may be sited those of Jurion and Henry (1967, 1969), Allan (1965), Gourou (1966), Miracle (1967), de Schlippe (1956), Schults (1964), Wills (1962), Trapnel & Clothier (1937), Jameson (1970), Trapnell (1943), Waldlock et al (1951) and Tondeur (1956), while from the point of view of the soil the indispensable work is that of Nye & Greenland (1960). Recently useful shorter articles have appeared by Vine (1968) and by Coulter (1972).

Thus two years of cultivation followed by eight of fallow would give a land use factor of 10/2 = 5. However, it is also important to give the actual years of customary fallow and to attempt to assess the degree to which this period is able to restore productivity. Allan divided land into categories according to the 'land use factor' and noted that the better soils of Uganda and Zambia have low land use factors of about 2, with 3-4 years cultivation followed by 2-4 years of grass fallow, but that on the poorer soils 1-3 years of cropping is followed by 20-30 years of fallow (giving a land use factor of 10 to 20). The better soils named are brown soils of volcanic origin, some hydromorphic and organic soils, and 'strong red clays and loams'. The poorest soils are leached sandy soils chiefly cropped by the citimene system which involves collecting vegetation from a wide area and burning it on the patch in order to concentrate fertility there. The examples he gave indicate the considerable extent to which traditional practices vary on different soils and give some indication of their natural productivity.

The collection of detailed information on local methods requires close contact with farmers over a period. Practical difficulties include that of obtaining crop yield data. This may involve measuring irregularly shaped farm areas and weighing and recording all yields taken, sometimes of several crops mixed, over an extended harvesting period. The more advanced and cooperative farmers (such as those selected for demonstration work) are not necessarily typical.

Of particular interest are the farmers' own views as to criteria used in selecting land for clearing, the reasons given for abandoning land at the end of the cropping period and the extent to which local methods are changed according to soil and other factors. Traditional methods, including traditional division of work between men and women, may militate against change.

Many African shifting cultivators will quickly change their methods if they see an advantage in so doing (the rapid spread of the cocoa industry in Ghana is often cited in support of this, and the development of intensive dry season vegetable gardens below dams in the savanna areas forms a more recent example). Fundamental to an understanding of shifting cultivation, however, is the realization that many or most shifting cultivators cannot afford to take risks. The system has evolved in answer to the need to ensure that there is always some food of some sort, i.e. to minimize the risk of total failure and starvation. The innovator comes alien idea of simply increasing yields and returns per area of ground, whereas the shifting with the cultivator would much rather spread his risk by having several low yielding patches scattered about than one very high yielding one which might fail altogether. He is often much more interested in the return per day of work than in the return per hectare of land. Research on shifting cultivation to be complete must therefore include research into social factors and attitudes towards change, as well as into economic considerations of prices and markets which will affect the extent and speed with which farmers can move from subsistence agriculture to commercial agriculture if they want to, and if the technical difficulties are overcome.

C. Fundamental research on soil and related aspects of shifting cultivation

i. What happens during clearing and burning

At any one time the total plant nutrients in the soil-plant system are stored partly in the soil and partly in the vegetation. Burning of the vegetation (usually after clearing) affects that portion of the nutrients stored in the vegetation, but also has some influence on that in the soil. When vegetation is burnt, the nitrogen and sulphur literally go up in smoke: the other nutrients generally remain in the ash. In some cases, as when there is an old established high forest growing on relatively poor leached soils, there may be more nutrients stored in the vegetation than in the soil, so that burning can have a very drastic effect on nutrients which have formerly been moving in a fairly closed cycle from vegetation to soil (mainly topsoil) and back to vegetation. Under natural forest vegetation, losses from such a cycle may be very slight indeed; fertility may be built up slowly over a long period. When the cycle is broken and the nutrients stored in the vegetation have been dissipated, the soil may be surprisingly poor in relation to the weight of vegetation it formerly supported, and have very slow powers of recovery. In savanna areas the weight of vegetation is generally much less than in forest, and so are the nutrients stored in it. These aspects have been investigated quantitatively by Nye & Greenland (1960).

Continuing research on clearing and burning and possible alternatives should have the fundamental aim of investigating the extent to which nutrients stored in the vegetation are retained in situ for use by crops. The alternative to burning is to let the dead vegetation decompose slowly to form humus but this has practical disadvantages, for fire is the cheapest and most convenient tool of the unmechanized cultivator, and the ash is often equivalent to an application of fertilizer. On acid soils, in particular, it raises the pH and influences mircrobial activity.

On a long term clearing-cropping-fallow experiment at Kade, Ghana (Ahn, 1970), traditional clearing and burning methods were compared with clearing by tree poisoning. Tree poisoning with 2,4-D has the advantage that it is very cheap, and that the dead plant tissues are slowly converted to humus. However, initial yields of cocoyam and plantain on plots cleared by poisoning were considerably lower than on the adjacent felled and burnt plots. This was attributed mainly to the beneficial effects of the ash, which considerably raised the pH of these acid soils. The same effect could probably have been got by an application of fertilizer, and in the long run this might have proved a better alternative.

Data given in Nye & Greenland (1960), and commented on by Vine (1968) indicate that although virtually all the nitrogen in the cleared vegetation is lost during burning, the potassium liberated from the leaves and litter alone of a good fallow is equivalent to a good application of fertilizer. For the equivalent of a good dressing of single superphosphate, however, it is necessary to burn the wood as well as the leaves and litter. The indirect effects of raising the soil pH on burning are particularly important on acid soils and may be more valuable than the direct P and K additions, though relatively little work, such as that of Meiklejohn (1955), has been done on the response of soil microfauna to these changes. In many cases the farmer does not have the money to invest in fertilizers as an alternative to the ash. The heat of burning itself has other effects, particularly below heaps of burning refuse, though elsewhere only a very thin layer of soil may be affected, as when a curtain of fire sweeps rapidly through savanna during the dry season.

The annual burning of savanna areas, as distinct from the occasional clearing and burning of areas being prepared for cultivation, is itself an important subject which has attracted very considerable attention. A very useful summary of the results of protecting savanna from burning, or of confining burning to early burning when the grass is less dry and the fire not so damaging, is contained in Ramsay & Rose-Innes (1963). Although it is difficult and probably not advisable to try to stop grass burning altogether, burning is far less damaging if confined to the early part of the dry season.

In summary, research on clearing and burning might include research on the following:

Minimizing losses following burning (particularly blowing away and leaching of ash).

Effects of fire itself on the soil, on microbial activity (partial sterilization effect; subsequent flushes of activity) and on other factors (weed seeds etc.).

Effects of ash on subsequent crop growth (direct nutrient content, effect on reaction) and extent to which these could be achieved by fertilizer applications.

Prospects of other methods of clearing and disposal of refuse (sanitary aspects; advantages of slow decomposition to give humus). These include mechanical clearing without burning, and the use of poisons or hormones to kill off vegetation.

Effects of killing vegetation on subsequent regrowth vegetation (which in forest in particular normally includes coppice shoots from old stumps and root systems which would be killed by chemical clearing).

On oil palm plantations in the Ivory Coast the cleared forest vegetation has been bulldozed into lines between alternate rows of palms, leaving one row free for access, and capable of being weeded mechanically because there are no obstructions, with the other row piled so high with rotting forest debris that the debris itself keeps down weeds as well as supplying a very long term source of humus and nutrients. An interesting line of development is one of chemical clearing allied with minimum cultivation and disturbance, with the new crop simply planted between the dead and dying trees. This avoids exposure to rain and reduces disturbance of the soil to a minimum, but the dead vegetation hinders subsequent access and mechanized maintenance.

ii. Changes during the cropping period

In general, we need to know:

(a) what changes occur during the cropping period

(b) what effects these changes have on soil productivity and on yields

(c) how can these changes be modified or compensated for.

In a detailed treatment of this topic, Nye & Greenland (1960) reviewed published information on yield declines during the cropping periods and concluded that often declines are more marked in forest than in savanna areas, since some savanna trials at least showed rather slow yield declines during several years of continuous cropping. They associated the cropping period with the following:

1 Multiplication of pests and diseases

2 Increase of weeds

3 Erosion of the topsoil

4 Deterioration in the physical condition of the soil

5 Deterioration in the nutrient status of the soil

6 Changes in the numbers and composition of soil fauna and flora

Research on the soil aspects of change during the cropping period (topics 3-6) uses two distinct types of evidence - (1) the evidence of crop yields, and (2) the evidence of measurements and observations which attempt to monitor the physical, chemical and faunal changes that take place in the soil. Some of the difficulties attending each of these approaches will now be discussed. A third type of evidence, the evidence of fertilizer trials, is considered below.

(1) The evidence of crop yields

The difficulty here is that yields reflect a wide range of factors of which soil conditions are only one. Yields are influenced by

- the date of planting
- the climate of that particular season
- management factors, including weeding
- crop spacing
- crop varieties
- the incidence of disease and attack by pests
- soil productivity-physical factors, chemical factors, fauna etc.

while the assessment of declining productivity in terms of yields alone is frequently complicated by the fact that crops are mixed, and that different crops succeed each other.

It is not easy, for example, to compare a first season yield of hill rice with a second year yield of cassava which, for part of its growing period, was intercropped with beans -- to quote an example almost at random. The crop planted first may be chosen because it is the most demanding (as in the maize, guinea corn, millet rotation of many savanna areas) or because the first crop is the one best liked and the second is merely a reserve which may or may not be harvested (as in the hill rice followed by cassava sequence of Liberia and elsewhere). Numerous curious examples of mixed crops and sequences were given by Jurion & Henry (1967, 1969) and other writers. The yield figures available are mainly for sequences in which crops are not mixed.

In many cases the farmer appears to give more attention to the first crop than to succeeding ones, and it often appears that a farm patch is abandoned not because yields have declined so much but because of the work of weeding it or because of greater interest in new patches elsewhere. Many writers have pointed out that it may need less work to clear a new area than to continue to weed the old, and pest and disease problems may reinforce this desire to abandon a plot even if it is still fertile. Coulter (1972) has noted that the new plot cleared may be less fertile than the old one abandoned, and that whereas the weeding is done by the women, the new clearing is done by a different group - the men. Nye & Greenland (1960) drew attention to the additional fact that the clearing is done in the dry season when other work is slack, but the weeding comes during the rains when there may be too much to do.

It is as well to remind ourselves that later crops in the succession may be relatively neglected, and that this alone would cause a yield decrease, and that though in some cases soil exhaustion is a cause for abandoning the plot, in other cases it clearly is not.

Another major difficulty in interpreting the evidence of yields alone lies in the fact that variations in climate from year to year themselves can cause yield fluctuations even when other factors are equal. Important are mainly the date of planting in relation to the date of onset of the rains, and the distribution and amount of rain in the growing season.

In an experiment conducted by the author at Kade, in the Ghana forest zone, an attempt was made to monitor soil changes when original forest was cleared, and then the plots planted to successive crops of maize for several years. The yields obtained are given in Table 1.

The experiment involved two adjacent plots of about the same size; plot A was on red gravelly clay soils developed over phyllite, plot B was on soils which were similar except that the subsoil colour was warm brown rather than red, and drainage was not quite so rapid as in A. Both plots, being adjacent, enjoyed the same climate, though plot B, slightly downslope from A, may have dried out somewhat more slowly during dry periods.

Table 1 - Maize yields (converted to lb/acre) from two plots at Kade, Ghana, in the first four years immediately following clearing from high forest.

		First rains (harvested July)	Second rains (harvested Jan/Feb)	Total for two seasons
First year (1964)	Plot A	1 018	522	1 540
	Plot B	810	478	1 288
Second year	Plot A	793	251	1 044
	Plot B	736	99	835
Third year	Plot A	679	496	1 157
	Plot B	912	287	1 199
Fourth year	Plot A	888	Negligible, owing	888
	Plot B	1 052	to drought at flowering	1 052
Average yield (4 years)	Plot A	844		1 157
	Plot B	877		1 093

The figures given do not lend much support to the idea that yields fall off rapidly and progressively after the first season immediately following clearing of the high forest. For plot A, the fourth year main season yield is only a little below that of the first crop, while nobody looking at the main crop yields for plot B would see any general decline. The third year main crop yield was larger than the first year crop, and the fourth year yield was even larger. The very low yields in the minor second season crop are a reflection of the lower rainfall in that season.

If observers find that recorded yields on plots, in successive seasons after clearing, jump about in an odd and unexpected manner, they probably attribute this to other factors such as rainfall variations, pests etc., and - rightly or wrongly - decide that the results are not worth publishing. If, on the other hand, the yields do happen to decrease somewhat with time, this is taken as evidence of declining soil fertility! In the plots referred to here, there was a high degree of soil heterogeneity and very marked patchiness within the plots themselves, with some patches tall and green and others short, yellow and stunted. This lack of uniformity within plots of a single soil series presents serious practical difficulties: in this case the patchiness seemed to change from year to year, and not be constant.

The design of experiments on shifting cultivation can be such as to take into account annual climatic variations simply by staggering the starting date (the clearing of the plots) over several years, as follows:

	First year	Second year	Third year	Fourth year	Fifth year
Plot A	1	2	3	4	5
B		1	2	3	4
C			1	2	3
D				1	2
E					1

In the fifth year a direct comparison can be made between first, second, third, fourth and fifth year yields under the same climatic conditions. The soil of each plot, and the previous history, would, of course, have to be very similar.

(2) <u>The evidence of direct observation of the soil</u>

Direct measurement of physical and chemical soil characteristics and observations of changing fauna and micro-flora have been attempted with very varying success. The difficulties include the following:

1. The fact that soils frequently change over short distances, and that even within one soil series the soil is often very heterogeneous, displaying marked variability even between points a foot or two apart, or less.

2. The difficulty and expense of sampling an area so as to get information which represents a reliable average for that field; and then to repeat this at intervals so as to monitor changes over a period.

3. Difficulties and errors in analysis, and in interpretation of the analyses. In particular, the relative importance of the different changes observed and their effects on productivity may be difficult to assess and separate.

Soil changes during the cropping period are associated with a decline in the amount of humus in the soil. This decline is often described as being rapid at first, and then progressively slower. Fundamentally the changes in humus levels may be thought of as being an adjustment from one set of conditions (soil under natural vegetation, either original or fallow (which has its natural humus 'equilibrium level' (the level at which gains and losses balance each other), to another, different set of conditions provoked by clearing of the land, cultivation and increased exposure to sun and rain, which have a humus 'equilibrium level' which is considerably lower than the previous one. In simple terms the amount of humus falls because the soil is receiving less raw organic material than it did before, so that the supply of new humus is lower while the ground is more exposed to the sun and heats up more so that mineralization of the existing humus in the soil is faster than it was. The initial relatively high rate of mineralization and humus loss becomes slower with time essentially because mineralization under constant conditions is about proportional to absolute amounts present, so that mineralization affects a fairly constant percentage of a decreasing residue, and thus itself gets less. Mineralization rates may even slow down as the more easily minerlized fractions of the humus are lost, and the remainder contains an increasing proportion of the more resistant fractions. This may explain why some soils decline to a certain humus level beyond which further decline is very slow indeed.

The amount of humus in a soil sample can be determined fairly accurately by measuring the easily oxidizable carbon by potassium dichromate in the presence of sulphuric acid (the standard Walkley Black method) and multiplying by a factor. If a sufficient number of core samples are bulked, thoroughly mixed and passed through an 0.5 sieve to increase homogenization, then it should be possible to monitor humus changes with reasonable accuracy. The laboratory determination is a relatively simple one.

Humus affects the soil in many ways, influencing its physical properties, its chemical properties, and the microfauna. For this reason humus changes have often been considered as fundamental ones which to some extent bring most of the other soil changes in their wake. Agriculturally so much importance has been attached to the problem of maintaining humus levels that perhaps insufficient attention has been given to the almost heretical attitude of ignoring them, or at least not bothering overmuch about maintaining them, and seeing to what extent we can learn to manage with lower humus levels than usual. On some soils which have an inherent structure apart from the granulation caused by humus (soils which Nye & Greenland referred to as having a good ''inherent constitution'') the role of humus in maintaining physical properties may not be as important as has sometimes been thought.

Decreases in the amounts of humus in the soil are often associated with:

- loss of crumb structure in the topsoil
- lower total porosity and lower macroporosity
- poorer aeration
- poorer rainfall acceptance
- increased likelihood of run-off and surface erosion
- lower cation exchange capacity
- possible changes in exchangeable bases, degree of saturation and soil pH
- lower release of nutrients due to lower amounts of humus mineralized

All these factors probably play some part in reducing soil productivity in shifting agriculture.

i. Physical soil changes during cropping

In addition to the possible physical removal of soil by sheet, wind or other types of erosion (particularly during the critical period after clearing when the soil may be left exposed to the full force of the first rains), the cropping period is characterized by physical changes which result from the exposure of the soil to heating up and desiccation, followed by sudden wetting and exposure to the impact of the falling raindrops. The progressive loss of humus referred to above also results in physical soil changes. Monitoring these changes would require attention to at least some of the following:

- Soil structure and aggregate stability changes
- Soil porosity (macro and micro) and bulk density changes with depth, and changes of these during the cropping period
- Soil texture, and the possible movement down of clay particles, so lightening the texture of the surface soil and in extreme cases, forming a clay pan below it

- Changes in rainfall acceptance, permeability and percolation, and water retention (field capacity, wilting point and available moisture)

The main difficulties encountered by research on these aspects relate to the heterogeneity of the soil in the field and the need to make a large number - - sometimes an impracticably large number - - of determinations in order to get a reliable average. Measurements of rainfall acceptance and percolation in the field often show a very wide range of results in a single plot: results may vary by a factor of 10, depending exactly where the determination is made. Results of many other measurements such as bulk density, porosity, structural stability and rainfall acceptance made on undisturbed samples taken to the laboratory (such as those described by Pereira, 1956) also show a wide range of variation, and there is the fundamental difficulty of ensuring that experiments on small samples in the laboratory are representative of what would happen in the field.

Even if standardized methods of determining structural stability and other properties are used, there is the difficulty of interpreting the numerical result obtained. In some cases an index of structural stability obtained in the laboratory has proved a very poor indication of the future behaviour of the soil under cultivation.

Some determinations, such as texture, can be made on disturbed soil; the moisture held at field capacity can also be determined on a disturbed or sieved soil, though there is a difference in field capacity determinations made on disturbed and undisturbed samples. With those determinations that do not require undisturbed samples, numerous core samples can be bulked and sub-sampled in order to give an average, as is done with many fertility investigations.

Nye & Greenland (1960) pointed out that the frequent emphasis on structural units often was not accompanied by any clear recognition of the kind of structure needed, and that this emphasis on structure ''directs attention ...... away from the all-important voids which lie within and between them.''

The amount and distribution of large pores appears to be very critical to the ability of the soil to give adequate aeration and to cope with the occasional heavy downpours and temporary water surpluses which are a feature on many tropical climates, even dry ones. This in turn is related to the proportion of soil particles or aggregates between 0.5 and 2-3 mm in diameter. Nye & Greenland have pointed out that forest fallows promote a humus topsoil with a favourable aggregation, but that fallow periods in savanna areas are much less effective. If research is to be concerned with the elimination of natural fallows, then it seems likely that we shall have to learn to use effectively soils with lower organic matter contents and weaker crumb structures. This is particularly true of the lowland tropics where humus mineralization rates are rapid and the effects of organic matter additions to the soil are often shortlived.

If the aggregating effect of the humus is lost, some topsoils nevertheless retain a marked degree of aggregation. This phenomenon is particularly marked in well weathered tropical soils high in iron and aluminium oxides, and is responsible for the fact that the texture of the soil as assessed by feeling it between thumb and finger is often much lighter than the texture as revealed by a mechanical analysis in the laboratory after complete dispersion.

This inherent structure or microstructure as the author prefers to call it (since the aggregates are usually less than 1mm across) is thought to be of very great practical importance to cropping. Although it occurs in soils of other parts of the world, it is particularly marked in kaolinitic tropical soils high in sesquioxides. The mechanisms of aggregation have been examined recently by a number of investigators (Deshpande _et al_., 1968; Greenland _et al_., 1968). Greenland _et al_. concluded that aggregation might be due more to easily soluble aluminium oxides than to the more obvious iron oxides with which they are generally associated. Baver (1972) referring to the work of Cagauan & Uehara (1965) stated that well-aggregated clays in thin section are often anisotropic, showing an increased degree of orientation both in the interior of the peds and in cutans. (Thin sections of soils show both the degree of orientation and also give direct evidence on the

Table 2 - True and 'natural' textures (obtained by mechanical analysis with and without dispersing agent) of a deep clay Oxisol (an Alfic Eutrorthox) developed over phyllite in the Ghana forest zone (data from Ahn, 1972).

HORIZON, AND HORIZON DEPTH (inches)		TRUE TEXTURE (using dispersing agent)				'NATURAL' TEXTURE (without dispersing agent)			
Horizon	Depth	% sand	%silt	% clay	texture	% sand	% silt	% clay	texture
A11	2	31.2	23.6	45.2	clay	71.3	21.0	7.7	sandy loam
A12	5	32.8	22.0	45.2	clay	69.9	22.7	7.4	sandy loam
B1	15	32.6	19.4	48.0	clay	65.5	27.3	7.2	sandy loam
B21	32	22.0	13.3	64.7	clay	61.0	27.7	11.3	sandy loam
B22	58	19.1	12.4	68.5	clay	62.8	31.0	6.2	sandy loam
B23	90	17.6	17.2	65.2	clay	62.4	35.5	2.1	sandy loam
B24	120	16.6	22.6	60.8	clay	44.3	54.2	1.5	silt loam
IIB25	160	29.4	24.2	46.4	clay	48.0	50.3	1.7	silt loam to sandy loam
IIB26	204	28.1	23.2	48.7	clay	49.0	50.4	0.5	silt loam to sandy loam
IIC	238	19.1	30.1	50.8	clay	34.2	60.7	5.1	silt loam
	264	19.4	32.9	47.7	clay	41.5	58.5		silt loam

Note: Although the true texture is a clay throughout the profile, with a maximum of 68 percent clay in the B22 horizon, in the field most of the clay is micro-aggregated to silt and to fine and medium sand size aggregates which survive the four hours of end-over-end shaking without dispersing agent used to give the 'natural' textures. The 'natural' texture so determined is a sandy loam in the A and B horizons, to 160 inches, and a silt loam in the IIB and IIC horizons. The 'natural' texture gives a better indication of the feel of the soil in the field, and its handling qualities, than does the texture obtained after complete dispersion.

size, shape and arrangement of soil pores). Whatever the mechanism of aggregation involved, the author believes that much greater attention should now be directed to reporting the extent of micro-aggregation in soils quantitatively, and that in studies on shifting cultivation this factor should be correlated with changes during cropping and the ability of the soil to maintain its ''constitution'' under cultivation.

In order to measure microstructure quantitatively and the effect it has on apparent texture, the author has used two parallel sets of mechanical analyses (Ahn, 1968 b, 1972). The first set employs standard techniques, including prolonged end-over-end shaking with Na-hexametaphosphate and Na_2CO_3, which is believed to result in complete dispersion of the soil into its ultimate sand, silt and clay particles. The second set of analyses differs from the first only in that the chemical dispersing agent is omitted: organic matter is first destroyed with H_2O_2 and the soil is then shaken without dispersing agent in an end-over-end shaker for 4 hours. The aggregates that remain are not due to humus, and are strong enough to resist the shaking treatment. It appears likely therefore that these aggregates would survive organic matter losses during cropping and be water stable, though it should be noted that they do break down progressively if the soil is rubbed or worked in the hand. Such manual working of these soils results in increased stickiness and plasticity of the soil with progressive kneading, thus suggesting the need for minimum cultivation, particularly when wet.

After shaking the sand, silt and clay are then measured in the normal way(pipette method and sieving). The 'sand' retained by the sieves now includes sand-sized aggregates which the author refers to as 'pseudo-sand' , and the silt also includes silt-sized aggregates. The texture thus determined is thought to reflect more accurately then the conventional method the apparent texture, feel and handling qualities of the soil in the field and is referred to by the author as the 'natural texture' to distinguish it from the 'true' texture after dispersion. A comparison of 'true' and 'natural' textures indicates not only the extent of aggregation of the clay fraction but also the empirically tested size of the water stable aggregates (Table 2).

This microaggregation is related to the water dispersible clay, a concept found useful in the definition of Oxisols, but goes beyond this in as much as it determines the size of the water stable aggregates and therefore the 'natural texture' in the field. Thus a soil which is technically a clay, perhaps with as much as 60-80 percent clay in it, may nevertheless be sufficiently microaggregated to have a natural texture of sandy loam. Which term, clay or sandy loam, gives the better indication of the handling qualities of this soil in the field? And which term better suggests what degree of porosity and aggregation might be left when cropping results in a loss of crumb structure due to humus? The author believes that the determination of natural textures alongside conventional textures, and a comparison of the two sets of results, gives useful information on fundamental soil properties.

The natural aggregation or microaggregation of the soil, as distinct from that caused by humus, varies markedly from soil to soil. In some cases it is possible to make broad generalizations in this respect. Thus Grohman (1960) working in Brazil found less decline in structure during cropping in Oxisols than in Ultisols. Numerous observers have noted more structural stability in red soils than in associated brown and yellow soils. Ahn (1972) found a relatively low degree of aggregation in some fertile West African forest soils (Tropudalfs and Eutropepts) developed over basic rocks, but found that in a range of profiles developed over phyllites and granites of the basement complex, microaggregation was greater in Oxisols (Haplorthox and Eutrorthox) of the older surfaces than in the more widespread Ultisols of contemporary slopes. To some extent the degree of weathering of subsurface horizons is indicated by the silt/clay ratio (Sys, 1960; Van Wambeke, 1962), and it was found that in most cases examined a high degree of micro-aggregation was associated with low silt/clay ratio.

The degree and stability of micro-aggregation can be expected to indicate to what extent a soil retains a favourable structure and ''inherent constitution'' after loss of humus during cropping. In a comparable way, the reserves of weatherable minerals in the soil can be expected to give an indication of long-term natural fertility after the fertility due to humus has declined or been lost. These two criteria together can, it is suggested, be used to give some indication of the long-term productivity of the soil. Unfortunately, the soils with the most stable microstructures are those which are highly weathered and lack weatherable minerals, while the young soils high in nutrient reserves in the sand and silt fractions are often those with the least stable physical properties.

ii. Monitoring fertility changes during cropping

Changes during the cropping period in the fertility of the soil (i.e. in its ability to supply plant nutrients) are associated with the decline in humus levels already referred to. This in turn brings with it a reduction in the supply of the very wide range of plant nutrients released when humus mineralizes, particularly nitrogen and phosphorus. The extent and speed with which individual nutrients become in short supply depends partly on management factors and the level of yields, but can be expected to be indicated to some extent by the degree of response to fertilizers. Fertilizer responses are considered in more detail below. The direct evidence of fertility changes is provided by soil analysis but as emphasized by Nye & Greenland (1960) this is, as yet ''an imperfect instrument for predicting nutrient deficiencies and their effects on yields''.

Apart from changes in humus levels, the measurement of which is discussed above, analyses can give information on

- Changes in the availability of nitrogen and changes in total nitrogen content
- Changes in the phosphorus status
- Changes in the amounts and availability of K, Ca, Mg and other nutrient cations, and changes in soil pH

(a) Total and available nitrogen

Total nitrogen in relation to total carbon is reflected in the C/N ratio, which is believed to change little during cultivation. The amounts of nitrogen released annually can easily be calculated if the rate of mineralization is known. Such calculations serve to indicate, for example, the frequent large differences in nitrogen supplying powers between forest and savanna soils. A forest topsoil which contains 3 percent carbon in its plough layer and 0.3 percent N, will contain roughly 0.3 percent of 2 million lb nitrogen, or 6 000 lb N per acre. If humus mineralization is at the rate of 5 percent per annum, then 300 lb of N are released every year - more than enough for most crops.

A savanna soil, or a long cultivated forest soil with only 0.5 percent in the plough layer would, other factors being equal, release only 50 lb of N per year. Those considerations help to explain why crops grown on ground newly cleared from forest or forest fallow usually fail to respond to added nitrogen, whereas responses are much more frequent in savanna areas and on long cultivated forest soils.

The mineralization of humus and of raw organic matter added to soil depends on temperature, moisture content, aeration, vegetation type and nature of the organic matter itself, and on soil pH. It is normally assumed that there are enough nitrite oxidizers to convert nitrite immediately to nitrate, but in general insufficient information is as yet available on bacterial activity in tropical soils. More microbial studies, such as those of Meiklejohn (1954, 1955, 1962) are needed. Such information as is available indicates differences between forest and savanna soils, and differences within forest areas between rain forest areas and the less wet and less acid semi-decidous forest areas, while nitrate nitrogen levels in soils have been shown by a number of workers to vary very much with the season (Birch, 1958; Greenland, 1958).

(b) Changes in the phosphorus status

Changes in total phosphorus during cropping are not usually worth measuring; they may be slight, and the relationship between total phosphorus and the phosphorus available to the plant is not constant. Changes in organic phosphorus may be more relevant to decreased availability, but are more or less proportional to changes in the total amount of organic matter which is measured much more easily.

There are many ways of estimating the so-called 'available' or easily extractable phosphorus. The amounts extracted vary very much with the extractant used and the nature of the soil. With a single extractant on a specific soil some changes might be observed during cropping, but it is very difficult to interpret these changes in relation to plant growth and possible responses, and even comparisons with other soils are of limited value. These considerations also apply to some extent to the more detailed and expensive methods of fractionating soil phosphorus, and of measuring surface activities by sophisticated techniques, including the use of P^{32}.

Considerable amounts of available phosphorus are usually found in the ash. That not taken up by the plant may be fixed by the soil in unavailable forms. Subsequently, most of the available phosphorus may be that released from the organic matter, but a great deal depends also on the differences between the mineral fractions of different soils, and on soil pH.

(c) Changes in the availability of nutrient cations and in soil pH

During cropping, nutrient cations are lost through plant uptake and perhaps through leaching and erosion losses. If losses exceed the amounts added by humus mineralization and by release from the reserves in the mineral soil, then the total amounts of exchangeable cations will fall. A fall in TEB (total exchangeable bases) will be reflected in a fall in the percentage saturation of the soil (TEB/CEC). This in turn is likely to be reflected in a fall in pH if the exchange capacity of the soil remains constant or falls at a lesser rate. In practice, loss of humus will result in some reduction in cation exchange capacity, and this will be particularly marked in topsoils, and in soils where the clay mineral is kaolinitic.

Measurements of cation exchange capacity and of exchangeable cations, (Ca, Mg, K and often Na and Mn) are frequently carried out in soil laboratories. These determinations can be expected to give some indication of soil changes during cropping provided that the sampling of the soil is such that sampling errors are small in comparison to the changes that take place. Because of the high degree of heterogeneity of many soils, a large number of core samples may have to be bulked in order to get a representative subsample.

The interpretation of these results is not easy. The effects of minor changes of pH, CEC, exchangeable Ca and Mg on yields are difficult to assess. The availability of exchangeable K appears related to the potassium saturation percentage (K/CEC) more than to absolute amounts, and so can be expected to change (and perhaps increase) as cation exchange capacity falls during cropping.

(d) Research difficulties related to soil heterogeneity

All research work on shifting cultivation which requires the determination of soil characteristics of a plot, or the monitoring of those changes over a period, comes up against the practical difficulties caused by soil heterogeneity, i.e. by the fact that many tropical soils change over very short distances. Even core samples taken 10 cm apart can show large variations from the average. On a typical forest zone farm one can see fairly obvious variations due to ash patches, piles of rotting wood and tree trunks, termite mounds and so on, while to some extent the soil under natural forest vegetation is thought to differ in relation to the particular tree species at that point. In a discussion of soil microvariability, Moormann (1972) has pointed out that the site of an oil palm (*Elaeis guineensis*) often shows distinctly better growth of a subsequent maize crop. Ahn (1965) sought to characterize the inherent variability of forest soils and of a savanna tropical black earth by a statistical analysis of variability of easily measured characteristics such as pH, air dry moisture content, total carbon and total nitrogen. In the case of an area of a seemingly fairly uniform forest soil, 476 determinations of the pH of the upper topsoil (A11 horizon), usually 2-3 inches thick, showed the surprisingly high range of pH 4.3 to 8.4, though the average pH was 5.9 and the distribution of the individual pH values was fairly symmetrical (Figure 1).

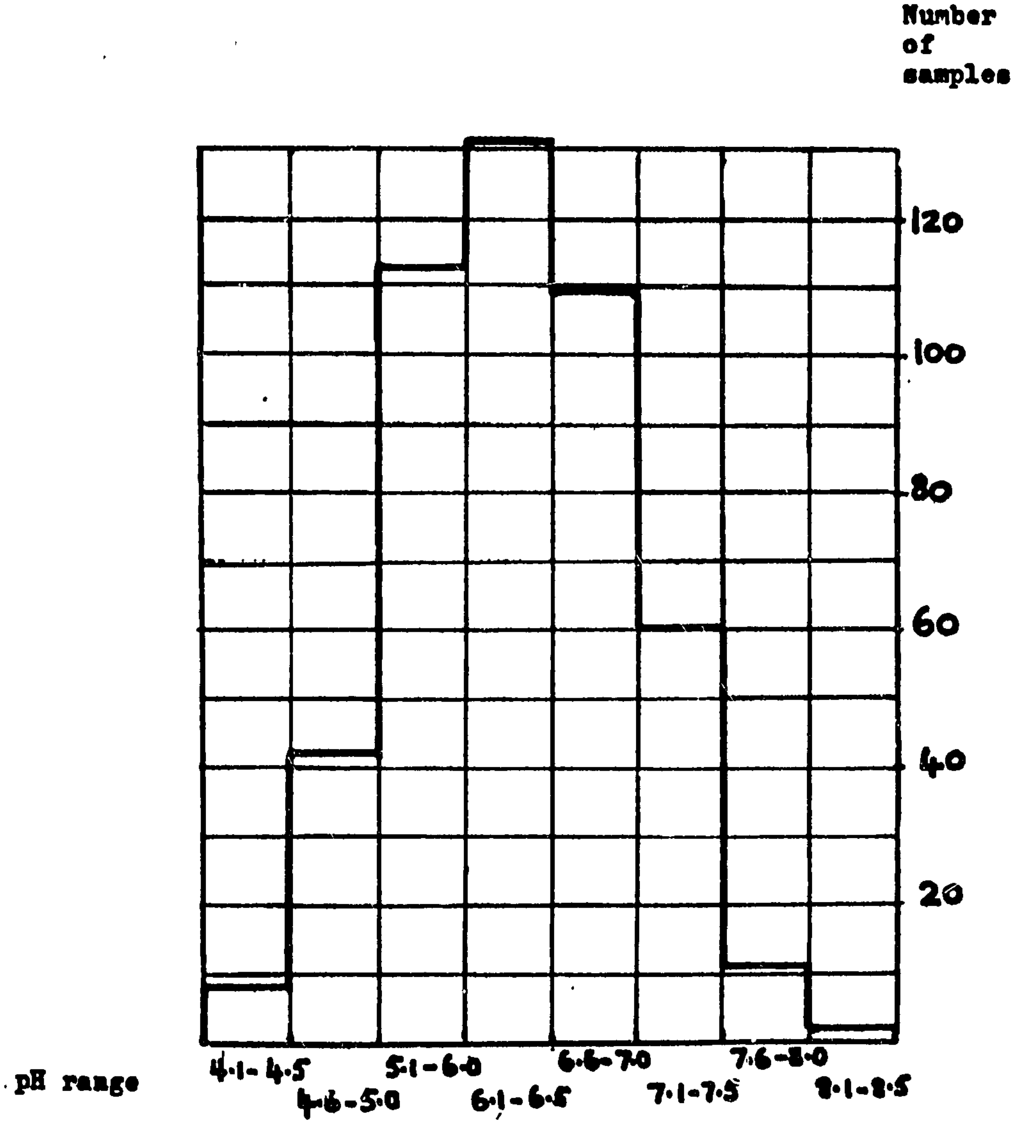

Figure 1. pH values of 476 upper topsoil (A_{11}) samples from a seemingly fairly uniform area of forest in Ahafo, Ghana (from Ahn, 1965).

iii. Changes during the fallow period

The changes that take place during the fallow period are in some respects similar to those that take place during cropping, but in the reverse direction. As in the case of changes during cropping, they are very much associated with changes in organic matter levels. The increase in humus content during fallow is particularly marked during the early years of fallow, when new growth is rapid. Forest regrowth vegetation is more effective at rapidly restoring humus levels than is savanna regrowth.

In order to monitor soil changes during fallow, the scientist has only the evidence obtained by direct observation of the soil and the vegetation; he has no evidence of yields, or of fertilizer responses, until the fallow is cleared again. In addition to monitoring physical and chemical soil changes by the methods discussed in the previous section on the cropping period, observations can be made on the nature, weight, species composition and rate of growth and change of the fallow vegetation supported by the soil. To a limited extent, differences in the type and rate of growth of regrowth vegetation give an indication of soil differences (Ahn, 1958).

Research on what actually happens to the soil during the fallow period appears necessary if we wish to consider ways and means of inducing the same changes more quickly, or by alternative methods. The rates at which these changes take place are also important; if the build up of fertility is greatest in the first few years, so that subsequent annual increments become smaller and smaller as the new humus equilibrium level is approached, then the benefit of each succeeding year that the land is unproductive also becomes less and less.

An optimum length of fallow would be one that continues only when the net gain curve is still steep, but is stopped when it begins to flatten. By this criterion some existing fallows may be too long in the sense that they can be shortened with only a proportionately small loss of productivity. However, other functions of the fallow, such as that of suppressing obnoxious weeds and giving a disease break, have also to be studied and taken into consideration.

D. Research on improvements and alternatives to shifting cultivation

The main criticisms of shifting cultivation concern (a) low yields and (b) the generally short period of cropping in relation to fallow. Both the increasing of yields and the lengthening of the cropping period are obvious ways of raising overall productivity of the system, and both of these are influenced by a wide range of factors apart from soil factors. Another way of raising productivity concerns the fallow period which follows the cropping; how can the beneficial effects of the fallow be obtained in a shorter time, or by means other than natural fallows, or, best of all, be eliminated altogether by a rotation which keeps the land constantly productive?

Just as the reasons for low yields are diverse, so are the measures that need be taken to raise them varied and complex. The use of fertilizers can be effective only where soil fertility is the limiting factor and where the plant is genetically able to respond to an improved nutrient supply, but many other limiting factors such as poor physical soil properties, water shortages, inadequate management in general (including weeding), poor husbandry methods (including wrong plant population densities and wrong time of planting), poor crop varieties, attacks by pests and diseases and so on also limit yields, so that maximum yields can be obtained only when a very wide range of factors are all favourable.

(1) The general level of management and choice of husbandry methods

According to Russell (1968b), possibly the most important single factor responsible for low yields in tropical Africa is wrong time of planting - usually too late. This appears to be due partly to caution, partly to the fact that at planting time the farmer is just too busy to cope with all that has to be done.

Another widespread factor responsible for low yields is wrong planting densities, which are often too low. These two factors, plus management factors such as timely weeding, could of themselves, if corrected, probably give more substantial yield increases than the use of fertilizers, particularly if fertilizers are used without attention to these factors as well.

Allan (1969) investigated maize yields on small farms in Kenya with and without good husbandry, and with and without hybrid seed and fertilizers. He defined good husbandry (GH) as early planting at the start of the rains, a density of 36 000 plants per hectare, and clean weeding up to tasselling time. Bad husbandry (BH) was described as planting 4 weeks late with a low population density of only 18 000 plants per hectare and only one late weeding. These two types of management were investigated both with local maize without fertilizer, (LM, no F) and with hybrid maize and fertilizer (H + F). Average yields for the four combinations were as follows:

Treatment		Yield (q/ha)
BH + LM, no F	:	19.2
BH + H + F	:	32.7
GH + LM, no F	:	48.8
GH + H + F	:	80.2

The difference between good husbundry and bad husbandry, both using local maize without fertilizers, is associated with more than a doubling of yields and with an increase of 29.6 q/ha. In contrast, if bad husbandry is used, the use of hybrid maize and fertilizers gives an increase of only 13.5 q/ha - despite the extra investment in fertilizers. In the circumstances examined by Allan therefore, correct time of planting, correct planting densities and better weeding together gave a much larger yield increase than did the use of hybrid maize and fertilizers without these improved husbandry practices. The yield increase associated with good husbandry as compared with bad husbandry was even greater when hybrid seed and fertilizers were used in both cases. The results also indicate that the use of fertilizers in this case was not very profitable unless also accompanied by improved management.

It will be noted that hybrid maize and fertilizers were tested together, not separately. In many situations, the local variety is well adapted to local conditions and resistant to local maladies, but is unresponsive to fertilizer application. In such cases it is little use applying fertilizer unless the crop variety is also improved, and little use using a variety with a higher potential yield unless the soil can meet the correspondingly higher demand for nutrients, though FAO fertilizer trials and demonstrations appear to indicate widespread fertilizer responses even where local varieties are used (Hauck, 1972; Richardson, 1968).

In areas of low and/or erratic rainfall much depends not only on selecting a suitable crop variety but on making sure that as much as possible of the rainfall enters into the soil and is then used by the crop. Increasing the effective rainfall includes measures designed to keep the soil open, and to reduce and slow down run-off. These measures include the use of mulches, contour ridging, basin listing and other measures which have been successfully demonstrated both in West Africa (Lawes, 1961) and in East Africa (le Mare, 1954), though not widely used as yet.

(2) <u>The extent to which fertilizer applications increase yields and prolong cropping</u>

A very considerable amount of information is now available on fertilizer responses in those areas of the world where shifting cultivation is widespread. In considering this information it is helpful to relate responses to the agricultural/ecological zone in which they occur, to see to what extent they form a consistent pattern related to the zone. It is also useful to distinguish between the evidence of fertilizer trials on experiment stations and the generally larger body of information relating to results on farmers' farms, such as those obtained in the numerous and widespread trials and demonstrations carried out by FAO.

Ultimately, increased use of fertilizers depends not on whether or not they give an increase in yield, but whether that yield increase is profitable. Russell (1968a) has pointed out that in most tropical areas fertilizers are more expensive than they are in the developed countries, while the crop produced is sold relatively cheaply, so that ''much higher crop responses per unit of fertilizer nutrient are normally needed in the tropics if fertilizers are to be profitable''.

A number of authors have pointed out that in Africa broad differences exist between fertilizer responses in forest and in savanna areas (Nye & Greenland, 1960; Ahn, 1968a; Russell, 1968a). In savanna areas responses to nitrogen are very frequent and responses to phosphate are frequent, but responses to potassium have been relatively uncommon even on soils which appear on analysis to be low in potassium. In forest areas the position is somewhat different, since responses to phosphorus and potassium are relatively frequent, but responses to nitrogen do not generally occur except in long cultivated soils low in organic matter. Responses to individual nutrients are now considered in more detail, together with some examples of related topics requiring further research.

(i) Nitrogen responses and green manuring

Nitrogen responses are closely related to organic matter contents and for this reason are to a considerable degree predictable. They are frequent in savanna areas because these areas are generally low in humus, and there is also evidence that some natural grass fallows inhibit nitrification in the first year after clearing. In forest areas organic matter levels are often higher than in savanna areas and responses are less frequent except after several years of cultivation and on degraded soils.

Research has paid attention to:

- Seasonal changes and flushes in nitrate production under natural conditions.
- The type of fertilizer most appropriate, including the acidifying effects of ammonium sulphate
- Symbiotic and non-symbiotic nitrogen fixation and the role of legumes in tropical agriculture.

Bartholomew (1972) has summarized current knowledge of nitrogen in the humid tropics and has pointed out that relatively low yields, such as 600-1200 kg/ha of maize, do not remove more than about 15 kg/ha of N in the harvested grain. He believed that, taking into account the natural N supply from rainwater and non-symbiotic fixation, such modest yields could be maintained for long periods with only small amounts of fertilizer. Nevertheless, he considered that available nitrogen may be the chief limiting factor to higher yields in many important food-producing areas of the tropics, and in order to achieve these higher yields more fertilizer nitrogen and/or the use of legumes will be necessary.

Russell (1968a) considered that ammonium sulphate is suited to the tropics in as much as the N is held against leaching as the ammonium cation and that the S contained is often beneficial, but nevertheless, because of the acidifying effects he made ''a strong plea that sulphate of ammonia should no longer be used as a standard nitrogen fertilizer ... except for the tea crop''. Applied research on shifting cultivation improvement should therefore include consideration of other forms of N fertilizer such as the calcium ammonium nitrate now fairly standard in Kenya for arable crops.

Nitrogen fixation is mainly by symbiotic bacteria, and these are associated with a fair numer of plants other than members of the Leguminosae (Norris, 1962) but it is important to remember that bacteria fix nitrogen only when other sources of supply are inadequate: nitrogen in the soil solution inhibits fixation, and adding N fertilizers may have this inhibitory effect even though nodules may form (Bartholomew, 1972). A promising field of research in the tropics concerns blue-green algae, for although they are thought of mainly in connection with their nitrogen-fixing role in swamp rice cultivation they can tolerate a wide range of moisture conditions and can live in moist or even dry soils. They can obtain all their needs from air, water and mineral salts and can therefore colonize areas which other micro-organisms needing organic residues cannot do.

Considerably more applied research is required on the use of legumes in areas of shifting cultivation, either mixed with other crops, as a rotation crop or as a form of fallow. During the growing period very little nitrogen escapes from the legume to become available to associated crops: the N, becomes available when the plant dies and decomposes, and it is this that accounts for the increase in available N when leguminous green manures are turned into the soil. However, the effect of the added N may be equivalent to only modest amounts of fertilizer nitrogen, so that the economics of green manuring need to be examined carefully.

Because of the mobility of nitrate nitrogen, leaching losses can be severe in high rainfall areas. The pattern of water movement in a soil may need to be studied in relation to the movement of nitrogen down to soil layers beyond the reach of the crop. Research on this topic is needed to formulate efficient N-fertilizer practices.

Although total nitrogen in the soil is simple to measure, tests for available nitrogen (NH_4 and NO_3) are made more difficult by the fact that these ions are present in the soil in small and fluctuating quantities. Seasonal variations in available nitrogen have been studied by Greenland (1958), Birch (1958) and others.

Greenland (1970) has pointed out that the reason why nitrogen tends to increase under natural grasslands is that the labile nitrate ion occurs only in very small amounts under such conditions, so that losses are kept very small, and even modest additions of N to the soil-plant system result in a net increase. He also refers to recent methods which would assist with the detailed quantitative analysis of the nitrogen cycle under different management practices, mentioning the acetylene-ethylene method for measuring nitrogen fixation (Hardy et al., 1968) and sensitive methods of gas chromatography to determine losses of nitrogen gas from the soil (Burford, 1969; Burford & Greenland, 1970).

(ii) Phosphorus responses and research on phosphorus

Possibly more attention has been given to phosphorus in tropical soils than to any other nutrient. This attention reflects both the belief that phosphorus is frequently a major limiting factor and the relative complexity of the problems associated with the uptake of phosphorus from the soil, include phosphate fixation. Some aspects of current knowledge regarding phosphorus in soils of the humid tropics have recently been summarized by Olson & Engelstad (1972).

Phosphorus responses have been widespread, both in tropical forest and tropical savanna areas, and appear to be related to the intrinsic qualities of the soil, particularly tc its phosphate fixing capacity. In the FAO Freedom From Hunger fertilizer programme some response to applied phosphate was reported for slightly over 90 percent of the very numerous trials reported (FFHC Fertilizer programme, 1968), responses being particularly large for tubers (including yams) and vegetable crops. The following figures give average yield increases in trials in West Africa and South America:

		Yield increase (kg/ha)
West Africa:	Maize (794 trials)	173
	Yams (377 trials)	895
Northern South America:		
	Maize (196 trials)	401
	Potato (53 trials)	2 762

Phosphorus is relatively immobile in the soil, so that the root has to grow to reach the applied phosphate. This fact, and the well known ability of a range of tropical soils to fix applied phosphate in various ways (usually as aluminium and iron phosphates in acid soils and calcium phosphates in alkaline ones) have contributed to the fairly low availability of applied phosphatic fertilizers and suggest the need for increased fundamental and applied research on increasing the efficiency of phospate fertilizers. Topics requiring further investigation include:

- the effects of granulation of phosphatic fertilizers in reducing fixation and prolonging availability
- the possible effects of coating fertilizer granules to reduce fixation
- the use of local rock phosphate supplies on acid soils
- the use of a little lime on very acid soils (below pH 5.0) with high exchangeable aluminium
- special problems of soils with particularly high phosphorus fication capacities (usually soils high in amorphous hydrated oxides of iron and aluminium)
- further investigations on method of application, including depth of placement in different crops and soils, and rates of application
- further investigations on the feasibility of predicting P responses by means of direct soil analysis and correlations both between different methods and between results and subsequent responses
- problems of seasonal variations (especially between wet and dry seasons) in test results
- the practical role of other diagnostic methods such as leaf analysis
- the use of added silicate to reduce fixation in soils with high iron and aluminium but low silicon
- possible harmful effects of P applications, e.g. depressing zinc, manganese or copper availability, especially in soils with a high pH
- assessing and improving the residual effects of phosphatic fertilizers

(iii) <u>Potassium</u>

Potassium, in areas of shifting cultivation, is much less frequently a limiting factor than are nitrogen and phosphorus. In some cases this is because the soil parent material contains adequate potassium (as in parent materials containing potassium feldspar and the micas), or because potassium release from humus mineralization is adequate. In many cases, such as soils of the West African savanna areas, both total and available K appears low when measured in the laboratory, and yet crops show little or no response to potassium fertilizers. This has been explained as being due to the fact that the crops involved are generally grasses (maize, sorghum, millet) which are relatively efficient extractors of potassium, and also to the fact that savanna soils which are sandy and low in organic matter have relatively low cation exchange capacities. A low cation exchange capacity means that even a small amount of exchangeable potassium can give a satisfactory potassium saturation percentage (exchangeable K/CEC), so that the small amount is nevertheless fairly easily available to the plant. More recent work, however, including trials with yields at higher levels, have shown increasing numbers of examples of responses to potassium fertilizers in the savanna areas.

In the forest areas potassium responses are more frequent than in savanna areas, particularly with bulky starch containing crops such as cassava, while K responses of coconut palms growing on sandy littorals have sometimes been particularly spectacular.

Further research is required on potassium leaching losses (particularly the role of phosphate, sulphate and chloride anions in facilitating the removal of K and other cations), and on the release of non-exchangeable forms of potassium in the soil to replace the removal of the more readily available forms. Further work on the determining of readily available and slowly available forms of K in the soil in relation to CEC and other factors affecting uptake should make it easier to identify in the laboratory those soils deficient in this element. A useful summary of existing knowledge of potassium in soils of the humid tropics has recently been made by Boyer (1972), who examined the various minimum levels of exchangeable potassium required by various crops as reported from different parts of the tropics. He divided crops into three groups according to whether their minimum exchangeable K requirement appears to be about 10 m.e. per 100 g, or less than this, or more than this. He also examined exchangeable potassium needs in relation to total exchangeable bases (K should be at least about 2 percent) and reviewed work on various potassium ''fertility scales''. Boyer also discussed the important question of equilibria with other cations, particularly K/Mg and K/Ca ratios, and possible interactions between potassium and nitrogen, phosphorus and iron.

This valuable summary of present knowledge indicates clearly that further work is needed on these topics, as well as on the problems of potassium leaching (referred to recently by Wild, 1971), and of potassium fixation in certain soils and climates, and the fact that the commonly used potassium fertilizer (KCl) sometimes has a depressive action or lowers the quality of some crops.

(iv) Sulphur

Sulphur deficiencies are now known to be fairly widespread in some areas of shifting cultivation, particularly in savanna areas. This may be because the sulphur is lost during the annual burning.

The sulphur in soils is mostly organic, and closely tied to organic nitrogen. In wet areas sulphur may be lost by leaching.

Sulphur responses have been reported from Brazil (McClung & Freitas, 1959), the Punjab of India (Kanwar, 1967), in East Africa (Russell, 1968a) and in West Africa (Nye, 1952; Greenwood, 1951; Braud, 1969). In many other areas deficiencies have probably been unwittingly made good by sulphur containing fertilizers such as ammonium sulphate and single superphosphate. In Senegal, Tourte et al (1964) reported an avarage sulphur leaching loss from lysimeter studies of 10 kg/ha. Since crop removal is usually of the order of 5-10 kg/ha, Olson & Engelstad (1972) suggested that the required rate of S application could in some cases be as high as 20 kg/ha, and stated that provided that sulphur applications are not allowed to lower soil pH to levels which would result in excessive S and Mn plant uptake, moderate sulphur applications to non-acid soils in particular can be expected to have a beneficial effect on the availability of a wide range of nutrients.

(v) Calcium, magnesium and liming

High soil acidity was formerly believed due to a high degree of hydrogen saturation of the exchange complex, but it is now known that in soils with a pH of 5.0 or less the predominant cation is exchangeable aluminium. This is due to the hydrolysis of aluminium and the production of hydrogen ions. Kamprath (1972) has recently summarized current thinking on these topics, and discussed responses to liming based on neutralization of exchangeable aluminium. This approach calls for the addition of lime, in relatively small amounts, only to very acid soils. Liming of moderately acid soils has met with very varied results so far, and is not likely to prove of widespread use. Some of the harmful effects of liming are related to the fact that all the trace elements except molybdenum are more available in acid soils than in neutral and alkaline soils, so that liming may induce trace element deficiences.

One of the beneficial effects of adding lime to very acid soils high in exchangeable aluminium is that their phosphorus fixation capacity may be lowered.

Considerable further research is required on the importance of soil pH in the tropics, and on useful ways of measuring it. Research on liming rates should probably be based on determining amounts needed to neutralize only the exchangeable aluminium. Frequency of application will depend on leaching rates, and field studies are needed to ascertain these.

The main effects of low calcium and magnesium in soils are indirect, i.e. on soil pH, but in a few cases direct shortages of these elements have been reported.

(vi) Micronutrients

Under shifting cultivation, with adequate fallows, it was generally thought that micronutrient deficiencies are unimportant. Recently, far more cases of trace element deficiencies have been reported. This is partly because increased yields put greater strains on micronutrients in the soil and show up deficiencies which were not apparent with less intensive agriculture, and partly because more research has been carried out on these topics. Current knowledge of micronutrients in the humid tropics has recently been summarized by Drosdoff (1972) who stated that in Africa deficiencies of molybdenum, zinc and boron appear to be the most prevalent, but copper, manganese and iron deficiencies have occasionally been identified. Deficiencies reported in Malaysia are mostly of zinc and boron, while in the Campo Cerrado area of Brazil, where the highly weathered and leached soils are developed over very old sediments, dramatic responses have been obtained to trace element applications, particularly to zinc, boron and molybdenum.

It appears very likely that more research on trace elements will reveal further examples of deficiencies. These are generally least likely on younger, more fertile soils well supplied with organic matter, and most likely to occur in highly weathered or sandy soils, developed from old sediments, which are also low in humus, or on organic soils.

(vii) Silicon

Silicon is not an essential plant element, but in many highly weathered tropical soils soluble silica may be relatively low and there is increasing evidence that added silicate can increase yields of certain grasses, particularly rice and sugarcane. In Japan large quantities are applied annually to the rice crop. In a review of recent work on this subject D'Hoore & Coulter (1972) refer to reported responses of sorghum in Mauritius and millet in Rhodesia, and conclude that there is considerable scope for research into the role and need for silica in tropical agriculture.

(viii) Fertilizer responses in the absence of other improved practices

The extent to which fertilizer applications alone can increase yields on farmers' plots has been the subject of considerable discussion and sometimes disagreement. Those concerned with the recent widespread FAO fertilizer trials in Africa have on occasion written enthusiastically of the very high proportion of cases in which responses have been obtained. Thus Hauck (1972) stated that

> ''The results obtained up to now from several thousands of fertilizer trials indicate: after the effect of the fallow on the plant nutrient content of the soil has gone, it is possible and economic to increase by relatively small quantities of fertilizers, not only the immediate yields but also, gradually the fertilizer level of the soil .... fertilizers can become the main factor for the intensification of the cropping period and eventually for a complete abolishment of the shifting cultivation''.

Richardson (in Russell, 1968a) wrote:

> ''Fertilizers used alone can be far more widely effective on the farms of traditional small farmers than had formerly been thought ..... For this reason we in FAO regard fertilizers as ''The spearhead of agricultural development''.

Richardson went on to state that of 8 746 demonstrations and 2 250 trials in West Africa, all of them ''showed positive responses'', and of these 85 and 99 percent respectively showed ''positive economic returns to at least one treatment''. Further details are given in Richardson (1968).

In contrast to this, and in direct reply to Richardson's views, Russell (1968a) quoting data supplied by Nye (some of it published in Nye & Stephens, 1962) stated that in Ghana alone nearly 1 200 trials were made before 1960 on peasant farms, nearly all with a 3 x 3 N and P unreplicated factorial design. Responses ranged from 4 to 42 percent of mean yield but many sites gave negative responses and Nye considered that the responses were profitable on considerably less than the 85 percent of cases reported for the FAO trials.

The FAO trials have undoubtedly amassed a considerable amount of data, and further work on these lines should possibly be concerned with relating trial and demonstration results to soils and climates, and analysing results in more detail than has been possible so far.

(3) Research on continuous cultivation

Shifting cultivation is concerned mainly with arable food crops. Alternatives to shifting cultivation include systems of arable cropping which are more permanent, including long term rotations, and also the greater use of permanent irrigated agriculture (particularly swamp rice) and of tree crops.

In an integrated landscape using different parts of a soil catena in different ways one can envisage permanent rice or bananas in valley bottoms, permanent tree crops on the more sloping ground, and arable agriculture confined to areas of gentle gradient. A broader view, considering the various ecological zones of West Africa as an example, would perhaps emphasize that the very wet rain forest areas are generally not as well suited to arable crops as they are to tree crops such as oil palm and rubber, so that rational land use here would include tree crops on uplands and permanent rice or banana in valley bottoms. In the less wet areas of the semi-decidous forest zone a much greater range of crops, including cocoa, can be grown but there is still a strong case for preferring tree crops to annuals on the slopes. In the savanna areas where gradients are usually more gentle than in forest areas, there appears to be more possibility of introducing mechanized arable agriculture involving appropriate rotations.

Two alternatives to shifting cultivation thus already exist: these are swamp rice and other irrigated crops, and permanent or semi-permanent tree crops. The third alternative, continuous arable cropping, or continuous cropping broken by grass legume leys or planted fallows, is not yet a well-tried workable alternative in most areas where shifting cultivation is practised and the great variety of soils and climates in which shifting cultivation is found implies a large number of different local solutions to the problems raised.

Considerable experimental evidence is now available on long term rotations of crops and on the effects of leys, green manures and other ways of maintaining productivity. The initial emphasis in the savanna areas of Africa was on the use of farmyard manure or compost. The two best known experiments at Kano in Nigeria and at Serere in Uganda (Russell, 1968a), relied on impracticably heavy applications of FYM but even with these applications yields at Kano fell off. Heathcote (1970) concluded that organic manures applied over a period of years at Samaru, Northern Nigeria, were effective because they corrected soil acidity and incipient potassium deficiency and provided trace elements, but claimed that ''no evidence has yet been found to suggest that the addition of organic matter as such is of value'', Farmyard manure has often been thought to have longer lasting effects than green manuring. Although green manuring and the introduction of grass/legume leys has proved valuable in some areas such as Zambia, it appears that it is mainly in relatively cool parts of the tropics that their effect is sufficiently long lasting to be worthwhile.

In the lowland tropics the additional organic matter supplied by green manuring is mineralized in a season or two, and the beneficial effects on the succeeding crop may correspond merely to those obtained by a small fertilizer application. All work on green manuring and the effects of leys designed to raise organic matter levels must be critically interpreted in relation to the climate, particularly temperature, and to the original organic matter level in relation to the equilibrium level, as discussed by Nye & Green (1960). As suggested above, research also needs to tackle realistically the question of maintaining yields even with relatively low organic matter contents.

Although there is clearly increasing evidence of our ability to raise yields and to prolong cropping periods, it nevertheless remains true that in many areas where shifting cultivation is practised, particularly in the lowland tropics, there is as yet no economic system of continuous arable cultivation which has proved workable. Current work, some of it referred to in this paper, is undoubtedly bridging the gap between intermittent and continuous cultivation but a very great deal of fundamental and applied research remains to be done to close this gap in the way it has been closed in temperate regions.

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WEEDS AND SHIFTING CULTIVATION

by

K. Moody*

INTRODUCTION

Shifting agriculture is the predominant practice on large areas of the potentially arable and grazing land of the tropics as well as a means of subsistence of over 200 million people. Even the most densely populated tropical areas (Southeast Asia) has about one-third of its farm land under shifting cultivation.

The method involves farming a piece of land for a short period of time following clearing until declining yields force the farmer to abandon the land to fallow for a longer period of time. The length of the fallow depends on the amount of land available, the pressure of population, the level of fertility, the rapidity of regeneration of the fallow and various other factors.

There is some question whether declining yields are due to declining soil fertility, increasing weed competition, increasing pest problems or accelerated erosion.

The luxuriant growth of weeds is one of the major problems of tropical agriculture. The depressive effect of weeds can be so great as to destroy the crop completely. The majority of tropical farmers who use the hoe to control weeds are forced to abandon the land when they can no longer control weeds or when clearing a new piece of land will give greater returns than extra weedings on the old piece. The fallow suppresses the weeds that were a problem and is a cheap and efficient means of weed control.

Inability to control weeds will be one of the greatest obstacles to continuous cultivation in the tropics. The methods presently used will have to be supplemented or supplanted by modern weed control methods.

In this report the role of weeds in shifting cultivation is described, alternative methods for their control are suggested and various research requirements are specified.

CULTURAL OPERATIONS

Clearing

Under optimum conditions, the bush fallow is a stable, almost completely woody community. Grasses and herbs are confined to the edges of roads, paths and open places (Obi & Tuley, 1973) The end of the forest fallow occurs with clearing of the land in the dry season followed usually by burning before the onset of the rains. Felling the forest is an arduous task and the farmer never completely clears the stumps and roots from which the forest regenerates in the ground (Clayton, 1958; Greenland, 1970; Hanson, 1970; Tempany & Grist, 1958).

Burning

In general, burning is used to remove debris rather than as a weed control practice (Crafts & Robbins, 1962). In most cases, fire seldom reduces the viability of weed seeds that have fallen to the soil surface (Crafts & Robbins, 1962) although there are reports that burning will destroy some of these seeds (Klingman, 1960; Oyenuga, 1967; Webster & Wilson, 1966). The degree of destruction depends on the intensity of the heat generated by the burn (Klingman, 1961).

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It is more likely that fire promotes weed seed germination by ending seed dormancy (Crafts & Robbins, 1962; King, 1966; Klingman 1961; Went, G. Juhren & M.C. Juhren, 1952) although there are reports that burning seemed to delay (Ahn, 1970; Brown, 1969) or had no effect (Went et al., 1952) upon germination.

Burning in association with clearing will also promote weed seed germination and growth by removal of competition of other plants, removal of litter, allowing more light to reach the surface of the soil and causing greater temperature changes in the upper soil layers between day and night (Klingman, 1961; Watters, 1958, Went et al., 1952).

In some areas, cleared land is protected from fire until after the first rains have fallen and the first weed seeds have germinated. A fierce burn should destroy these young plants and reduce the need for subsequent weed control (Parsons, 1970).

In the savanna, grass remaining at the end of the dry season is burnt. Crop seeds are then sown into the resultant ash without the use of any tools (Duckham & Masefield, 1971) or sown into land that has been worked with a considerable amount of labour (Bartlett, 1956). In some cases, the grass is allowed to sprout again to provide forage for animas (Duckham & Masefield, 1971; King, 1966).

Land burned too often frequently becomes overgrown with perennial grasses which may render it useless for agricultural production using simple tools (Bartlett, 1956). Repeated burning kills desirable grasses replacing them with less palatable species and prevents the shading out of undesirable weeds during the fallow period.

In the forest zone, when the land is cultivated repeatedly, grasses often increase in amount. Frequent fires will then kill the seedling forest trees and the vegetation eventually converts to savanna (Bartlett, 1956; Clayton, 1958; Jurion & Henry, 1967; Keay & Onochie, 1940; Ochse et al., 1961; Orsenigo, 1970; Vine, 1953). Thus the normal ecological succession is interfered with by repeated burning.

Seed dormancy and cultivation

Following clearing and burning, the land is often weed free (Ruthenberg, 1971). Fallowing usually prevents growth and thus further seeding of arable weeds and allows a gradual diminution of the weed seed content of the soil. Weeds having short-lived seeds can be controlled by this means but fallowing will not eliminate arable weeds completely.

The seeds of many weeds retain their viability for twenty years or more when buried in the soil (Crafts & Robbins, 1962). They will not germinate because of unfavourable conditions and can outlive virtually any fallow period irrespective of its length.

Crops are planted with minimum disturbance of the soil as disturbance encourages weed seeds to germinate (Roberts & Feast, 1973). However, more weed growth in the first year after clearing when leaf litter was removed and where no tillage had been practised has been reported (Anon., 1971). In addition, bush regrowth in the dry season following the first year of cropping was greatest in these plots (Curfs, personal communication).

Weed seeds will germinate at the same time as the crop, and unless controlled can lead to complete loss of the crop (Anon., 1971; Tempany & Grist, 1958). Some workers (Brown, 1969; Laudelot, 1958; Ruthenberg, 1971) have reported that little weeding is required in the first year after clearing; others (Hanson, 1970; Laudelot, 1958; Nye & Greenland, 1960; Watters, 1971) have stated that as cultivation continues the weed problem increases and is one of the primary reasons for abandonment of the land.

PROBLEMS ASSOCIATED WITH WEEDS

Weed competition greatly reduces crop yields and Ashby and Pfeiffer (1956) estimated that losses in the tropics are two to three times greater than in the temperate zones. Yield decreases of 50 percent or more due to weeds within two or three seasons after clearing have been reported (Brown, 1969; Jurion & Henry, 1967). Crop losses due to weeds at IITA have ranged from 19 percent for maize to 100 percent for upland rice (Anon.; 1971, 1972) (Table 1).

Weeds also become such a problem that they cannot be controlled by the simple techniques presently used by the farmer (Jurion & Henry, 1967; Ochse et al., 1961; Watters, 1971). In fact, more energy is expended on weeding of crops than on any other single human task (Holm, 1971). In western Nigeria at least 50 percent of a farmer's working time is spent weeding (Anon., 1972).

If an assessment were made of the economics of major crops of a number of tropical countries, it would probably be surprising how often weed problems would be the factors that either limit the yield of the crop or are a major item in the cost of production (Ashby & Pfeiffer, 1956).

Maximum yields will be obtained when the crop is grown without any weed competition. If this cannot be achieved weed control in the early growth stages of the crop is essential (Ochse et al., 1961).

Nieto et al. (1968) observed that if a maize plot was kept weeded for the first thirty days following planting, the yield was only 5 percent less than that from a plot kept weed free for the entire growth cycle. Similar results were observed at IITA with cowpeas and soyabeans, but yams must be kept weed free for three months to achieve the same results (Anon., 1971,1972). Thus, weeds appearing after thirty days in crops of maize, cowpea, and soyabean and after three months with yam have little effect on yield but may harbour pests and make harvesting difficult.

In maize, the presence of weeds during the first 12 days depressed production by only 3 percent. However, by 20 days after seeding, yield had been depressed by 12 percent and by 30 days, 22 percent (Nieto et al., 1968). Weeds growing in association with cowpeas caused no appreciable losses until thirty days after emergence of the crop (Anon., 1971). Further trials revealed that an average yield reduction of only 11 percent occurred if the cowpeas were weeded once three weeks after emergence. Yield losses were negligible if the crop was weeded twice, one and four weeks after emergence (Anon., 1972. With soyabeans, however, if weeds were left growing in association with the crop for ten days a 10 percent yield reduction occurred. A further 10 percent reduction occurred in the next ten days (Figure 1).

Most of the cropped land in the tropics is still weeded with simple tools such as hoes and matchets. It is a slow business and is usually commenced after weeds have begun to exert a depressive effect on crop yield. Assuming a farmer takes five days to weed one hectare and he commences weeding twenty days after emergence of the crop, by the time he has finished weeding three hectares he has lost 40 to 50 percent of his yield of maize or soyabeans. Losses will be less for cowpeas.

Once the crop has developed an extensive root system and grown enough to shade the soil partially, weeds are less competitive. In many crops, weeds that develop two or more weeks after the crop are low in vigour and do not develop sufficiently to hurt the crop (Furtick, 1970). Tempany and Grist (1958) agreed that after crop establishment weed competition is less serious, but stated that weed growth is so rapid and strong that its control is one of the most serious problems facing the farmer. Mayer and Chabrolin (1972) noted that weeds germinate throughout the growing season and compete with upland rice as long as the crop does not cover the soil adequately. At present, farmers do not weed early enough to prevent major damage. If they are going to benefit from weed control they must either cultivate or hand weed very early or else rely on pre-emergence herbicides (Furtick, 1970) (Table 2). Additional late weedings may be required in some crops.

Weeds are often a greater problem in a sole crop or in simple crop associations than in the multi-crop multi-storied associations that occur over most areas under shifting cultivation (Watters, 1971). The more complete cover provided by a mixture of crops not only helps in protecting the soil but reduces the need for weeding by competing with the weeds.

In a study conducted in northern Nigeria, sole crops accounted for only 19 of the 179 different crop enterprises, or less than 17 percent of the total cultivated crop area of 890 acres (Normen, 1970). In Western Nigeria, a survey of three villages revealed that only 13.8 percent of the field plots were devoted to one crop (Anon., 1972). For the introduction of modern methods of weed control it would be much more advantageous if single crop planting was practised. However, in western Nigeria, many farmers prefer to intercrop rather than sole crop to reduce costs (Williams & Alao, 1972).

Weeding has also limited the size of tropical farms which rarely exceed 2-3 ha per family (Terra, 1959). When the crop area per family is too large, planting may be no problem but weed growth will be so great that either some of the land will have to be abandoned or the productivity will be very low (Dumont, 1970; Terra, 1959).

Soil erosion and possible methods of control

While it is important to keep crops free of weeds in the early stages of their growth it is also at this time that the soil has the least protection and thus has the greatest susceptibility to erosion. Run-off and soil erosion losses can be reduced greatly by mulching (Anon., 1972). In Samoa, a mulch of dead vegetation was spread over the ground between plants to reduce weed growth and on steep slopes live weeds were retained to prevent erosion even though they reduced yield (Watters, 1968).

Mulching is not very practical in that large amounts of material are needed which may have to be grown on land that could have been used for economic crops. It then has to be cut and transported which is time consuming and adds to the cost of growing cash crops (Crafts & Robbins, 1962).

An alternative is to practise minimum or zero tillage. By this method, run-off and soil losses have been decreased and the available water storage holding capacity of the surface soil increased compared with conventional tillage for maize (Anon. 1972). Weed growth, primarily annual grasses, was less but bush regrowth was greater on the no tillage plots (Lal, personal communication). Use of this method is dependant on suitable herbicides being available for weed control.

In the U.S.A., satisfactory results are being obtained with no tillage in maize but perennial broadleaved species are becoming a problem. Also, annual grass control is less satisfactory in no-tillage fields than in conventionally cultivated fields. In soyabeans, annual weed control has been satisfactory but serious problems have been encountered when perennial weeds are present (Peters, 1972).

Overcultivation and changes in weed populations

As cultivation continues, the weed population may also change. In Peru (Sanchez & Nurena, 1970), weeds in rice have changed from broad-leaved weeds to grasses after two crops. Similarly, in areas recently cleared from forest at IITA, grasses comprise about 40 percent of the weed population whereas in areas that have been cultivated for two or three years the proportion may be as high as 85 percent. De Schloppe (1956) reported that weed composition changes in the fourth year after clearing and that certain weeds (*Bidens pilosa*, *Chloris* spp., *Eleusine indica*, *Commelina benghalensis*, and *Pennisetum pedicellatum*) are indicators of soil degradation.

In many areas, where overcultivation has occurred *Imperata cylindrica* becomes established (Clayton, 1958; Jurion & Henry, 1967; Ochse *et al.*, 1961; Schlippe, 1956; Tempany & Grist, 1958). *Imperata* is a poor competitor and can be destroyed by shading out by other more desirable grass species such as *Panicum maximum*, *Chloris pilosa*, *Hyparrhenia rufa*, and *Andropogon tectorum*.

In the derived savanna in Nigeria, Imperata is suppressed by A. tectorum which in turn is gradually replaced by grasses consisting mainly of Hyparrhenia subplumosa, H. rufa and Schizachyrium sanguineum (Clayton, 1958). In southeast Nigeria, over-cultivation gives rise to a grass and herb flora usually dominated by P. maximum or A. tectorum. At this stage, if the land is rested, it quickly returns to bush fallow. If further cultivation continues there are indications of a succession of arable weeds and smaller grasses culminating in the appearance of bracken (Pteridium aquilinum) (Obi & Tuley, 1973).

Jurion and Henry (1967) reported that Imperata cylindrica was successfully smothered by pulses; in order of effectiveness, these were Pueraria javanica, Stylosanthes gracilis and Calopogonium mucunoides. But Ogborn (personal communication) stated that legumes will not establish in the presence of Imperata if they are broadcast on unploughed land. The land must be ploughed if Imperata is to be partially eradicated. Adegbola et al.(1970) in endeavouring to eliminate Imperata obtained the best results by seeding Andropogon gayanus or A. gayanus plus S. Gracilis after ploughing. In addition, the seedlings of many introduced grasses and legumes make slow initial growth and do not compete satisfactorily with weeds; even Cynodon IB8, a selection of Cynodon nlemfuensis, which inhibits the germination of many weed seeds and suppresses seedling growth requires weeding for establishment (Crowder, 1971).

Abandonment

Most of the plant species which make up the forest fallow can be found during the later stages of the cropping cycle provided no clean weeded plants are used for closing the cycle (Laudelot, 1958) Greenland (1970) stated that the land is abandoned bacause the rate of redevelopment of the forest creates a weed problem that is more difficult to manage than clearing an older area of forest.

Abandonment occurs when the farmer considers that the return to be gained from labour expended in clearing a new site will exceed the return expected from extra weedings of the current site. In addition, clearing is done during the dry season when the farmer has little else to do, whereas weeding must be carried out during the growing season. Thus the farmer reduces his work load at the busiest time of the year, distributes his work more evenly and may even be able to earn wages elsewhere (Norman, 1970; Watters, 1971).

Laudelot (1958) emphasized that the cropping cycle should close with plants such as cassava or plantain for which no cultivation and very little weeding is necessary. These plants complete their growth cycles in a tangle of regrowth which can be considered as the onset of the forest fallow. With their harvest, the cycle of cultivation comes to an end.

Abandonment of the cultivated area to fallow is one of the cheapest and most effective forms of weed control. It rapidly suppresses the growth of weeds that may have been difficult to control during cultivation (Hanson, 1970; Vine, 1968; Watters, 1971). At IITA, on a piece of land that had been cleared and then immediately abandoned, Panicum maximum which dominated the flora within five months following clearing, was completely suppressed by bush regrowth 18 months after abandonment.

Following abandonment of the cultivated area various vegetation communities will succeed one another until the final phase, a stable community, is reached (de Schlippe, 1956). Keay and Onochie (1940) suggested a sequence by which grassland dominated by Loudetia arundinacea is converted to mature high forest, while Clayton (1958) described vegetation complexes on clayey, sandy and poorly drained soils of the forest zone of Nigeria.

Once the final stage of regeneration has been reached the forest is then cleared again. Clearing may occur prior to this time, but if it does it is delayed until certain plants have become established, indicating that weeds which were a problem during cultivation have been suppressed, or until undesirable weeds have disappeared (Jurion & Herry, 1967; Nye & Greenland, 1960; de Schlippe, 1956).

Possible solutions

Weed control is one of the major problems in many tropical areas yet most weeding is still done by hand. At present, in a number of areas, crops are sown by broadcasting which makes weeding much more difficult. Tiley (1970) stated that the most effective way of reducing the burden of human toil of weeding would be to sow all crops in rows.

In Mexico, the period of cultivation in the shifting cultivation cycle has been extended by ploughing (Watters, 1971). Watters (1971) stated that one of the most important innovations needed for continuous cultivation of the land is the introduction of ploughing. However, he noted that ploughing may be difficult in most parts of the humid tropics for a number of years following clearing because of undecomposed roots and tree stumps.

The introduction of mechanical equipment brings an increased output per worker enabling him to do the work faster. In addition, the physical burden of farm work is lessened because the drudgery of hand labour is eliminated (Miller, 1970).

Inter-row cultivation has the disadvantage in that it does not kill all the weeds in the row. These may have to be removed by hand. Also it may not be possible to carry out cultivation at the correct time because of soil conditions. The use of herbicides is therefore advantageous.

The answer to many of the tropical weed problems may be in the use of herbicides which can be more selective and thorough in their action than cultural methods (Ashby & Pfeiffer, 1956). They can also be applied at an earlier stage of crop development, even before the crop emerges from the ground, and remain active until the critical period of weed competition has passed.

Herbicides have been successfully used by farmers in shifting cultivation areas (Sharman, 1970; Watters, 1971) but some concern (Brown, 1969; Chang, 1968; Renaut, 1972) has been expressed that herbicides are too costly to be used by the majority of farmers in the tropics. However, in many parts of the world, increasing labour costs or the unavailability of labour at critical times are rapidly causing the use of herbicides to become more economic than hand labour. In Colombia seven crops treated with herbicide showed an average yield increase of 19 percent over local weeding practice. The farmer usually weeded too late to prevent substantial yield losses (Furtick, 1970) (Table 2).

In western Nigeria, the major problem encountered by agricultural extension agents was persuading the farmers to weed two or three times, as recommended for both maize and upland rice. The farmers complained of shortage of labour and money (Williams and Alao, 1972).

Jurion and Henry (1967) suggested that present methods should be supplemented by the use of herbicides. Orsenigo (1970) noted that chemical methods of weed control are more attractive and acceptable for large-scale farming where hand labour is inefficient and inadequate. For small farms or for specialized crops, hand labour may still be the cheapest and most efficient way of controlling weeds.

Herbicides may be the only replacement for present weed control practices in upland rice. Mechanical methods currently available are unsuitable (Anon., 1972; Renaut, 1972), but unfortunately many of the herbicides that can be used successfully in lowland rice are unsatisfactory for upland rice.

In addition to the possibility that herbicides may be too expensive for present day use in the tropics other problems arise. These include:

1. Herbicides are impossible to use in the multicrop associations that the farmer is presently using. This means that he will have to grow a single crop or a simpler crop association. This is advantageous not only for weed control but also for pest control. Herbicides to be used in the present cropping system would have to be harmless to a large number of crops; consequently fewer weeds would be affected and eventually little or no weed control would be achieved.

For simple crop associations, herbicides that do not affect the components of the association can be used. If damage to any of the components occurs, then techniques such as banding, delayed planting and crop protectants might have to be used.

2. Ideally herbicides kill aall vegetation except the desired crop plant. If this is the case, the 'local vegetables' (which are weeds in the true definition of the word but form a portion of the farmer's diet) will also be destroyed.

3. Non-granular herbicides (liquids and wettable powders) require water and a sprayer for application. Granules, even though they are more expensive, can be applied by hand in association with fertilizer and may be more acceptable to the farmer. Furthermore, the proportion of the active ingredient in granules is constant whereas other herbicides have to be mixed and applied carefully to obtain the same precision.

4. At present, even though research is being conducted at a number of places in West Africa, adequate information is not available on herbicides that should be applied to tropical crops or on the economics of such applications. Much more research needs to be done to solve the present problems.

Research requirements

At the present time, throughout the tropics there are probably 100 trained weed scientists; in West Africa, there may be as few as ten. In Nigeria, there is one part-time weed scientist in the area to the north of the Niger and Benue Rivers. In proportion to the immensity of the problem facing them, there are far too few weed scientists.

There is a critical need for training of personnel particularly in practical aspects of weed control in tropical and subtropical countries. Universities and agricultural schools must include weed control training as part of their curriculum.

More information is needed on the losses caused by weeds, and efforts should be made to determine when they cause these losses. The weeds that are causing the major losses in crops must be identified and studied. Changes in weed populations over time both with and without herbicide applications must be determined. As weed populations change, control methods may have to change also.

Suitable methods of weed control must be determined. Alternatives must be offered for the methods presently used.

(a) There is a need for adaptation of presently available tillage methods to tropical conditions especially for small farms. Animal and tractor power may have to be introduced and better accessory equipment must be manufactured. The possibility of using minimum tillage should be investigated.

(b) Herbicides already developed will selectively control certain weeds in most crops. Extensive research may be needed to find those compounds best suited to the particular weeds, crops and conditions found in the tropics.

If alternative methods of weed control prove to be superior to the methods presently used and also economically feasible, a concerted effort must be made to pass on the information to the farmer.

Conclusions

Weeds are one of the major limiting factors of crop production in the tropics. They are present from the time the farmer clears the land until he abandons it to fallow. They restrict the area that a man can farm and their removal occupies more of his time than any other farm operation.

During the first crop after clearing weeds may be controlled fairly easily, but during subsequent crops the task becomes much more difficult. Because the farmer is unable to control weeds, and because of the reduction in yield caused by them, he is forced to abandon his land. The subsequent fallow provides a cheap means of weed control.

If the farmer cannot control weeds under the system he presently uses, how will he fare if continuous cultivation is introduced? The greatest limitation to continuous cultivation in the tropics will be man's ability to control weeds. Extensive research needs to be carried out to find economic alternatives to the hand methods presently being used.

Finally, there is an urgent need to train more people in weed science, without which the problems may never be solved.

Table 1 - Average crop yield losses (%) as a result of not weeding certain crops

Crop	Year 1970	Year 1971	Year 1972
Maize	19	19	28
Cowpea	51	48	59
Soyabean	-	-	60
Yam	-	-	73
Sweet Potato	-	-	91
Cassava	-	-	92
Upland rice	100	100	100

Table 2 - Effect of weed competition on the yield of crops in Colombia

Crop	Average Loss (%)	Average increase in yield over local farmer practice from herbicide treatments (%)
Potato	17	20
Barley	19	16
Wheat	29	17
Cotton	31	13
Maize	46	21
Bean	51	24
Rice	54	24

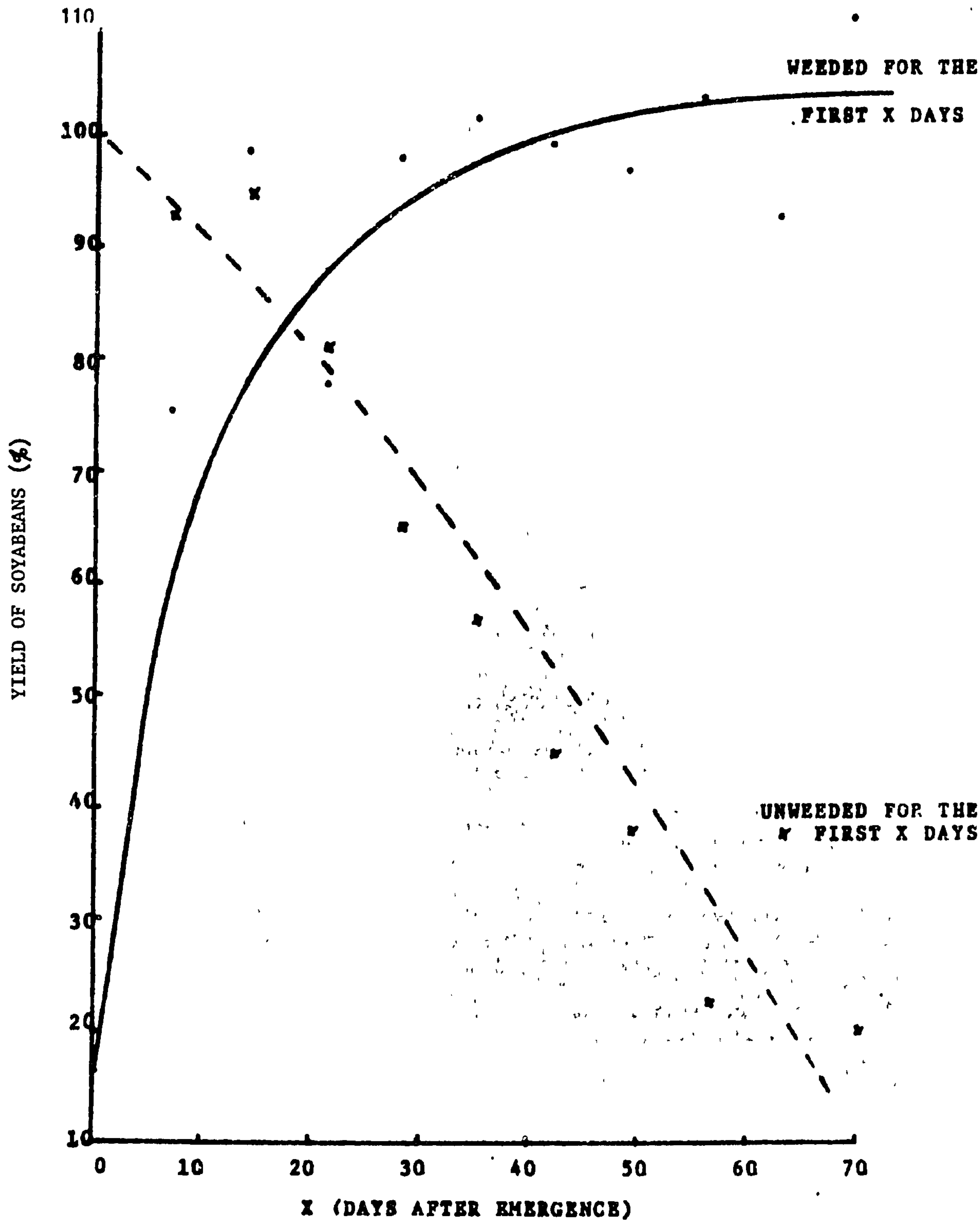

FIGURE 1. SOYABEAN YIELD AS A PERCENTAGE OF YIELD OBTAINED FOR COMPLETELY WEED FREE PLOT

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CROP RESPONSES TO FERTILIZERS: LIMITATIONS IMPOSED BY SOIL PROPERTIES

by

A. Wild*

Introduction

The amount of fertilizer used in West Africa is relatively small. In 1970/71 the consumption of ($N + P_2O_5 + K_2O$) ranged from a negligible amount in Guinea and Niger to 4.4 kg/ha in Dahomey, and in most countries the average was less than 1 kg/ha of arable land (Hauck, 1973). In contrast, the amount in North and Central America was 68.5 kg/ha and in Europe 169.6 kg/ha of arable land.

The reason for the lack of fertilizer use in west Africa is basically an economic one; the cost to the farmer is high compared with his available capital, and this is probably combined with a lack of awareness of the advantage of using fertilizer. There is certainly good evidence from both the humid tropics and the seasonally arid areas that fertilizers can raise crop yields substantially (Nye & Greenland, 1960; Anon., 1972).

Examples of some responses in Nigerian experiments are given in Table 1. By comparison with other parts of the world the responses are generally similar for N and are very much higher for P. However, the responses are variable. In the experiments of Goldsworthy (1967 a, b), the response per kg N varied between 11 and 24 kg grain with maize and between 2 and 9 kg with sorghum; and per kg P the response ranged between 3 and 30 kg grain with maize, and 3 and 24 kg grain with sorghum. In spite of this high variability, responses to N and P are generally high in the Nigerian experiments, though they were less with sorghum than with maize, probably because long-season varieties were grown.

Table 1. Responses of some grain crops to fertilizer nutrients

Place	Crop	Crop response (kg grain/kg nutrient) N	P	K	Notes	Ref.
Ibadan Nigeria	Maize grain	10	75	26	Mean of 8 varieties over 3 seasons	1
Northern Nigeria	Sorghum grain	6	16	ND	154 trials over 12 seasons, farmers land, local varieties	2
Northern Nigeria	Maize grain	17	13	ND	50 trials over 8 seasons, farmers land, improved varieties	3
France and U.S.A.	Maize grain	15-25	ND	ND		4
Northern Europe	Wheat/barley, oats, grain	15	6	ND	From summary of old expts. by Crowther and Yates.	4

Refs. (1) Agboola (1972); (2) Goldsworthy (1967a); (3) Goldsworthy (1967b); (4) Cooke (1967).
ND denotes not determined.

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Several factors may limit the response to fertilizers. Most obviously the soil might already be well supplied with nutrients, but there are many reasons why poor responses may occur even where there is a deficient supply of nutrients (Table 2).

Table 2. Reasons for poor crop response to fertilizer when analysis shows deficient nutrient supply

1. Growth of unresponsive or unsuitable crop variety.
2. Lack of water, or other unsatisfactory physical condition of the soil.
3. Lack of other nutrients not supplied in fertilizer.
4. Toxicity, e.g. of Al and Mn in acid soils, as can be caused by use of NH_4^+ fertilizers.
5. Loss of fertilizer nutrients by leaching (N), denitrification (N), fixation (P), and in run-off water (N,P,K,S, etc.).
6. Insufficient seeding rate.
7. Inadequate cultivations.
8. Planting date too late.
9. Harvesting not completed.
10. Inadequate control of weeds, disease, insect pests.
11. Shading and competition from trees and interplanted species.
12. Damage caused by predators, e.g. rodents, birds, monkeys, elephants.

Any of the factors in Table 2 may limit the response to fertilizer. When all are taken care of, we can speak of good crop husbandry and under these conditions fertilizer efficiency should be high. There are examples in West Africa where improvements in the standard of crop husbandry, combined with fertilizer use on a responsive variety, have resulted in two-fold increases in yield on farmers' fields (Galland, 1963; de Geus, 1967; Harkness, 1970). There are also the results of Allan (1968) in Kenya where maize yields were improved by (a) earliness of planting, (b) weeding efficiency, (c) selection of the correct variety, and (d) adequate use of fertilizers; the importance of the factors decreasing from (a) to (d). Fertilizer responses therefore depend very much on the general standards of husbandry, and hence field experiments require close supervision if dependable results are to be obtained.

Some, and probably a large part, of the variation in crop responses to fertilizer mentioned above, is likely to result from differences in the standards of crop husbandry between experiments. Generally these standards can be improved, or at least enough is already known for advice to be given to farmers. But two factors in Table 2 merit special attention. The first is nitrate leaching and the second is the reaction of phosphate in soil. Either may lead to a low use of fertilizer nutrients and therefore a low return on the investment. The evidence for each will be considered. The process of nitrate leaching will also be examined, partly because of its importance and partly because as yet it is incompletely understood.

Nitrate Leaching

The ideal circumstance would be to maintain some of the soil N in a form such as NH_4^+ which is leached only slowly, if at all. Nitrification inhibitors and slowly available sources of N may have a place in the future. However, at present fertilizer N is either added as NO_3, or is quickly converted to NO_3. This NO_3 may be lost to the crop by denitrification, biological immobilization or by leaching, but only the latter will be considered here.

Nitrate is subject to leaching because, being an anion, it is held by electrostatic forces only when the soil contains sufficient positive charges. Adsorption has been shown to occur in some soils in Hawaii (Singh & Kanehiro, 1969). More usually nitrate is not held to any measurable extent by the soil components under normal field conditions.

The leaching process. Nitrate leaching results from water draining through the soil. The amount of drainage is the difference between amounts added in rain and irrigation water, and losses from run-off, evaporation, transpiration, and changes in water storage. This may be expressed as:

$$Dw = P - R - E - T - \Delta w$$

where Dw = drainage, P = rainfall (plus irrigation), R = run-off,

E = evaporation from soil surface, T = transpiration from crops,

Δw = increase in water storage; all measured in cm.

After a free-draining soil has been wetted to field capacity, Δw is approximately zero a few hours after further addition of water. With a bare soil protected from run-off and evaporation, R, E, and T are also zero, and under these restricted conditions Dw = P. If θ is the fractional volume of water in the soil (percent water by wt, x B.D./100), then under these same restricted conditions and on the simplest assumptions, the theoretical depth of leaching of surface-applied nitrate down the soil is P/θ. More generally, depth of leaching is Dw/θ. For a range of soils, the depth of leaching per cm drainage (or per cm rainfall under the restricted conditions defined above) is therefore inversely related to the water content at field capacity (Table 3).

Table 3. Relationship between theoretical depth of leaching per cm of drainage or per cm of rainfall (where Dw = P) and water at field capacity (vol. %).

F.C. (%)	Depth of leaching cm/cm drainage
10	10
20	5
30	3.3
40	2.5

This bears out field experience that light textured soils lose nitrate quickly and heavy textured soils more slowly.

The rate of nitrate movement is most simply related to the velocity of flow of water by the equation

$$J = VC$$

where J = rate of downward movement of nitrate ($g/cm^2/sec$),

V = velocity of flow of water ($cm^3/cm^2/sec$)

C = concentration of nitrate in soil solution (g/cm^3)

However, as the result of mixing caused by two processes the concentration (C) becomes less as leaching occurs. The two processes are:

(i) molecular diffusion caused by concentration gradients and described by the equation

$$J = -D \frac{dC}{dx}$$

where D is the diffusion coefficient

x is the vertical movement of water.

(ii) hydrodynamic dispersion, described by the equation

$$J = -K \frac{dC}{dx}$$

where K is the coefficient of hydrodynamic dispersion.

Combining the equations and ignoring interactions

$$J = \frac{dC}{dx} \quad (K + D)$$

Although D, the diffusion coefficient, can be calculated fairly reliably for soils, K is much more difficult. We know that hydrodynamic dispersion results from (a) the variable velocity of water flow because of the frictional drag near soil surfaces, and because of different flow rates in pores of different sizes, (b) the turbulence caused by a change in velocity of flow as the pore size changes, (c) the direction of the large pores not always being vertical, and (d) density differences between the nitrate solution and the surrounding solution.

As a result, nitrate moves down well-packed columns in the laboratory as a 'wave', showing a maximum concentration which decreases as the wave moves downwards. In the field, dispersion is often very much greater. This is especially so where the soil contains a wide range of pore sizes which include cracks and large channels, and where rainfall intensity is high. Hence, at present nitrate leaching needs to be measured in the field because it is not possible to predict rates with any dependability, nor can the results of leaching in laboratory columns be applied directly to field conditions.

The measurements of leaching rates that have been made in West Africa in field plots and by lysimetry will now be described in relation to this outline of the leaching process.

Leaching measurements in West Africa. The amounts of drainage water at some sites in West Africa are given in Table 4. They assume no run-off and that the soil has a crop cover whenever there is sufficient rainfall.

Table 4. Monthly amounts of rainfall (P) and potential evapotranspiration (E_t) Cocheme and Franquin (1967)

	Zinder, Niger			Kano, Nigeria			Kaduna, Nigeria			Ilorin, Nigeria*		
	13°46'N,8°58'E			12°00'N,8°31'E			10°28'N,7°25'E			8°32'N,4°34'E		
	P (mm)	E_t (mm)	$(P-E_t)$	P (mm)	E_t (mm)	$(P-E_t)$	P (mm)	E_t (mm)	$(P-E_t)$	P (mm)	E_t (mm)	$(P-E_t)$
January	0	138		0	129		0	195		10	117	
February	0	153		0	139		3	186		18	123	
March	0	185		2	176		15	196		64	140	
April	3	192		8	197		64	174		104	143	
May	27	198		71	205		147	157		170	138	32
June	55	185		119	164		170	122	48	193	122	71
July	153	158		209	136	73	226	106	120	142	107	35
August	232	128	104	311	115	196	292	95	197	132	95	37
September	71	146		137	133	4	290	113	177	257	106	151
October	7	167		14	151		86	134		168	115	53
November	0	144		0	135		5	143		28	130	
December	0	130		0	122		0	172		13	126	
Year	548	1924	104	871	1802	273	1298	1793	542	1299	1462	379
Est. drainage (mm)			4			173			442			279

* from Elston, J. (Personal communication)

At the driest station, Zinder in Niger, P exceeds E_t only in August, and annual drainage is almost nil if a moisture deficit in the soil profile of 100 mm is assumed. The annual drainage calculated for Kano is 173 mm, and for Kaduna 442 mm. Ilorin has almost exactly the same annual rainfall (1299 mm) as Kaduna, but the calculated annual drainage is less (279 mm) because the rainy season and the period of evapotranspiration are longer. It is probably of ecological and agricultural importance that as long as there is a cover of vegetation leaching becomes less when passing from sites with a single rainfall peak to sites with two annual peaks. This occurs in West Africa approximately in the Savanna/Forest Mosaic. Of course drainage again increases south of this belt as annual rainfall increases.

There has been only a little West African work relating amounts of drainage to leaching of nitrate. At Samaru, Nigeria, Wild (1972) calculated the amount of drainage on field plots kept free of vegetation, and measured the rate of leaching of the nitrate which was produced at the start of the rainy season by mineralization and nitrification. The rate of nitrate leaching was much less than the rate expected from the type of data given in Table 3. A comparison with other results (Table 5) shows that this may be common even where nitrate is applied as fertilizer. The probable explanation lies in the physical properties of the soil and in the intensity of the rains (or rate of addition of irrigation water). The soil at Samaru is a sol ferrugineux lessive with a well-developed textural B horizon containing cracks and root channels. Much of the rain falls in thunderstorms and it seems probable that much of this rain passes through the soil too quickly to allow the nitrate to diffuse into the larger pores that carry the drainage water.

Table 5. Relation between 'theoretical' and actual depths of nitrate leaching

Source	Actual/theoretical
Levin (1964). Field plots, sand, irrigated	1.0
Evans & Levin (1969). Columns, dry soil, three textures	0.4-0.5
Cassell (1971). Field plots, loam soil	0.7
Blondel (1971d). Lysimeters, sandy soil	1.2
Wild (1972). Field plots, sandy loam, clay loam subsoil	0.3-1.0
Babiker (1973). Field plots, several soil textures	0.2-0.7

Note: 'Theoretical' depth of leaching calculated as Dw/θ (see text).

Field sampling was also used by Blondel to follow the leaching of nitrate and ammonium through soils at three sites in Senegal: Bambey (Blondel, 1971a), Sefa (Blondel, 1971b), and Nioro-du-Rip (Blondel, 1971c). Only the plots kept under bare fallow will be considered here.

At all three sites nitrate added as fertilizer, or resulting from nitrification, was rapidly leached below 20 cm. However, for deeper leaching there were big differences between the sites which appear to be due to differences in soil properties. In the sandy soil at Bambey the nitrate was carried below 1 m in the two years of measurements when annual rainfall was 532 and 823 mm. At Sefa on a sol ferrugineux lessive, with 13 percent clay in the horizon 0-10 cm and a textural B horizon containing up to 42 percent clay, substantial amounts of nitrate remained at a depth of 80 cm at the end of one year (1966) when 1254 mm rain fell. In 1967 after 1439 mm rain the nitrate concentration was low to 1 m depth. Similarly, at the third site, Nioro-du-Rip, also on a sol ferrugineux lessive, the nitrate concentration remained high at a depth of 80-100 cm towards the end of the one season of measurement after 952 mm rain.

Blondel (1971a) gave the rate of leaching on the sandy soil at Bambey as 7 cm per cm of rain, whereas on the two sols ferrugineux lessive it was about 0.7-1.0 cm per cm of rain. Also on a sol ferrugineux lessive at Samaru, Wild (1972) found an average rate of 0.5 cm per cm of rain. These differences in leaching rates are too great to be explained by differences in water content at field capacity. It seems likely that in both the Senegal and Nigerian experiments leaching was slow on the sols ferrugineux lessive because, as explained earlier, rainfall intensity was high and the soils contained cracks and channels in their textural B horizons.

Measurements of nitrate leaching in Senegal have also been made using lysimeters. Forty lysimeters 35 cm x 35 cm x 40 cm deep were installed at Bambey in 1959 and filled with a sandy soil containing 3 percent clay. For the first few years they were used to measure nutrient losses under crops, fallow, and bare soil, without the use of nitrogen fertilizer.

From results for one year from Vidal & Fauche (1962) it will be seen (Table 6) that the loss of nitrate by leaching was small when plants were growing in the soil, but was greater, as was the amount of drainage, from bare soil. Other results from this early set of experiments have been given by Tourte et al. (1964).

Table 6

Leaching losses from the lysimeters at Bambey, Senegal in 1959: 450 mm rain (Vidal and Fauche, 1962)

	Drainage m^3/ha	Nutrients in drainage water (kg/ha)				
		N	P	K	Ca	Mg
Millet, green manure	952±22	1.6±0.2	0.06±0.01	3.2±0.2	17.9±0.6	2.6±0.2
Natural fallow						
- incorporated	967±86	6.3±1.1	0.07±0.01	5.7±0.5	22.0±1.2	12.1±2.4
- burned	913±76	6.6±0.7	0.04±0.01	5.1±0.5	20.9±1.4	6.1±1.2
Bare fallow	1393±26	45.6±0.8	0.13±0.02	11.5±0.6	55.4±3.2	23.2±2.0

More recently, Blondel (1971d) has reported the leaching rate of fertilizer N during one year using the same lysimeters. Total rainfall was 851 mm, most of it falling in the period July to September, and total drainage was 201 mm. A summary of the results is given in Table 7.

Table 7

Nitrogen balance in the Bambey lysimeters, 1967 in kg/ha (Blondel, 1971d); total rainfall for year 851 mm

	Treatment				
	A	B	C	D	E
N in fertilizer	+300	+600	+300	+600	NIL
N in drainage	- 64.9	-108.6	- 9.9	- 17.9	- 3.9
N in millet - shoots	-100.6	-268.1	-200.0	-238.9	- 8.6
- roots	- 10.0	- 26.8	- 20.0	- 23.9	- 0.8
Balance	+124.5	+196.5	+ 70.1	+319.3	-13.3

Treatment A 300 kg N/ha as potassium nitrate at planting time.

B 600 kg N/ha potassium nitrate, half at planting time and half during growing season.

C 300 kg N/ha as ammonium sulphate at planting time.

D 600 kg N/ha as ammonium sulphate, half at planting time and half during season.

E control, no N fertilizer.

It will be seen that a large proportion (23-41 percent) of the fertilizer N was not accounted for. The author expressed the opinion that this N was probably assimilated by the soil microflora because a laboratory experiment did not show any evidence for denitrification.

The loss of N by leaching was 22 percent from potassium nitrate applied at planting, 13 percent from the split dressing, and only 3 percent from the two ammonium sulphate treatments. Nitrification of the NH_4^+ may have been restricted by the high rate of application to the sandy soil.

It was also observed that the nitrate concentration was highest in the drainage water after a cumulative drainage of 33-34 mm, which was a little below that expected from the water content at field capacity (40 mm). This phenomenon of early displacement of nitrate might be expected from a sandy soil where there are no large aggregates but where there are 'dead pores' which do not conduct drainage water.

To conclude, nitrate leaching cannot as yet be reliably predicted under field conditions. Instead it must be measured, and to extrapolate it to other sites the following information is needed:

a) amount of drainage,
b) water content of soil at field capacity,
c) rainfall intensity,
d) pore size distribution.

Even with this information it remains a problem for research to provide a basis for extrapolation.

Some recommendations can also be made to reduce leaching losses, though not all are practicable.

a) Soil organic matter should be maintained at a high level so that as much as possible of the crop requirement is met by mineralized N.

b) Split applications of N fertilizers will be advantageous where leaching is intense. However, experiments have not always shown a beneficial effect of split applications. This is possibly because differences between split and single applications are less than the main effect of fertilizer, but also because of differences in leaching rates between seasons.

c) Planting early in the rains should increase the efficiency of use of soil and fertilizer N. An early planted crop will reduce drainage loss because of increased evapotranspiration, and it will also give the crop a chance to take up the NO_3 before the height of the rains. Here, rate of root growth is important in relation to the rate of leaching.

d) It should also be an advantage to maintain the soil in an aggregated condition. This will permit rapid drainage between aggregates whilst some nitrate is held within aggregates. This gives a second reason for maintaining a high level of organic matter (see (a) above) in that it helps to form aggregates. Organic matter also increases the water content of soil at field capacity and this in turn reduces leaching rates.

e) Some 'artificial aids' may be used. Possibilities are the use of nitrification inhibitors, and the use of more slowly available sources of N such as sulphur-coated urea, urea-formaldehyde, and other urea derivatives, etc.

In spite of these possible improvements, nitrate leaching seems likely to remain a serious limitation to the efficient use of N fertilizers on light-textured soils in the wet tropics.

Soil phosphate

Crop response to P fertilizers may be very large in West Africa as the results in Table 1 show. Further, as Russell (1968) has made clear, there is good evidence that a single application of a P fertilizer benefits not only the crop to which it is given, but has a residual value as well. In the West African savanna, experiments demontrating a residual value have been reported from Ghana (Nye, 1954; Stephens, 1960), northern Nigeria (Greenwood, 1951; Goldsworthy, 1968), Dahomey (Thevin, 1967), Mali and Ivory Coast (Pichot & Roche, 1972). In view of the papers by Russell (1968), Greenland (1971) and Olson & Engelstad (1972) only two aspects of soil phosphate will be considered here.

(i) Measurement of phosphate sorption There is evidence that in West Africa soils differ quite considerably from each other in their ability to adsorb phosphate, and it may be assumed that this capacity is related to the amount of P fertilizer required for an optimum response (Beckwith, 1964; Ozanne & Shaw 1968). For example, Bouyer & Damour (1964) found with soil samples from Senegal, Upper Volta, Dahomey, Niger, Guinea, and Togo, that hydromorphic soils had a much higher phosphate sorption capacity than Ferrallitic soils, which in turn were higher than Tropical Ferruginous Soils. Enwezor & Moore (1966b) found a low phosphate sorption capacity of samples from nine savanna and forest soil profiles in Nigeria. Bhat & Bouyer (1968) also found a low sorption capacity by a sandy soil from Senegal but a much higher capacity in a heavier-textured Hydromorphic Soil. Phosphate sorption data have also been reported recently on Nigerian soils by Juo (1971) and Udo & Uzu (1972). Apart from the Hydromorphic Soils the capacities are generally lower than those reported from temperate countries, for example those reported by Bache & Williams (1971).

Unfortunately, comparisons are unreliable because the conditions of measuring phosphate sorption differ considerably. In order to make comparisons it is essential to standardize the following conditions: (a) time of reaction, (b) temperature, (c) pH (using either a fixed pH or the pH of the soil), (d) concentration and nature of salt, (e) soil: solution ratio, (f) fineness of grinding of sample, (g) method of calculating the adsorption maximum when the Langmuir isotherm is non-linear. The paper of Bache & Williams (1971) may provide the basis for a standard method. An agreement on methods is urgently needed.

(ii) Organically combined phosphate. Poor correlations between organically combined phosphate and uptake of P by crops have been reported from Ghana (Nye & Bertheux, 1957) and Nigeria (Homer, 1962; Bache & Rogers, 1970). It would be wrong, however, to conclude that mineralization of organic P is unimportant in crop nutrition; the correlation between total soil nitrogen and uptake of N by crops is also poor.

The evidence of Nye & Bertheux (1957) was that organically combined phosphate mineralizes at about the same rate as the organic matter as a whole. Acquaye (1963) found substantial mineralization in samples of forest soils from Ghana, and Omotoso (1971) found in Nigeria that the response of cocoa to fertilizer P decreased as the soil organic P increased; implying that the mineralization of organic P made a substantial contribution to the P uptake by the crop. Nye & Bertheux (1957) found a mean content of 99 ppm organic P in 21 surface (0-15 cm) forest soils in Ghana, and if the annual mineralization rate is put at 4 percent, it can be calculated that about 5 kg P/ha is released each year.

The rates of build-up and release of organic P under cropping/fallow cycles are therefore of some importance. However, methods of measuring organic P in tropical soils need more attention, to judge from the comparisons made by Enwezor & Moore (1966a), Omotoso (1971), and Ipinmidun (1973), and only a little work has been done on the chemistry of the organically-held phosphate in tropical soils (Omotoso and Wild, 1970). Factors affecting the rate of mineralization appear to be similar to those for nitrogen (Birch, 1961), but more work is needed especially on West African soils.

To conclude, among the many aspects of P fertilizer reactions in soils of the tropics, there is the need for standardization of methods of measuring phosphate sorption, and there are outstanding gaps in our knowledge of organically-held P and its transformations.

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THE PRACTICE OF AGRI-SILVICULTURE IN THE TROPICS WITH SPECIAL REFERENCE TO NIGERIA

by

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Deforestation and shifting Agriculture

It is a commonly observed ecological phenomenon that many of the vast treeless, or virtually treeless areas in Africa possess all the climatic requirements favouring the development of natural forest ecosystems. Despite this, however, savanna regions are continually being extended at the expense of high forest.

Authoritative students of this phenomenon in tropical and subtropical regions of the world are virtually unanimous in their conclusion that the primary agency causing the advance of savanna at the expense of high forest is man, as an agriculturist and pastoralist using fire rather wantonly as his tool, and it is believed that almost all African savanna vegetation, where not forming stages in secondary successions, is a biotic climax determined by these activities (Richards, 1957). ''Man has transformed much of the central African equatorial forest into grassland by primitive agriculture, fire and grazing. By overgrazing and repeated burning, he has moved the zone of thornbush to actual desert'' (Bartlett, 1956). This advance towards xeric, unforested conditions has been so universal in Africa, including Nigeria, that one authority has suggested that we are witnessing slow stages in the drying up and degeneration of tropical Africa (Aubreville, 1947). It is estimated that in Africa south of the Sahara the area of closed tropical high forest has shrunk by at least 100 million hectares as a result of shifting agriculture. The situation is similar in tropical America (Bartlett, 1956; Watters, 1971; King, 1968). Little timber of quality now remains in Nigeria outside forest reserves. The area of forest within the reserves is approximately 9 million hectares which represents 10.1 percent of Nigeria's land surface. Of this area approximatly 7 million hectares are savanna and 2 million hectares are high forest. Thus, it is likely that only 2.1 percent of Nigeria's land surface is now covered by high forest (Redhead, 1971). Nevertheless, because of the rapid increase in population, and the consequent shortage of fertile agricultural land, parts of even this relatively small forested area are in danger of dereservation and conversion to agricultural purposes. It is the view of the writer, however, that further dereservation could possibly result in an overall decrease rather than an increase in food production in Nigeria. It is hoped that the validity of this comment will be apparent in the light of this paper.

The Role of Forestry in Food Production and Rural Development in Nigeria

The destructive effects of undirected, shifting agriculture on natural forest ecosystems when population density reaches a certain level are evident throughout the tropics. However, it is the thesis of the present paper that the process can be sociologically and economically beneficial when it forms part of an integrated resource management plan. Its destructive aspects can be eliminated and a system of agri-silviculture developed which, under certain conditions, may allow the integration of traditional patterns of food production with the requirements for successful timber production. A number of assumptions underly this thesis and these are enumerated below (see Schlippe, 1956: Dumont, 1966; Makings, 1967; King, 1968; and Kio, 1972).

1. Through agriculture, however primitive, every environment has taught its inhabitants a certain way of life.

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2. Attempts at improved agricultural output, to be successul sociologically, and not merely in terms of output statistics, must take into account the way of life, customs and needs of the peasant farmer.

3. Rapid industrialization and rapid expansion of agricultural production for market are not in the short-run necessarily synonymous with improving the welfare of peasant peoples in the tropics.

4. The drastic technological change that must in time occur in tropical agriculture is best introduced by stages, particularly when the utilization of available labour is low and the drift from rural areas to cities is high.

5. Although the traditional structure of subsistence agriculture in the tropics is unsuitable in the long run for commercial farming, designed to feed large non-food producing urban populations, output can be considerably improved within familiar traditional patterns of production.

6. Structural change is necessary only when output can no longer be increased within the traditional forms of production. However, when this stage is reached, technological change is likely to be evolutionary and thus less disruptive of the rural welfare of peasant peoples.

Many reports dealing with agricultural development in Nigeria have been strongly influenced by single use concepts and have treated forestry as an activity quite separate from that of agriculture. In general, forestry is presented as an industry concerned with cellulose production. Yet, as a a number of authors have noted (Charter, 1970; Adekunle, 1971; Ajayi, 1971; Nicol, 1972; Lowe, 1972) the forests of Nigeria not only provide very significant amounts of protein and carbohydrate but also support a large array of rural based industries and traditional crafts. As pointed out by Watters (1971) in his work on shifting agriculture in Latin America, even without systems of agri-silviculture, '' ... forest employment suitably linked with traditional occupations, would mean that the shifting cultivator would no longer be dependent on his meagre crops. It would also allow him to limit somewhat the extent of the land under cultivation, and perhaps to improve his archaic techniques by investing some money in the purchase of fertilizers, tools etc.''

Charter (1970) has provided an analysis of statistics on the economic value of wildlife in Nigeria. The overall averages for locally produced animal foods in the rural areas of the southern part of Nigeria indicated that about 19 percent was obtained from wild animals, 60 percent from fish and only 24 percent from livestock. Consumption of bushmeat was valued at 20.4 million Naira in the year, and all meat from domesticated animals at 26 million Naira. As pointed out by Charter (1970) the large quantities of local fish consumed is a striking feature of these figures, and since a proportion of this catch is from forest reserves it may be regarded as forest or wildlife produce. In regard to these statistics, it is important to note that the highest percentages of bushmeat eaten compared with that for all meat consumed relate to areas in or adjoining the larger forest reserves, e.g. Benin 82 percent, Uyo 84, Calabar 80, and Ondo 67 percent (Charter 1970).

These facts, together with the facts pertaining to other food sources from the forest not referred to by Charter but covered by Nicol (1972) and others, should profoundly influence research and development in natural resource management. To date, however, and apart from forestry departments both Federal and State, they appear to have had little effect, and are not seriously taken into account in reports on agricultural development in the Guinea Zone in Nigeria. Many such plans often seem to relate to theoretical situations and do not appear to evolve from a deep knowledge of the reality of tropical ecosystems and the way of life of rural peoples.

Modern forestry is not to be understood as an activity designed merely to ensure a steady supply of cellulose. If it were, then it would represent a view of forestry which does not prevail among foresters in Nigeria, and which is everywhere giving ground to the ecosystem approach to natural resource management. Hence, in many countries in recent years university and government departments of forestry have been transformed into departments concerned with the management of renewable, natural resources of which forest resources are a part. Nigerian foresters are clearly conscious of their role as resource managers. They believe that ''along with agriculture, forestry constitutes a single subject - the industrial biology of the land - which incorporates many natural and social sciences that demand specialized knowledge'' (Harley, 1971). It is, therefore, fitting that their work in developing local solutions to the problem of shifting agriculture, and to the elimination of its undesirable side effects, be presented at this conference.

Agri-silviculture in the Tropics

King (1968) solicited information on agri-silviculture practices from 72 Government Forest Departments throughout the world. The codification and analysis of the data received represents the most complete account in English to date of agri-silviculture practices. What follows in this section is a summary of King's work which should be consulted for a more complete account of agri-silviculture in the tropics. Although the word taungya is commonly used by foresters in the English speaking tropics, King has rightly observed that the term agri-silviculture is to be preferred ''because of the multiplicity of names by which the system is now known, because it would probably be more intelligible to agriculture, and because the vernacular names now used, with their connotations of primiti might exercise a psychological limitation to the acceptance of the system as a progressive form of land use.'' In this paper, therefore, the term agri-silviculture is used exclusive except in passages which are direct quotations and in which the world taungya occurs.

Agri-silviculture has been defined as a method of raising forest crops in combination with agricultural crops, and the number and variety of the names applied to this system is a measure of its universality throughout tropical and sub-tropical countries. Twenty seven names have been listed, the best known of which in the English speaking tropics is taungya.

The aspect of agri-silviculture that is common to most countries is that the system begins with the clear-felling and burning of either the remains of recently exploited forest or secondary scrub. The subsequent operations can vary considerably. In 60 percent of the countries investigated the first agricultural crops were planted before the tree crop, in 30 percent after the tree crop, and in 10 percent at the same time. Where the agricultural crop was planted first, the period between the initial planting of the agricultural crop and tree planting ranged from a few weeks to five years depending on the type of crop and tree species planted. Sixty-one percent of the Forest Departments reported that the sequen of their planting operations was designed to assist the farmer. Most of the remainder were designed to serve forestry interests.

King (1968) listed 79 woody species and genera, and 42 agricultural crops used in systems of agri-silviculture in the tropics. The woody species include bamboos, conifers and broadleaved species adapted to a very wide range of site and climatic conditions. Though many different kinds of light-demanding tree species are planted on the cleared areas, e.g *Nauclea diderrichii*, *Lovoea trichilioides*, *Khaya ivorensis*, and *Entandrophragma* spp., teak (*Tectona grandis*) is by far the most common species planted.

The choice of agricultural crop in general bears no relation to the biological demands of the associated tree species, but is a function of the agricultural and feeding habits of the cultivator. Certain agricultural species are tolerated in forest plantations in some countries but not in others, e.g. banana, plantain, cassava, maize, rice, sugar cane, tobacco and yam. However, ''freed from local variations the essential features of tropical systems of agri-silviculture are that the farmer receives land from the forest department on which to plant his food crops, and in return for this, he is generally required to clea fell and burn the existing forest and tend the (planted) forest trees. He does not pay in cash for his use of the land, nor is he paid in cash for his labour'' (King, 1968).

In discussing the legal conditions controlling the system of agri-silviculture, it was pointed out that although it is a modification of shifting agriculture the relationships between the two are more physical and biological than legal. The land utilized under shifting cultivation is not owned and its development planned and controlled by a second party. In a system of agri-silviculture the land is owned by the state or a local authority. ''in short the rights which the shifting cultivator formerly enjoyed through status are now his as a result of contract'' (King, 1968).

One third of the countries which replied to King's questionnaire reported that no document was used to formalize arrangements between the Forest Service and cultivator. In countries where written agreements existed they were called either contract, licence, permit, lease, or agreement. According to King, the form of tenancy known to English law as a licence most aptly describes an agri-silvicultural agreement. A licence is defined as ''A permission given by the occupier of land which, without creating any interest in land, allows the licensee to do some act which would otherwise be a trespass'' (Megarry, 1949 quoted by King, 1968).

From his survey of agri-silvicultural systems prevailing in the tropics King stated that there seemed to be very few unsurmountable biological problems in connection with the system of agri-silviculture. He went on to conclude ''A great deal of social upset has already been caused by the abandonment of shifting cultivation, and until tropical economies become self-sustaining, until they are able to afford the fertilizers, machinery, and implements that are necessary for tropical sedentary agriculture, until storage facilities are improved, and until new genetic strains suitable to tropical conditions are evolved, until then, agri-silviculture may offer some help in the solution of tropical land use problems, and the development of a stronger rural and national economy'' (King, 1968).

The existence and continued vigour of systems of agri-silviculture in the tropics are attributable to a number of factors. Most of these do not relate directly to forest management. There are however, two important factors which do pertain to forestry and which are also undoubtedly influential.There relate to the nature of natural forest ecosystems in the tropics, and to the pressure on forest land for food production.

Natural forest ecosystems in the tropics, because of their heterogeneity and low productivity and because many species are not utilized, are in general of low commercial value. Desirable commercial species may occur in very low numbers. In the past, following exploitation in such forests, regeneration of desirable commercial species, when sought by foresters, was regulated by a variety of shelterwood and selection systems. By and large throughout the tropics these systems have been abandoned because of lack of success, and conversion of natural forest ecosystems to plantation of fast growing species, often exotic, is taking place. In many instances this conversion is economically feasible only when carried out by a system of agri-silviculture. Dawking (1961) in discussing present and future trends in tropical forestry, has indicated that when demands on the forest are intense, that is, when optimum utilization is needed, intensive replacement of natural forest ecosystems takes precedence over extensive improvement. This is the position in Nigeria at the present time and is one of the factors favouring the existence and vigour of the systems of agri-silviculture prevailing, particularly, though not exclusively, in the southern part of the country.

The second factor influencing the prevalence of systems of agriculture in the tropics pertains to the demands on forest reserves for food production. In certain areas these demands are such that on occasion the introduction of a system of agri-silviculture is the only method of ensuring the survival of the forest estate in these areas. This is graphically illustrated by Onyeagocha's (1966) account of the history of the Eme River Forest Reserve in Eastern Nigeria. The ''Eme River Forest Reserve has had a chequered History. As originally constituted in 1928 the area was 48 sq. miles (12 430 hectares). Constant pressure due to land hunger led to the reduction of the area first to 20 sq. miles (5 180 hectares), then to 7.5 sq. miles (1 940 hectares) and finally in 1952 to 0.82 sq. miles (210 hectares). Even so, the small remaining area was subject to great demands from the farmers, and it was therefore decided to establish <u>taungya</u> farms in 1953''.

Agri-silviculture in Nigeria

Though agri-silviculture systems are operative in many parts of the federation there are very few accounts published by non-foresters available, and some of the most spectacular successes have not been published at all. It has been left almost entirely to foresters both to implement and to report on systems of agri-silviculture, despite the fact that the knowledge required for the successful planning and management of such systems is multidisciplinary. It is to the credit of Nigerian foresters that they have not hesitated to initiate agri-silviculture systems which require an understanding of rural sociology, economics, agriculture and marketing of agricultural crops. Furthermore, they have not hesitated to publish accounts of their efforts which, besides forestry observations, also comment on the sociological repercussions of their work. At least one Forest Department in the Federation is engaged not only in producing agricultural crops in forest reserves, but is also engaged in processing and marketing them, as well as building villages for farm and forest workers. All these developments appear to be taking place with little input from any of the other non-forestry disciplines referred to above, and with a minimum of publicity.

Since there is an absence of reliable quantitative data and detailed, multidisciplinary analysis of agri-silvicultural systems in the Federation, only a general account of the role of foresters in their establishment and management can be given here. However, since the positive role of foresters in harnessing shifting agriculture and in enhancing food production in the Federation does not appear to be fully appreciated by related disciplines, it is hoped that this general account will not be without value.

As early as 1928 St. Barbe Baker reported a system of agri-silviculture in high forest at Sapoba in the Midwestern State. Twenty-six acres (10.5 ha) of degraded forest was divided into half-acre plots, each of which was cleared and cultivated by one farmer. Oil palms were planted to demarcate boundaries between farms, and a number of tree species, including the exotic teak, were planted at a spacing of 6ft x 12 ft (1.8 x 3.6 m) between agricultural crops. An average of 300 trees were sown per farm, and the most common agricultural crops were maize, yam, groundnut, okra, beans and peppers. A bonus was given to farmers who succeeded in establishing not less than 500 trees to the acre (St. Barbe Baker, 1928).

From this inauspicious beginning, systems of agri-silviculture have spread throughout the country and 38 years later it was possible for Edun (1966) to observe ''In many parts of Southern Nigeria where there is a scarcity of land for agriculture and forestry under single land use, the introduction of taungya has come to stay, especially in parts of the Western and Midwestern Regions. It may eventually prove to be one of the cheapest means of establishing forests of all kinds and at the same time supplying food for the general population.'' The gradually increasing acreage brought under systems of agri-silviculture in the southern parts of the country is indicated by the statistics for the Ondo Charge in the Western State where the area was increased each year from 20 acre (8.1 ha) in 1961 to 1 698 acre (687.2 ha) in 1970 to give a total of 5 213 acre (2 110 ha) (Adetogun, 1971).

Onyeagocha (1966) reported the successful establishment, after some initial difficulties, of plantations of a number of important tree species by a system of agri-silviculture in the Ukpom Bende and Eme River Forest Reserves in the East Central State. He concluded that the experience gained in these reserves provided a pattern for further development in many parts of Eastern Nigeria and initiated the concept of forest villages in reserves where distance from villages is a limiting factor in systems of agri-silviculture. It appears that the optimum distance between place of work and village is less than three miles (4.8 km) (Redhead, 1960; Onyeagocha, 1966; Jaiyesimi, 1966).

Based on the observed success of systems of agri-silviculture in the Benin Division, Jaiyesimi (1966) proposed that where possible forest reserves should be managed under a system of agri-silviculture for the production of food as well as forest products. To achieve this he advocated the establishment of forest villages. This same author underlined a major problem when he pointed out that farming in a forest reserve is an offence under forestry law, and that if forest authorities must retain control of forest reserves ''it is essential that the legal status of taungya farmers be regularized'' (Jaiyesimi 1966).

Enemuoh (1966) gave an account of the successful settlement of 232 farmers, in the Manu Forest Reserve in the East Central State. This settlement coincided with the change in forest policy leading to the abandonment of natural regeneration schemes and the initiation of artificial regeneration of exploited and degraded forest. Eighty percent of the farmers settled were married. The average size of the household was six comprising the farmer, his wife, three children and one relative. The average size of the farm was one acre (0.4 ha) and the average crop yield about five tons (250 kg) of yam. Each farmer received a net income of between 40 and 50 Naira from the sale of yams, as well as providing enough for the household for 6 to 8 months and seed yams for planting the following year. Quantities of maize, cassava, tomatoes and peppers were also sold.

The social evolution of the settlement was indicated by the development of trades and local industries as part-time occupations of some of farmers e.g.

Occupation	No. of farmers engaged
1 Carpentry	2
2 Tailoring	2
3 Firewood collection	10
4 Tapping raphia palm	2
5 Pitsawing	60
6 Carriers (converted timber)	20
7 Herbalists	2

Enemuoh (1966) provided a formula for determining the number of settlers for a given area, tree species, and rotation age of tree crop. He also listed a number of social problems which arise in such settlements and made recommendations for the successful establishment of future settlements.

The social problems which arose during the establishment of Mamu Forest Reserve settlement were as follows:

1. Social stratification, clique formation, and clan groupings were evident. There was a lack of leadership, and social unity and cooperative effort were not fostered.

2. Children of school age had to be sent to their respective home towns for schooling (for the younger children the farmers employed a girl with Standard VI education).

3. There was a lack of medical facilities.

4. There were no good roads within the settlement farms, and no regular means of transport between the settlement and important towns and markets.

Enemuoh (1966) concluded his interesting and informative account of a forest settlement in Nigeria with the following comment: ''It will be seen that the foundations for the ideal <u>taungya</u> settlements have already been laid in some parts of Nigeria. The next task should be to organize and develop the systems. The settlement should be large enough for a balanced communal life, and essential facilities such as an adequate system of communications, good water supply, stores, petty markets, local industries, schools, technical staff, and social, health, and marketing services should be provided.'

The system of agri-silviculture established in the Mamu Forest Reserve is illustrative of the situation in other forest reserves in southern Nigeria which are presently being utilized for the production of both food and wood. There are of course, local variations (Okeke, 1966; Redhead, 1960). For example in the South-East State where a number of forest villages have been established, farming is carried out directly by the Forest Department which is also responsible for the construction of villages and for the processing and marketing of the food crops.

Agri-silviculture systems in the Federation have not been confined to root crops and maize. Cash crops such as cocoa have also been established in forest reserves simultaneously with commercial tree species (Lamb, 1941, 1967; Okeke, 1966). Lamb left the country after the initiation of his experiments, but returned 23 years later and reported on numerous forestry matters including what he referred to as 'The Taungya Plantation Systems.' In his report (Lamb, 1967) was unequivocal in his strong advocacy of systems of agri-silviculture. Referring to the Benin area he had this to say: "Every effort should now be made to extend the taungya scheme gradually throughout the forests of Benin as pressure on land increases with the rising population. Such a system can carry in perpetuity a population of about five families per square mile (260 ha) of forest in villages of 60 to 100 families each. In the expansion of this system lies the best hope of making the forests of Benin more productive and the people prosperous."

In 1965/66 the then Eastern Nigeria Forest Service planted 83 acre (33.6 ha) in the Ikom district with cocoa and commercial tree species. The cocoa was planted at 10 ft x 10 ft (3.04 x 3.04 m) to give 435 plants to the acre, and forest trees at 20 ft x 20 ft (6.1 x 6.1 m) to give 109 trees per acre. The forest trees were planted between the cocoa lines and the species used were Nauclea diderichii (de Wild.) Merrill, Khaya ivorensis A. Chev. and Terminalia ivorensis A. Chev. When Okeke (1966) reported on this work, both commercial tree species and cocoa were doing well. In concluding his report Okeke (1966) stated "The forest reserves provide for the whole of Nigeria about 33 974.5 sq miles (9 million hectares) of land. The taungya settlement promises employment, development for the rural areas, financial gain for the settlers, and a brighter future for forestry."

Lowe (1973) has given a global estimate of food production by agri-silviculture systems in the high forest zone in Nigeria. A summary of part of this report follow. In the southern states the Forest Services annually clear about 20 000 acre (8 000 ha) of natural forest and re-stock the cleared area with fast growing tree species. At the same time, and prior to the development of the tree crop, very substantial amounts of food are produced on these cleared lands. These agri-silvicultural operations annually produce food to the value of one million Naira, which, at present values, could rise to ten million Naira during this decade. According to Lowe, the peasant farmer and his wife can clear and maintain one acre (0.4 ha) of new land each year. In certain situations, for example on fertile soil such as that at the Gambari reserve in the Western State, and by concentrating on producing yams, the farmer can substantially increase his earnings to the extent that they may exceed the government's basic labourer's wage of approximately 270 Naira per annum.

Soil Fallow and Soil Fertility

Nye and Greenland (1960) have pointed out that after a quarter of a century of experiment in the African Tropics "we have failed to introduce to the forest regions any method of stable food production superior to the system of natural fallowing used in shifting cultivation." They concluded that as long as subsistence crops continue to be grown on forest soils, some form of rotation involving natural or planted fallows seems likely to persist in the forest regions for many years. Little progress appears to have been made since then, for 10 years later it was possible for Greenland (1970) to state in relation to forest areas in the tropics that "in the present state of knowledge there does not seem to be any safe method of developing an economic stable system of continuous management of many forest soils for intensive food production."

Dumont (1957) has described the failure of continuous cultivation experiments in equatorial rain forest. The first agricultural scientists in the former Belgium Congo, appalled by the native practice of shifting agriculture, attempted a European style agriculture on a number of experimental plots. The forest was cleared and leguminous crops were sown. These were used as green manure and various grasses were also sown. The land was ploughed a second time and then cultivated on a two year rotation. A crop of upland rice was followed by two of manioc and one of groundnut.This was followed by a leguminous cover crop. The results were disastrous,and the yield of every crop fell rapidly, and the 150 acre (60.7 ha) on which the experiment had been conducted had to be abandoned after a few years.

The poor results of these early experiments led the Belgian and French agronomists in West Africa to look more closely at traditional patterns of peasant cultivation. The ecological wisdom inherent in the traditional practice became obvious, and in time French speaking West Africa develcped methods of forest fallowing which increased food crop output within traditional patterns of production, while maintaining soil fertility and preventing erosion. An example of the kind of local knowledge that is requisite to such a development is contained in De Schlippe's (1956) work on shifting agriculture in Africa.

Lamb (1967) has pointed out the value of a system of agri-silviculture in maintaining fertility of sandy soils in areas of high rainfall. The soil in the region of Sapoba in the Midwest State is described as Benin sand. It is a deep, excessively drained, red sand unsuited to continuous food cropping because of rapid leaching of its fertility which is derived entirely from forest litter. Rainfall is 100 in. (2 540 mm) per annum in the area. Yet under a system of agri-silviculture this same area has supplied food crops to the surrounding people since 1938 without soil deterioration. Furthermore, the system proved itself over a 30-year period as a means of regenerating the most valuable tree species and answered arguments for dereservation of unimproved exploited forest (Lamb, 1967).

Maximizing production within traditional agricultural patterns means at the present time improving the techniques of the shifting cultivator rather than stabilizing his agriculture (see Watters, 1971). This can be done and has already been done in Nigeria and French-speaking West Africa, by regularizing and systematizing the period and size of the forest fallow within a forest management plan. Soil fertility can be maintained and erosion avoided while meeting the social and economic needs of rural peoples. It is not suggested that this is a permanent solution to the problem of shifting agriculture. It is, however, suggested that until problems of soil fertility in the tropics under continuous cropping are solved and until rural based industries have developed sufficiently to allow peasant peoples to assume without social disruption a higher agricultural technology, systems of agri-silviculture will have an important role to play in rural development and in the economic and social welfare of rural peoples.

Agri-silviculture and Government Policies

Part of the conclusions of the recent FAO document on shifting agriculture in Latin America (Watters, 1971) makes sombre reading. For although it is asserted that sound technical solutions to shifting agriculture are all ready in sight - tree crops being suggested as one solution - it is also pointed out that ''In a largely laesez-faire environment, in which unguided market forces determine resource allocation, cumulative movements in regional and class income inequalities will persist. This process of 'circular causation' will continue to attract most capital, skilled labour and enterprise to the more productive capitalistic sector, and the traditional sector will continue to be drained of resources needed for its development, while remaining imprisoned in its vicious circle of under-development'' (Watters, 1971).

It is outside the scope of this paper to examine in detail the extent to which the above comment applies to Nigerian conditions. Nevertheless, since it raises a matter of fundamental importance it cannot be ignored entirely, and in any event few foresters would disagree with the view that the future implementation of systems of agri-silviculture in Nigeria may be hindered not by a lack of technical knowledge or the reluctance of peasant farmers to innovate, but by a chronic lack of adequate capital.

The pattern of economic development in the Federation bears a resemblance to that of a number of Latin America countries where super-cities may eventually dominate their respective countries and monopolize most of the industrial activity of each country within, or close to, the metropolitan areas (Watters, 1971). ''Nourishing these industries and feeding the millions of urban dwellers, and possibly overseas markets, will be a relatively small island of progressing capitalistic farming located in the nearby regions of fertile lowlands. And surrounding or lying inland of these progressive islands of modernism there will remain large areas of backward peasantry, supported by shifting cultivation and other archaic agricultural systems and deprived of much of its present small-scale industry due to backwash and the greater profits to be derived from industrial concentration and centralization'' (Watters, 1971).

Giving Mexico as an example, Watters (1971) pointed out that industrialization by itself is not the only instrument for nation building. Mexico has had an outstanding rate of industrialization during the past 25 years. Yet this has not resulted in uniting the plural cultures of the country into one nation or one economy. Furthermore, rural-urban migration does not solve the problem. On the contrary, as well as greatly increasing the problems inherent in the rapid, unplanned development of cities, declining rural population densities ''carry with them the danger of the perpetuation of labour-extensive systems such as shifting cultivation'' (Watters, 1971). Similarly, Venezuela, a rich oil producing country, continues to have large numbers of its peasantry engaged in shifting agriculture, and major economic and social disparities persist between sectors of its society.

Thus it can be said that the successful extension and implementation of agri-silvicultural systems in the future in Nigeria may depend less on multidisciplinary scientific effort than it does on government policies for the economic and social development of the nation. Radical innovations in economic policy, are necessary if the peasant farmer of Nigeria is to be freed from the burden of subsistence agriculture and his powers liberated in nation building.

Conclusions and recommendations

Some tentative conclusions and recommendations may be drawn from the above observations:

1. Systems of agri-silviculture are operative in many parts of the tropics and in recent years have grown in extent and importance.

2. Such systems may considerably reduce the destructive effects of shifting agriculture while meeting the social and economic requirements of rural peoples.

3. Furthermore, these systems havs been proved successful in the conversion of degraded forest to commercial plantations both in Nigeria and other parts of the tropics. For this reason they are not wasteful of land, as the fallow period is utilized for growing plantations of forest trees on rotations which may be as short as five years.

4. Since to date there is no proven and agreed method of fallowing in the Guinea Zone superior to that of forest fallow, since agricultural land is increasingly in short supply, and since at the presant time in Nigeria it is socially desirable to stabilize rural communities, it is likely that systems of agri-silviculture have an important part to play in rural development in Nigeria for many years to come.

5. Since large supplies of protein as well as carbohydrate are provided by the forest estate of the nation, it is important to avoid single une concepts in relation to the management and development of this estate.

6. Multiple use management of the forest estate will ensure not only a continuous supply of cellulose but also a continuous and significant supply of both carbohydrate and protein during the critical transitional period between primitive shifting agriculture and the introduction of a technology allowing continuous cropping.

7. The successful implementation and extension of systems of agri-silviculture in Nigeria require a multidisciplinary approach. Nevertheless, even if all the requisite technical knowledge was available, success may be sharply curtailed by a lack of capital for rural development. For this reason it is important that government policies on rural development be imbued by modern economic concepts of growth in a developing country. Thus in the preliminary phases of development, efforts to achieve and sustain increased production by the rural based masses should take precedence over, or be given equal emphasis to, efforts designed to facilitate urban-based mass production. In such an economic environment maximum impetus will be given to the implementation of systems of agri-silviculture.

8. Much important research data on diverse aspects of shifting agriculture have been produced in French speaking Africa. The published accounts of this work are mostly in French, and there is some evidence that this has hindered the more complete dissemination of the results in English speaking West Africa. There is, therefore, a need for closer cooperation between the English and French speaking countries of West Africa on the problems of shifting cultivation and on systems of agri-silviculture.

9. There is a need in Nigeria to codify and assess the available information on all aspects of systems of agri-silviculture in the country. When this has been completed it will be possible to assess the relative value of the systems in rural development, and to plan a programme of applied research and extension work based not on small experimental plots but on the actual, operative programmes of State Forest Services.

10. The Department of Forestry, University of Ibadan, is strongly positioned to produce graduates well grounded in multiple use concepts, and thus capable of managing and improving agri-silvicultural systems. This same department because of its position within the Faculty of Agriculture, Forestry and Veterinary Science, and because of its wide spectrum of expertise in land use disciplines, which include not only foresters but also natural resource economists, wildlife and plant ecologists, and a geographer, is also strongly positioned to develop extension programmes for systems of agri-silviculture. Thus the activities of this department in resource management teaching and research should be oriented more strongly towards agri-silvicultural systems, and brought into even closer cooperation with personnel in Federal and State departments of forestry concerned with the implementation and management of these systems.

11. The accelerated conversion by agri-silvicultural systems of heterogeneous natural forest ecosystems with their multiplicity of species to homogeneous monospecific plantations will result in ecologically-based forest management problems of profound importance. These problems cannot be treated here. However, it is necessary to point out that one of the consequences of this transformation will be the elimination of the remaining species-rich, stable natural forest ecosystems. It is essential, therefore, that representative samples of the natural forest ecosystems of the country be conserved. These areas conserved need not be large but they should be sufficient in number to ensure the perpetuity of samples of the natural flora and fauna of the country, including its multiplicity of tree species, many of which, presently not utilized, will undoubtedly be of commercial importance in the future. Such areas will also be the main source of material for future programmes of selection and breeding of both plants and animals.

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SOCIO-ECONOMIC ASPECTS OF TAUNGYA IN RELATION TO TRADITIONAL SHIFTING CULTIVATION IN TROPICAL DEVELOPING COUNTRIES

by

E.E. Enabor*

Introduction

Agriculture and forestry constitute a dominant sector of the economy in most tropical developing countries. The continued and increased production of food crops for local consumption, cash crops for export and a wide range of forest products for local consumption and export are regarded as essential conditions for accelerated economic development in these countries. Consequently, the development of agriculture and forestry have generally been accorded the highest priority in the development plans being prepared in the developing countries. However, both agriculture and forestry represent intensive uses of land expansion of production in the sector frequently requires acquisition of considerably large areas of land. Hence the impact of problems of land utilization in the developing economy may tend to be felt first in this sector.

The process of economic development in the tropical developing country may entail progressive increases in the demands for land for agricultural and forestry production. A shortage of land for these uses could have serious consequences in terms of inadequate food supplies, short falls in foreign exchange earnings and social instability especially in rural areas. King (1963) has stressed the importance of land capability classification and land use planning as basic pre-requisites for efficient land utilization in any economy. A systematic survey and classification of land resources constitutes the only rational basis for the efficient allocation of lands between different uses in the light of a nation's wants.

The apparent shortage of land resources and the generally low productivity of land in many tropical developing countries are the result of political, natural, institutional and socio-economic factors. With particular reference to agriculture and forestry, the socio-economic factors have been most important. Agricultural practices and methods of production have remained undeveloped and highly wasteful of land resources. The cultivation of agricultural land is carried out mainly by illiterate small-scale subsistence farmers under a system known as shifting cultivation. Consequently, forests have been razed to the ground, soils have deteriorated, erosion has occurred, and deposition of soils has resulted and flooding rivers have damaged crops (King, 1963). If agriculture is to prosper in tropical developing countries, shifting cultivation must be discontinued or at least controlled. One method by which this is being done is to make available lands previously reserved exclusively for forestry, for the simultaneous raising of forest trees and agricultural crops under a system known as taungya.

Two main problems - biological and socio-economic - in the successful adoption of the taungya system in a developing country have been recognized (King, 1968). The biological aspects concern the interrelationships between the various forestry and agricultural crops to be raised in relation to the site. The socio-economic aspects involve the relationships between the system and those who operate it - namely foresters and farmers. Specifically,

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how do the foresters and farmers see the taungya system? What can they get or expect from it? How can the system be operated so that it best fulfils the aspirations of those engaged in it and of society as a whole?

The present paper deals with the socio-economic aspects of the taungya system in relation to traditional shifting cultivation and attempts to answer some of the questions posed. It is divided into four parts. The first part is a brief discussion of shifting cultivation in tropical developing countries, its impact on land utilization and the need for its control. The second part is a historical sketch of the development of the taungya system, its nature and potentialities as a means of controlling traditional shifting cultivation. The third section is a detailed discussion of the socio-economic aspects of taungya and the implications for the successful development of the taungya system. In the fourth section the main points in the paper are summarized, followed by conclusions drawn from them. For lack of data from elsewhere, the facts and opinions preferred in the present paper are based on Nigerian experience. It is believed however, that conditions in the agricultural and forestry sectors of most tropical developing economies are sufficiently similar to make our conclusions meaningful in a wider context.

Shifting Cultivation and Land Utilization in Tropical Developing Countries

Shifting cultivation is a prevalent feature of agricultural practices in tropical developing countries. It is a system of rotational cultivation in which the farmer successively farms blocks of virgin lands until he is 'forced' to return to a previously abandoned farmland (after a period of fallow) either because of lack of further virgin lands or inaccessibility or both. Under a system of shifting cultivation the farmer brushes, burns and clears a piece of land on which he plants his crops. The land is then cultivated for a period varying from two to five years before it is abandoned and the farmer moves to another site, repeating the same process. In a newly settled area where there is abundant fertile virgin land and population is small, shifting cultivation can be practised with minimum adverse effects on land primarily because the period of fallow will be long enough to allow for the full recuperation of the soil (Nye and Greenland, 1960; Bedard, 1960). As population increases, the demand for land by new members of the community reduces the amount of land available per head and the period of fallow under shifting cultivation is necessarily shortened. The reduction of the period of fallow ultimately leads to serious depletion of the soil fertility which is in turn reflected in declining farm yields. In the long run, the community will be unable to produce enough food for its maintenance and survival.

The fragmentation of agricultural land and the progressive reduction of the period of fallow due to population growth have serious adverse consequences for a community whose agricultural practices are hinged on shifting cultivation. First, it prevents efficient utilization of land resources for maximum benefits. Second, the decline in farm yields resulting from decreased soil fertility could mean perpetuation of a standard of living at subsistence level. Third, it could create serious social problems as young men unable to find arable land for farming move out of rural areas to the urban centres in search of work. The movement of virile and active young men away from rural areas could lead to instability and impoverishment of such areas and their eventual disappearance. Finally, shifting cultivation destroys forests and other vegetation, exposes the soil, causes extensive erosion and flooding, depletes wildlife resources and could possibly alter the local climate.

The need to control shifting cultivation in view of its adverse impacts on land utilization, the rural communities and national economy in general has been advocated by several writers (Bedard, 1960; Nye and Greenland, 1960; Webb, 1966; Kio, 1972). The ideal solution is settled agriculture. But as Kio (1972) observed, 'only few tropical forest soils are inherently capable of sustained arable agriculture.' Furthermore, even where land is available in adequate amounts, settled agriculture can only succeed with the aid of expensive inputs in the form of manures, fertilizers, machinery and technical knowledge. In most tropical developing countries these inputs are either not available or are in short supply. In addition, there is the problem of educating the farmers who are predominantly illiterate, to enable them to adopt the techniques and methods of modern agriculture.

The alternative is the possibility of applying either restrictive or incentive controls or some combination of both. Restrictive controls would comprise laws and regulations to discourage the practice of shifting cultivation and provide penalties against offenders. Incentive controls would aim to discourage the practice of shifting cultivation by offering settled farmers attractive and acceptable rewards. Webb (1966) pointed out that the use of restrictive controls in the form of prohibition by government must lead to negative results because ''they require inflexible judicial punishment to be effective; as a result they frequently evoke in humans the spirit of rebellion even though the prohibition is just and in the best interest of society.'' He concluded that the practice of shifting cultivation cannot be halted by government laws and regulations alone. It is the only available method to the farmer of supplying his food needs and is a system that has been practised in his area from time immemorial; shifting cultivation has become a way of life for him. Farmers could be persuaded through publicity campaigns to abandon shifting cultivation but with doubtful results as most of them are illiterate and can hardly be reached through modern communications media. Even when the farmer understands such propaganda and is convinced of the destructive effects of his practices, ''it is not realistic to suppose that he can or will stop those practices: shifting cultivation is his tradition, he has little alternative if he wishes to continue to feed his family'' (Webb, 1966).

The aim of incentive controls is to evoke the spirit of the people against shifting cultivation as a socially undesirable practice by providing tangible rewards to those members who abandon it. They do not stir up the spirit of rebellion because every member of society can see the tangible rewards. There is no single best pattern of incentive rewards. They should be designed carefully to fit the culture, the time and the spirit of the people so as to change gradually their attitudes to the practice and thereby eliminate it as rapidly as is economically feasible. Incentive control of shifting cultivation may be implemented through timber concessionaires, forest managers, local authorities or through the farmer himself.

Taungya System and Control of Shifting Cultivation

The taungya system constitutes one method of incentive control of traditional shifting cultivation. Taungya*, which literally means hill (taung) cultivation (ya), is of Burmese origin and describes the method of raising forest trees with agricultural crops on the same piece of land. It has also been defined (Kio, 1972) as ''the method of employing shifting cultivators to raise forest trees.'' Essentially, taungya is a form of multiple use of forest land. In many countries the system may actually be a quasi-multiple use since the agricultural use to which the land is put does not generally continue throughout the rotation of the forest crop, but is confined to that period which ends with the closing of the canopy of the forest crop (King, 1968). The significance of the taungya system probably rests on the fact that it is an attempt to reconcile the increasing demands for virgin arable land (only available within forest reserves) by shifting cultivators with the need to conserve and develop the forest estate in order to meet the rapidly increasing requirements for forest products in the tropical developing countries. The taungya system thus provides an excellent opportunity for the maximum utilization of land resources, while at the same time effecting the desired control of traditional shifting cultivation.

Although the practice of taungya is now virtually confined to tropical developing countries, and particularly those of Asia and Africa, there is evidence that it has been adopted at one time or other in some of the developed countries of Europe. Its virtual disappearance in the latter area and proliferation in the former, would suggest that there are certain distinct characteristics of a country which favour adoption. The conditions necessary for the successful introduction of taungya in a country include:

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* Several terms which are synonyms for taungya have been used in various parts of the world. These include ''agri-silviculture'' (King, 1968), and ''agri-forestry'' (Kio, 1972). For a comprehensive list of the synonyms see King (1968).

(a) A low level of income or standard of living

(b) Land hunger among the farming population

(c) Under-employment or unemployment

These factors constitute important elements of the so-called vicious cycle of poverty and may, to some degree, be attributed to the practice of shifting cultivation.

The introduction of taungya to Nigeria dates from the nineteen twenties in a silvicultural experiment at Sapoba in the Mid-Western State ''to find out the best means of regenerating the high forest'' (Jaiyesimi, 1966). By the thirties it became one of the conditions for reservation of forest land as government required an undertaking by the forest department ''to make available annually 1 000 acres for farming in return for an additional 1 000 square miles to the forest estate'' (Ogbe, 1966). Subsequently the practice became very popular with the forest services and was widely adopted in the southern parts of the country for the establishment of large-scale plantations in the high forest zone. The main attraction of the taungya system was the substantial reduction in the cost of plantation establishment*. Later, however, the need to accommodate landless farmers and to promote the maximum utilization of land resources in the interest of society as a whole became an important consideration. Thus, Jaiyesimi (1966) has suggested that 'one of the cardinal points of forest policy should be that wherever possible, forest reserves should be managed for food as well as forest products through the use of taungya, thereby releasing unreserved land for permanent crops.' It is now generally believed that unless shifting cultivators (the ultimate owners of forest land in Nigeria) can be accommodated under the taungya system, they may cause enough trouble to warrant dereservation of forest lands with serious consequences for forestry in the country.

The taungya system in Nigeria follows a definite pattern of multiple use of reserved forest land in which the forest crop is the dominant use and the cultivation of agricultural crops is limited to a period when they do not constitute undesirable rivals of the forest crop. Where conditions favour the adoption of taungya, the forest area to be planted in a particular year is demarcated in the preceding year and allocations of plots ranging from one to three acre (0.4 - 1.25 ha) are made to qualified farmers. The farmer clears the bush, burns the debris and generally prepares the site in December at no cost to the forest department. (The farmer is sometimes paid for removing large trees). He then plants his crops according to a list and at a spacing approved by the forest department in April or as soon as the rains begin. Soon after, the forest department interplants forest trees with the farm crops using direct forest labour. In some cases, the forest department only marks the planting spots and supplies the planting stock which the farmer plants at an agreed wage. In the first year the farmer tends both his crops and the forest trees by carrying out operations such as cleaning and weeding. The forest department carries out necessary tending operations from the second year but the farmer may be permitted to continue cultivation of the land for a second and sometimes third year. Thereafter he is given a fresh allocation of arable land in a new area demarcated for the planting of forest trees. Frequently, a farmer may receive a new allocation of farm land which he cultivates along with the previous year's farm.

Under the taungya system in Nigeria, the farmer is regarded strictly as a tenant and the Forest Department is the landlord. The farmer is bound by the rules and regulations laid down by the forest department. Individual farmers are able to increase the size of their holdings through proven hard work and efficiency in tending forest trees. Farmers who

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* Estimates of regeneration costs in Eastern Nigeria show the cost of direct establishment by the forest departments to be ₦56 acre as against ₦8 per acre by taungya. (see Okeke 1966).

allow their farm to revert to bush lose their allocations which are given to more deserving applicants (Redhead, 1960). In addition, the forest department decides what agricultural crops may be planted, the choice being based on the ability of forest trees to withstand their competition rather than expected total production under the system. However, the majority of farmers appear satisfied with the present arrangements as long as they can be assured of a steady supply of fertile arable land.

The taungya system has proved very successful in Nigeria as a means of cheap afforestation, while at the same time removing agitation among local farmers by giving them access to additional fertile lands for farming. Taungya is however, not a permanent alternative to shifting cultivation. Indeed, taungya is a modified form of shifting cultivation with the difference that farmers' actions are now circumscribed by externally-imposed rules and regulations. However, it will be beneficial to continue the system and if possible to increase the number of farmers involved until development of the agricultural and industrial sectors of the economy makes it no longer necessary. It is clear that in the short-term efforts should be made to sustain taungya which will serve the important functions of accelerating the rate of afforestation and contribute to improvement of living conditions especially in rural areas.

Socio-Economic aspects of Taungya

King (1968) has stated that the success or even continuance of the taungya system in tropical developing countries is not a certainty. This is because of the assumption in the application of the system that ''the predominant desire is to establish the tree crop as soon as possible and that any benefits which accrue to the agriculturists are only incidental.'' Where the benefits farmers derive from taungya continue to be less attractive than those from traditional agriculture or from industry, there will be no incentive for them to continue participation. The farmers may then move out of forest reserves to seek employment in the city or revert to traditional shifting agriculture. In the latter case there may be pressures on government to dereserve forest lands, and inefficient utilization of the land resources will continue. It is therefore incumbent on foresters to pay particular attention to the socio-economic aspects of taungya. According to King (1968), taungya can play its full part in the rural economy of developing countries ''only if the farmers are regarded, not as mere handmaidens to the serious business of establishing forest plantations but as the hub around which the agri-silvicultural activities spin.''

The importance of socio-economic aspects of taungya is clearly brought out in some recent statements of objectives of the scheme in Nigeria (Enemuoh, 1966; Okeke, 1966). These are:

1. To reafforest remote parts of the country and reduce establishment costs of forest plantations by paying only operational costs.

2. To reduce congestion in densely populated areas by moving people to less thickly populated areas.

3. To increase overall productivity of the country by bringing under food production the rich uncultivated parts of forest reserves.

4. To provide employment for the rural population and reserve the present drift of population from the villages to cities.

5. To raise the living and social standards of the community.

If the above objectives are to be achieved it is necessary to ensure substantial and adequate economic benefits to the farmer. In addition, it is essential to provide other special incentives in the form of social amenities and facilities in taungya areas in order to improve the quality of life in the rural areas as compared with urban centres.

Economic aspects

The economic benefits the farmer derives from the taungya system can be assessed in terms of its contribution to an improvement in his standard of living. The yardstick of measurement for this purpose is the amount of money income accruing to the farmer. It should be pointed out that the financial gain is the most important consideration from the farmer's point of view. For example, Jaiyesimi (1966) stated that in Western Nigeria each farmer may derive an annual 'profit' of as much as ₦300. Estimates from Eastern Nigeria (Enemuoh, 1966; Okeke, 1966) show that the annual income from sale of farm produce by taungya farmers is between ₦40 and ₦124 per acre. By comparison it is reported (King, 1968) that the net return to the farmer in Kenya varies between nil and £200 per annum, is about 6 000 francs per hectare in Dahomey and fluctuates between 200 and 400 rupees per acre in Orissa (India).

Part of the year's production by the Nigerian farmer is usually reserved to meet his family's needs and for future planting. The share of total output that is thus reserved depends on family size, anticipated size of next year's farm and the quality of storage facilities. In any event, the level of money income from sale of farm produce is directly influenced by the proportion of output reserved and this should be taken into account when assessing the economic benefits. In addition, many farmers are able to supplement their incomes by doing other forestry work in return for wages (e.g. cleaning, thinning, beating up, etc.), carrying on local trades such as carpentry, tailoring and pitsawing as well as free collection of minor forest produce (including firewood). The exact amount of income from these supplementary sources cannot be precisely determined but may be as high as ₦60 per annum.

The level of financial returns to the taungya farmer depends on such factors as size of farm, the types and quantity of crops planted, quality of the site, methods of cultivation as well as level of prices for farm produce. The size of farm is based primarily on size of a farmer's family and ranges from 1.5 to 5 acre (0.6 to 2.0 ha). Individual allocations are made bearing in mind the needs of each farmer, his proven ability and the requirement for efficient tending of forest crops. It has been suggested (Edun, 1966) that the size of taungya farms in Nigeria is generally too small to support a living standard above subsistence level. However, Redhead (1960) stated that many farmers (in the Mid-Western State) were unable to keep up necessary tending operations, with the result that many farms reverted to bush with adverse consequences for the forest crop. Moreover, it would seem that where the total forest area to be planted in a given year is fixed, the size of farm will tend to decrease the larger the number of farmers to be accommodated. To ensure adequate economic returns to the taungya farmer he should be allocated a sufficiently large area of land, but the optimum size of farm for any given farmer may require careful assessment.

The types and quantities of crops planted directly influence financial returns to the farmer. In particular, the types of agricultural crops to be permitted on taungya farms has given rise to some controversy not only in Nigeria but elsewhere (King, 1968). Agricultural crops planted in Nigerian taungya farms are predominantly annual and biennial food crops such as yam, cassava, groundnut, maize, beans, pineapple, tomato, pepper and millet among others. In contrast cash crops such as cocoa, oil palm, cashew, and coffee, and food crops with spreading crowns such as cocoyam and plantain are excluded or permitted on a very limited scale.

Several reasons have been adduced to justify exclusion of permanent cash crops from taungya farms in Nigeria. First, such crops compete unfavourably with forest trees for light and nutrients. For example, Jaiyesimi (1966) stated that it is not uncommon to find forest trees suppressed by agricultural crops such as cassava in Western Nigeria. Second, the farmers are likely to concentrate more on its maintenance to the detriment of the forest crop. Third, the long term tenure which cultivation of cash crops necessitates may encourage farmers to establish claims of ownership to forest land. Fourth, as Jaiyesimi put it, ''in the event of finding that forest trees harbour pests attacking such crops, it is obvious that the first solution that will occur to politicians and administrators will be the removal of the forest trees''. No doubt, there is some truth in these claims, but undue emphasis may have been placed on what may be no more that mere suspicion.

The taungya system in Nigeria as been described (King, 1968) as a quasi-multiple use of forest land primarily because of the exclusion of permanent agricultural crops. Evidence on the harmful effects of agricultural crops on forest trees and vice versa is inconclusive. Experiments conducted in various countries, however, seem to indicate that sometimes the planting of agricultural crops with forest trees has reduced productivity and depleted the soils, but in a majority of cases a mutual increase in productivity without significant adverse effects on the soil have resulted. In other words, biological considerations do not constitute a major obstacle to the joint production of agricultural and forest crops.

King (1968) pointed out that the considerations which have influenced foresters in selecting agricultural crops for taungya farms have been mainly socio-economic. The choice has generally been based on the agricultural and feeding habits of the cultivator rather than on the possible effects of the agricultural crop on the tree crop or on its possible resistance to competition from the tree crop. As long as only annuals and biennials are permitted, farmers in taungya areas will continue to live at subsistence level since output is hardly large enough to leave a marketable surplus which they can use to obtain other necessities for a decent life (Edun, 1966). It is therefore strongly advocated that farmers be allowed to plant permanent cash crops in taungya areas especially where no known harmful effects for the forest trees or soil will result.

The productivity of the soil and cultivation methods are other factors influencing yields of agricultural crops. As stated above most tropical soils are not fertile enough to meet the demands of intensive agriculture. The situation may be worse where reserved forest lands include areas that are judged to be of relatively low quality. Improvement of the soil can be effected by application of fertilizers, and the crops best suited to the available sites should be selected. The problem of efficient cultivation methods is related to the ignorance of farmers who may prefer to persist in their traditional but poor techniques. Better strains of agricultural crops should be developed and farmers taught how to grow them. It is also necessary to protect crops against attacks by insects, pests and fungi. These problems cannot be solved by the forester who does not possess the requisite agricultural training. He needs the assistance and cooperation of the agriculturist to ensure that techniques, methods and facilities available to farmers generally are also extended to taungya areas.

Finally, the price of farm produce is of paramount importance. It is well known that the demand for agricultural products is generally inelastic. For small-scale farmers there are added difficulties in disposing of small quantities of output at irregular intervals. They can obtain better prices only by combining to form an organization for marketing their products. For example, the formation of a cooperative by the farmers to buy the output of individual members and in turn to find a market for the larger stock is essential. In some cases the forest department carries out this function but, as in farm settlements, the taungya farmers are not satisfied because they have to wait long periods for payment by the Treasury for the produce delivered. Also, the marketing function involves the forest department in additional administrative responsibilities which could hamper efficient control of the system. It should be pointed out that Nigerian taungya farmers have no problems in disposing of surplus food crops at reasonable prices. However, significant losses sometimes occur due to lack of storage facilities. Where a farmers' cooperative exists, it could handle this problem as well.

In summary, the economic returns to the taungya farmer can be substantially improved by increasing the size of his farm, permitting the planting of permanent agricultural crops, improving the quality of the soil, encouraging him to adopt better methods and techniques of cultivation and ensuring he receives good prices for his products. These problems can be solved through joint efforts by foresters and agriculturists. They should jointly undertake essential research into the various aspects of taungya farming, establish a training programme for farmers and share costs of supplying necessary inputs such as fertilizers, machinery and tools. In other words, it is suggested that there should be an integrated approach to the management of taungya farms with a view to improving yields of agricultural crops. This approach will not only facilitate communication between agriculturists and foresters on matters of land use but will also remove once and for all, the general misconception in many tropical developing countries that forestry is an obstacle to development of agriculture. According to King (1968), ''the essential considerations here must be cooperation between the agriculturists and the foresters in search for mutual solutions to their problems and the evolution of management tools which would permit production of the two crops as a joint effort.''

Social Aspects

Although the taungya farmer's standard of living can be improved through the higher income which will accrue to him from planting a wider range of crops and the adoption of better inputs and techniques of cultivation, other special incentives are necessary to keep him in the scheme and in the rural area. The incentives are intended to enhance social life in the rural areas and include adequate housing, supply of water, electricity and means of transportation as well as the provision of hospitals, schools and recreational facilities. The type and extent of social amenities provided will vary from country to country or even between regions of a country. However, unless some minimum amount of these facilities is supplied, a higher money income may induce farmers to move to urban centres where their existence makes life more confortable.

Social amenities and facilities are costly to provide and certainly require government assistance. The provision of such facilities by government in taungya areas will be nothing new, since it is already undertaking such responsibility in respect of farm settlements. By undertaking to provide these facilities, government will not only be emphasizing the importance it attaches to elimination of shifting cultivation and the important role forestry can play in this task, it will also be advancing its general policy to improve and develop rural areas. However, the amenities should be provided without giving the impression that special or privileged rural communities are being created. It is important that the value of such facilities is brought to farmers through their participation. The policy of self-help is already well established in Nigeria and farmers should be encouraged to make token contributions to the costs of providing housing, schools, health centres and water in their areas. Such contributions can be easily collected by deductions from proceeds from sale of farm produce over a specified period of years. The significance of such a step is that farmers will be more reluctant to abandon a scheme whose development they have partially financed and the result will be more stable taungya villages or communities.

In addition to facilities to improve social life in taungya areas, other specific incentives have advocated. These include loans and advances (Shebbeare, 1921; Blanford, 1924), land outside the taungya area but within forest reserve for additional farming (but not permanent crops) (Shebbeare, 1921; Blanford, 1924), free building materials and other forest produce, bonuses for good farms, and tax exemptions (Blanford, 1924). King (1968) has advocated the provision of areas away from plantations but in some convenient place in the reserve for farmers to grow permanent crops.

The provision of social amenities and facilities and of specific incentives for taungya farmers has received little attention in tropical developing countries. Several reasons have been given for this state of affairs but it would seem that the most important is that the welfare of farmers was not fully considered at the onset of the schemes. In situations of acute land hunger and ignorance of farmers, specific incentives to 'bribe' farmers into taungya areas may be considered unnecessary. The provision of social amenities cannot be undertaken by the forest department as this will wipe out any gains from using taungya labour in afforestation. Additional funds must be made available by the government. Such assistance may not be forthcoming until government is convinced of the value of taungya to the national economy. It is clear however, that if farmers are to remain in the taungya system and be productive, some kind of incentive scheme must be designed to give more meaning to their participation.

Prospects for the Taungya System

The real value of the taungya system in tropical developing countries lies not in the reduction of the direct costs of establishing plantations of forest trees but in the contributions to their economic and social development. The system can lead to greater stability of rural areas by providing incomes and employment for the people and thereby preventing the drift to urban areas. In addition, the taungya system ameliorates the disastrous effects of traditional agriculture based on shifting cultivation on the land resources of a country by providing fertile farming land within forest reserves. Finally, the system facilitates maximum land utilization by enabling the simultaneous production of food crops and essential forest products required in developing countries.

The importance attached to the agricultural sector and rural areas in the development plans of most developing countries leads one to suggest that the initiation and continued expansion of the taungya system has good prospects. Experience in Nigeria so far indicates that both farmers and foresters have adopted a favourable and positive attitude to ensure the success of the scheme. It should, however, be stressed that it is essential to sustain the initial impetus and goodwill through proper organization of the scheme, provision of social facilities and incentives and thorough long-term planning.

The establishment of forest villages (taungya settlements) constitutes a sound basis for organization of the taungya system. In other words, special communities largely or wholly dependent on a taungya scheme should be created. Although natural villages possess certain advances (King, 1968), forest villages are to be preferred from a planning point of view. First, the location of the village in relation to the areas to be planted can be deliberately chosen so as to reduce travelling distance and improve productivity. The disruption of existing social structures in natural villages by introduction of 'outsiders' is avoided. Farmers selected for the scheme will be of the best quality and character among those available and these will be more stable than those from natural villages because they depend on the scheme for their livelihood. Consequently, the control exercised by the forester over the farmer will also be greater. On the other hand there will be problems of fostering social harmony, homogeneity and a spirit of unity among men possibly drawn from different communities with varying customs and traditions, conflicting attitudes to life and widely different levels of expectations. It is believed, however, that with time the initial social conflicts and friction can be overcome. Finally, forest villages represent heavy investment in provision of facilities and infrastructure.

In establishing a forest village, factors to be considered include the area of forest land to be planted, the present number of cultivators and prospective increase in their number in the foreseeable future, the average travelling distance consistent with good productivity as well as the need to create a community large enough to justify investment in facilities and ensure a balanced life in the village. In Nigeria it has been estimated (Eneumoh, 1966; Okeke, 1966; King, 1968) that the maximum distance taungya farmers are willing to travel is 3 miles (5 km). If a 3 mile radius is taken as the limits of a taungya settlement, the total available area for taungya farms, for housing the villagers and providing for roads and other structures would be about 30 000 acre (12 000 ha). If a reduction factor of 0.2 is applied to the total area to allow for village site, roads, schools and other structures, the net potential taungya farm area will be about 24 000 acre (9 600 ha). The total number of settlers that can be accommodated in the settlement is then determined from the number of years in the rotation and size of farm per farmer. The equation for this calculation is given by:

$$Y = A/RS$$

where Y = number of *taungya* farmers

A = net forest area available

R = rotation in years and

S = size of farm per settler.

For example, if the net area for a hypothetical case is 30 000 acre, the rotation for the given species, say teak (*Tectona grandis*), is 30 years and average size of farm is 2 acre, the number of settlers is:

$$Y = 30\ 000/30 \times 2 = 500$$

It should be stressed that although the number of settlers that can be accommodated is ultimately limited by the total forest area, the actual number in a given area may be increased or decreased by a change in the rotation length, or size of farms or both. On the other hand, the coordination of a *taungya* scheme to make different but suitably located forest reserves available to the same *taungya* village should be considered at the initial planning stage. Some of the factors that should guide decision-making in this respect include the need to accommodate the largest possible number of farmers applying for land, the need to make allowance for the future natural growth of the village population and the need to take advantage of the farmers', enthusiasm, usually apparent at the early stages of a *taungya* scheme, to accelerate the rate of afforestation.

In some cases, an existing natural village may be suitably located and large enough to form the nucleus of a *taungya* settlement. More often however, such a village may be non-existent and a new one has to be created. Opinions vary on how sophisticated such villages should be and the nature of facilities to be provided. It is obvious that whether a forest village will be patterned on existing villages, comprising clusters of mud-walled houses with corrugated aluminium roofing and a few amenities, or will be similar to more modern projects such as farm settlements comprising permanent structures, direct governmental assistance will be needed to bring them into being. The advantages of the latter type of village are many. *Taungya* farmers will get more satisfaction, the disaffection arising from the feeling that farmers are regarded as second class citizens to be provided only inferior facilities is avoided, the general environment of work is improved and the permanent structures represent future substantial savings in their having lower maintenance costs. Experience in Kenya (Wamugunda, 1970) and elsewhere indicates that government responsibility for forest villages ensures their stability and represents wise investment.

The degree of government's involvement in *taungya* schemes, however, depends on publicity and presentation of a worthy case by the forester. This is no easy task, especially in countries where the impact of forestry on the economy at large is slight or the forest service is relatively weak. In Nigeria, no representation on the need to create forest villages has so far been made to the government. This is mainly because adoption of the *taungya* scheme has been on an experimental basis and also because a decade of political crisis in the country has disrupted planning in the forestry sector. The revival of normal economic activities and initiation of large-scale afforestation projects after 1970, should present fresh opportunities not only for organization of *taungya* schemes and efforts to create forest villages but also for furthering forestry at the national level.

Summary and Conclusions

In this paper we have identified and discussed the nature and consequences of shifting cultivation in tropical developing countries. If standards of living in these countries are to improve, shifting cultivation must be discontinued and replaced by a suitable alternative. Given the state of the agricultural arts in developing countries, the transition to modern agriculture is bound to take some time, and meanwhile an acceptable means of maintaining a livelihood must be provided for the farmers. The taungya system is a unique and attractive alternative to traditional shifting cultivators in tropical developing countries. As a multiple land use system, it fundamentally reconciles conflicting agricultural and forestry interests in land use, conflicts which often threaten political and social stability in these countries. The taungya system can also make significant contributions to the national economy by creating employment for rural communities and thus stemming the aimless drift to urban centres. It could ensure higher and more stable incomes for farmers, and provide a more spatially balanced national economy.

The successful adoption of the taungya system depends greatly on the amount of attention that is devoted to the socio-economic aspects. It is essential to ensure reasonable and adequate financial benefits to the farmers, provide social amenities and facilities and offer special incentives to make the scheme attractive. It is suggested that one way towards solving the economic problems is to permit a wider range of crops to be planted by farmers. In particular, permanent crops such as cocoa, coffee and oil palm, which it has been shown can be successfully grown with forest trees, should be included. Social amenities and facilities such as water, electricity, housing, hospitals and schools should be provided but farmers should make token contributions towards their cost. The purpose of providing such amenities is not only to increase productivity of farmers but also to give evidence of a change from their previous living conditions. The provision of special incentives could be useful, but these may not be so important or even necessary where the scheme has been designed to ensure adequate financial returns from normal farming operations.

Judging from experience in Nigeria, there are good prospects for the taungya system in tropical developing countries, where the transition from traditional shifting cultivation to modern agriculture is bound to take some time. However, it will be necessary for the government to be more directly involved in the scheme as is the case with farm settlements. With government backing, essential facilities and amenities can be more readily provided and the farmer's interest can be sustained. The present organizational structure of the taungya system, whereby the farmer is regarded as no more than a non-paying guest, can hardly arouse government interest. The farmer should be more deeply involved in the taungya scheme through the establishment of forest villages and creation of rural communities wholly or largely dependent on forestry operations for their livelihood. Finally, the forester should undertake adequate publicity both to attract farmers to taungya schemes and to acquaint fully the government, as well as other agencies concerned with land resources, with the nature of the taungya system, its potentialities and benefits to the economy at large.

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FERTILIZERS IN THE IMPROVEMENT OF SHIFTING CULTIVATION

by

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INTRODUCTION

About 200 million people earn their livelihood from agriculture carried out as a system of shifting cultivation. This is perhaps the oldest form of agriculture developed by man, and variations of it are to be found in West and Central Africa, in South and Central America, as well as in Southeast Asia.

It is generally agreed that the system is wasteful, uneconomic and seemingly inappropriate to the second half of the twentieth century, and yet there is not, so far, any system which can satisfactorily replace it, particularly in the context of the rain forest zones of the humid tropics. In such areas, with the exception of swamp rice, a system of shifting cultivation is always found.

In the past, with a stable or slowly increasing population, man's activities, as represented by cultivation, were in equilibrium with the forest land. Fallow periods as long as 15-20 years are still recalled by old people in the villages. However, with the pressures of a rapidly growing population, the fallow periods are being increasingly shortened and the soils become poorer with each cycle. Moreover, hitherto unused steep slopes and hills are, under current pressures, being brought into cultivation, inevitably leading to significant problems of soil erosion. The kind of soil will, in some cases, augment this worsening situation; for example, the light sandy soils of Sierra Leone lead to rapidly decreasing soil fertility.

As crops decline, farmers are forced to clear larger areas each year in order to cover the needs of their families, and this again shortens the resting period for the land under forest fallow. At the same time, weeds and pests increase and sometimes, as in the Lophira savanna in western Sierra Leone, a kind of bush savanna is the outcome of this chain of events, the forest having been completely destroyed.

The main function of the FAO Fertilizer Programme is the carrying out of a large number of trials and demonstrations on farmers' fields. Demonstrations usually make use of a package of fertilizers, improved seeds and good cultivation methods. This paper gives the results of some of these trials and demonstrations that were carried out on farms under shifting cultivation in Nigeria and Sierra Leone.

ENVIRONMENT

(a) Nigeria

In the forest zone, red loams prevail, changing to yellow loams further south and east. North of the forest zone, in the so-called derived savanna, loams are still found, but here they contain iron concretions of a gravelly character which sometimes form solid layers of laterite. In the forest zone of Mid-West Nigeria, the Benin soil types consist of a sandy topsoil with a subsoil of heavy red loam or, further south, a yellow loam. In Eastern Nigeria light sandy soils are common. Taking control yields as a measure of natural soil fertility, it is obvious that the forest zone is more fertile than the savanna. As rainfall is increasingly constant towards the north, the reason for the lower fertility must lie in the increasingly gravelly character of the savanna soils as well as in the infestation of spear grass.

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Yields of annual crops are generally somewhat higher in Western Nigeria than in Eastern and Mid-West Nigeria due to the adverse effects of poorer soils and higher rainfall. However, tree crops such as oil palm and rubber do better in Mid-West and Eastern Nigeria.

(b) Sierra Leone

Rainfall in Sierra Leone is much higher than in Nigeria, varying between 137 in. (3425 mm) in Freetown and 94 in. (2385 mm) in Yengema, and inland town. Almost all rain falls between April and November, the remainder of the year being extremely dry. In consequence of these conditions, there are many inland swamps in Sierra Leone and rice is not only a highly suitable annual foodcrop but, in fact, the only one. (Under the best experimental conditions, yields of up to 5 000 kg/ha have been reached by Chinese experts). The main part of the FAO fertilizer programme was, therefore, concentrated on the different types of rice.

It will be appreciated that the environmental conditions of Sierra Leone result in leached soils of low fertility and, in hilly country especially, the danger of soil erosion is high when forest is cleared. However, there is now very little forest left; almost all the dry land has been, at some time, under upland rice cultivation using the shifting system.

The so-called ''boliland'' is a flat strip of land about 20 miles (32 km) wide and and 60 miles (100 km) long which floods during the rainy season. As the soils are sandy and extremely acid, only special varieties of rice can be grown on the boliland, but tractors can be used as the land dries out completely in the dry season.

Groundnuts are grown in the northern provinces and, in the dry season, on the banks of rivers in the south and east of the country. Yields are comparable to those in other African countries.

TRIALS AND DEMONSTRATIONS

Field technique

The trials and demonstrations referred to in this paper formed but a small part of the full FAO fertilizer programme from which they were abstracted for the purpose of providing information on the use of fertilizers in the improvement of shifting cultivation.

In Nigeria, certain combinations of N (at 0, 22.4 and 44.8 kg/ha), P_2O_5 (at 0, 11.2, 22.4 and 44.8 kg/ha) and K_2O (at 0, 22.4 and 44.8 kg/ha) were compared or demonstrated in 97 trials and 1245 demonstrations with a wide range of crops. Most of these were located in the forest zone.

In Sierra Leone, the effects of certain combinations of N (at 0, 22.4 and 33.6 kg/ha) and P_2O_5(at 0, 22.4, 33.6, 44.8 kg/ha) were demonstrated in 298 sets of rice plots and 70 sets of groundnut plots.

As no detailed soil maps were available at the time (1967-68), it is not possible to specify the soils on which the crops were grown.

RESULTS

(a) Nigeria

The results of trials and demonstrations in Nigeria are given in Tables 1 to 4.

(i) Maize

In the minor season there were small net returns following the application of N at 22.4 kg/ha in the forest area. The same dressing applied to savanna areas gave somewhat higher returns with value/cost (V/C) ratios over 2.0 (Table 1).

In the major season, N at 22.4 kg/ha gave a similar increase in yield as in the minor season, but as the price of fertilizer had by then been reduced by a subsidy in West Nigeria the V/C ratio rose to 3.7 in the forest area. In the savanna area of the Western Region trials showed that N at 22.4 kg/ha gave the highest net return ($ 13/ha) at a v/c ratio of 4.3, although the demonstrations had suggested the best net return ($19/ha) from N at 44.8 kg/ha plus P_2O_5 at 22.4 kg/ha (V/C ratio 2.6)(Table 1). In the Mid-West the economic returns were marginal because of the higher cost of fertilizer (Table 3).

(2) Rice

Rice was grown in the major season only.

(i) Upland rice

In demonstrations in the West on forest land, N alone (at 22.4 kg/ha) gave net returns of $58/ha (v/c = 15) which rose to $68-113/ha with the addition of P at the same rate (V/C= 15-14). Demonstrations (three only) in the savanna indicated net returns of $138/ha (V/C= 17) (Table 1).

Trials in the West on forest land showed that N or N+P (each at 22.4 kg/ha) gave net returns of $46-56/ha at V/C ratios of 12-7, with small additional economic increases from N at 44.8 kg/ha (Table 2).

In the Mid-West, where fertilizer prices were higher, demonstrations of NPK or P alone on forest land indicated net returns of $32-34/ha with V/C ratios of 3-4 (Table 3).

(ii) Swamp rice

In the Mid-West demonstrations on forest land, N (at 44.8 kg/ha) plus P (at 22.4 kg/ha) gave the highest net returns ($20-22/ha) at V/C ratios of 2.7-2.2 (Table 3).

(iii) Floating rice

Demonstrations in the Mid-West suggested that the use of N alone (at 44.8 kg/ha) with a net return of $19/ha (V/C = 2.6) might be justified (Table 3).

(3) Yam

Demonstrations in both the West and Mid-West forest zones indicated that N+K gave good economic returns, sometimes at high V/C ratios. The particular treatment combinations compared in the West were suggestive that K might only play a minor role (Tables 1 and 3). In the savanna of the West, N was fairly clearly the important element (Table 1).

Trials in the forest zone of the West showed a net return of $94/ha from N (at 44.8 kg/ha) plus P (at 22.4 kg/ha) at a V/C ratio of 8.6 (Table 2). Trials in the forest of the Mid-West emphasized the great value of K. The mean response to any single nutrient was high, the V/C ratio for any single nutrient or pair of nutrients ranging from 7.7 to 38.8 (Table 4).

(4) Cotton

In the forest zone of the Mid-West, N (at 22.4 kg/ha) plus P (at 22.4 kg/ha) raised yields by 260 kg/ha, representing a net return of $41/ha at a V/C ratio of 4.2 (Table 3). Demonstrations in the savanna zone of the West, where fertilizers were cheaper, also indicated the value of N (this time at 44.8 kg/ha) plus P in raising yields by 321 kg/ha over those of control plots. No prices were quoted for the crop, but it seems likely that the response was economic, (Table 1).

(5) Cassava

Demonstrations in the forest zone in the West showed that NPK (each at 22.4 kg/ha) gave a small response at a V/C ratio of 2.2 (Table 1). In the Mid-West, NK (each at 22.4 kg/ha) gave a somewhat higher response at a v/c ratio of 3.1 (Table 3).

In trials in the forest zone of the Mid-West, the largest response was to N; K was also important. Prices, however, were such that N+K (each at 22.4 kg/ha) gave the highest net return of $16/4 at a v/c ratio of 2.9 (Table 4).

(6) Groundnut

In demonstrations in the Mid-West forest land, yields were increased by 408 kg/ha of unshelled nuts following the use of P+K (each at 22.4 kg/ha). The net return averaged $37/ha at a v/c ratio of 4.8 (Table 3).

(b) Sierra Leone

The results of demonstrations only on rice and groundnut are given in Table 5.

(1) Rice

Only N and P, alone or in combination, were used in the demonstrations, the rates of application being dependent on the environment in which the crop was grown.

(i) Upland rice

N was applied at 22.4 kg/ha and P_2O_5 at the same rate. Control yields ranged from 888 to 1603 kg/ha, and the responses to N+P (which were larger than those to either nutrient alone) ranged from 285 to 1244 kg/ha (26 to 78% with v/c ratios from 2.6 to 11.2.

(ii) Swamp rice

Rates of application of N and P were both 33.6 kg/ha.

Control yields ranged from 1045 to 2243 kg/ha. Responses to N+P in five of the six regions varied between 38 and 69%, net returns were $41-111/ha, and v/c ratios were 3.8-8.6. In the sixth region (Makeni) responses were small and the net return was marginal.

(iii) Boliland rice

N was applied at 22.4 kg/ha and P_2O_5 at 44.8 kg/ha. In both regions where the demonstrations were carried out, N+P showed a higher response than P alone. Net returns were $37 and $66 per hectare at V/C ratios of 3.6 and 5.7.

(2) Groundnut

Demonstrations concerned the use of P_2O_5 at rates of 22.4 and 44.8 kg/ha, the higher response always being to the heavier rate of application. The net return varied between $2 and $51 per hectare at V/C ratios of 1.3 to 6.8.

CONCLUSIONS

Almost all the demonstrations and trials were carried out on farms under shifting cultivation, and the main conclusion is that within a short period the use of fertilizers could increase yields between 25 and 60% without introducing great changes into existing traditional methods of cultivation. Where the pressure on land is high, this is obviously valuable in that the farmer can reduce the area he has to clear and the fallow period can therefore be extended. Experience in Sierra Leone has already shown that farmers respond in this manner to assured higher yields. Furthermore, it is likely that many farmers who currently use land for a single cropping season will, with the aid of fertilizers, be able to extend the cropping period to two or three successive years, and that higher yields per unit area will enable them to change from a subsistence to a more market orientated economy.

Table 1. Western Nigeria. Demonstrations: Regional Averages of Results by Crops 1967/68

Region and Fertilizer Treatment $N-P_2O_5-K_2O$ (kg/ha)	Yield Increase kg/ha	Yield Increase %	Net Return $/ha	Value/Cost Ratio
Minor Season 1967/68				
Maize (185)				
Forest (124)				
Control	1120	-	46	-
22.4 0 0	337	30	6	1.9
22.4 22.4 22.4	344	31	-4	0.8
Savanna (46)				
Control (14)	494	-	20	-
22.4 22.4 0	510	103	6	1.4
44.8 22.4 0	572	116	1	1.0
Control (29)	1209	-	50	-
22.4 0 0	410	34	9	2.3
22.4 22.4 22.4	619	51	8	1.4
Control (3)	662	-	27	-
22.4 0 0	433	65	10	2.4
44.8 0 0	556	84	8	1.6
22.4 22.4 0	232	35	-6	0.6
22.4 22.4 22.4	464	70	1	1.1
44.8 22.4 0	542	82	-	1.0
Forest (15)				
Control	1113	-	46	-
22.4 0 0	257	23	3	1.4
44.8 0 0	257	23	-4	0.7
22.4 22.4 0	254	23	-5	0.7
22.4 22.4 22.4	316	28	-5	0.7
44.8 22.4 0	294	26	-11	0.5
Major Season 1968				
Maize (285)				
Forest (138)				
Control (75)	1422	-	58	-
22.4 0 0	356	25	11	3.7
22.4 22.4 22.4	471	33	9	2.0
Control (63)	1514	-	62	-
22.4 22.4 22.4	423	28	7	1.8
Savanna (147)				
Control (53)	1117	-	46	-
44.8 22.4 0	699	63	16	2.3
22.4 22.4 0	573	51	15	2.8

Table 1. Western Nigeria. Demonstrations: (cont'd)

Region and Fertilizer Treatment $N-P_2O_5-K_2O$ (kg/ha)	Yield Increase kg/ha	Yield Increase %	Net Return $/ha	Value/Cost Ratio
		Maize (cont'd)		
Savanna (cont'd)				
Control (17)	1144	–	47	–
22.4 0 0	256	22	7	2.6
22.4 22.4 22.4	291	25	2	1.2
Control (52)	1393	–	57	–
44.8 22.4 0	774	56	19	2.6
Control (25)	1553	–	64	–
22.4 22.4 22.4	315	20	3	1.3
		Upland Rice (90)		
Forest (87)				
Control (53)	1249	–	172	–
22.4 0 0	446	36	58	15.4
22.4 22.4 0	551	44	68	9.0
Control (34)	1264	–	174	–
22.4 22.4 0	880	70	113	14.4
Savanna (3)				
Control	506	–	70	
22.4 22.4 0	1064	210	138	17.4
		Yam (132)		
Forest (26)				
Control (11)	8464	–	203	–
22.4 0 0	1631	22	40	11.0
22.4 0 22.4	1849	22	39	8.1
Control (15)	8286	–	199	–
22.4 0 22.4	2345	28	51	10.3
Savanna (106)				
Control (44)	10496	–	252	–
22.4 0 0	4591	44	106	27.6
22.4 0 22.4	3614	34	81	15.9
Control (62)	10228	–	245	–
22.4 0 22.4	2861	28	63	12.6

Table 1. Western Nigeria. Demonstrations: (concl.)

Region and Fertilizer Treatment $N-P_2O_5-K_2O$ (kg/ha)	Yield Increase kg/ha	%	Net Return $/ha	Value/Cost Ratio
		Cotton (21)		
Savanna (21)				
Control (8)	735	-		
22.4 11.2 0	208	28	n/a	
44.8 22.4 0	316	43		
Control (13)	718	-		
44.8 22.4 0	321	45		
		Cassava (9)		
Forest (9)				
Control	18376	-	147	-
22.4 22.4 22.4	2713	15	12	2.2

Table 2. Western Nigeria. Trials: Regional Average of Results by Crops 1967/68

Region and Fertilizer Treatment $N-P_2O_5-K_2O$ (kg/ha)	Yield Increase kg/ha	Yield Increase %	Net Return $/ha	Value/Cost Ratio
	Major Season 1968			
	Maize (40)			
Forest (18)				
Control	1046	-	43	-
22.4 0 0	352	34	10	3.6
44.8 0 0	301	29	4	1.5
22.4 22.4 0	380	36	7	1.9
22.4 22.4 22.4	384	37	6	1.6
44.8 22.4 0	411	39	4	1.4
Savanna (22)				
Control	1263	-	52	-
22.4 0 0	418	33	13	4.3
44.8 0 0	385	30	8	2.0
22.4 22.4 0	329	26	5	1.6
22.4 22.4 22.4	463	37	9	1.9
44.8 22.4 0	343	27	2	1.1
	Upland Rice (9)			
Forest (9)				
Control	1304	-	180	-
22.4 0 0	360	28	46	12.5
44.8 0 0	429	33	51	7.4
22.4 22.4 0	470	36	56	7.7
22.4 22.4 22.4	439	34	51	6.1
44.8 22.4 0	549	42	63	6.1
	Yam (25)			
Forest (10)				
Control	6883	-	165	-
22.4 0 0	651	9	12	3.9
44.8 0 0	1356	20	25	4.1
22.4 22.4 0	786	11	10	2.2
22.4 22.4 22.4	3804	55	81	9.2
44.8 22.4 0	4434	64	94	8.6
Savanna (15)				
Control	8226	-	197	-
22.4 0 0	4122	50	95	24.8
44.8 0 0	4320	53	96	13.0
22.4 22.4 0	3193	39	68	9.1
22.4 22.4 22.4	3593	44	76	8.7
44.8 22.4 0	4218	51	89	8.2

Table 3. Mid-West Nigeria. Demonstrations: Regional Averages of Results by Crops 1967/68

Region and Fertilizer Treatment $N-P_2O_5-K_2O$ (kg/ha)	Yield Increase kg/ha	Yield Increase %	Net Return $/ha	Value/Cost Ratio
Major Season 1968				
Maize (116)				
Forest				
Control (40)	1307	-	58	-
22.4 22.4 22.4	501	38	7	1.4
Control (76)	1206	-	53	-
0 22.4 22.4	375	31	7	1.7
22.4 22.4 22.4	439	36	4	1.3
Upland Rice (140)				
Forest				
Control (68)	1157	-	127	-
22.4 22.4 22.4	448	39	34	3.2
Control (72)	1226	-	135	-
0 22.4 0	382	31	32	4.4
22.4 22.4 22.4	438	36	33	3.1
Swamp Rice (32)				
Forest				
Control (17)	1110	-	122	-
44.8 22.4 0	326	29	17	1.9
Control (15)	1119	-	123	-
44.8 0 0	286	26	20	2.7
44.8 22.4 0	367	33	22	2.2
Floating Rice (20)				
Forest				
Control (10)	1347	-	148	-
44.8 22.4 0	294	22	14	1.7
Control (10)	1428	-	157	-
44.8 0 0	278	19	19	2.6
44.8 22.4 0	256	18	10	1.5
Yam (106)				
Forest				
Control (53)	8063	-	355	-
44.8 0 22.4	2201	27	82	6.7

Table 3. Mid-West Nigeria. Demonstrations: (cont'd)

Region and Fertilizer Treatment $N-P_2O_5-K_2O$ (kg/ha)	Yield Increase kg/ha	Yield Increase %	Net Return $/ha	Value/Cost Ratio
		Yam (cont'd)		
Forest				
Control (53)	7801	-	343	-
22.4 0 22.4	1902	24	75	9.8
44.8 0 22.4	2307	30	87	7.0
		Groundnuts (unshelled) (33)		
Forest				
Control (17)	956	-	108	-
0 22.4 0	231	24	19	3.8
Control (16)	965	-	109	-
0 22.4 0	343	36	32	5.7
0 22.4 22.4	408	42	37	4.8
		Cassava (22)		
Forest				
Control (17)	8202	-	66	-
22.4 0 22.4	2375	29	10	2.2
Control (5)	5872	-	47	-
22.4 0 0	1917	33	9	2.6
22.4 0 22.4	3328	57	18	3.1
		Cotton (54)		
Forest				
Control (27)	289	-	60	-
22.4 22.4 0	142	49	17	2.3
Control (27)	315	-	65	-
22.4 0 0	173	55	30	6.1
22.4 22.4 0	260	83	41	4.2

Table 4. Mid-West Nigeria. Trials: Regional Averages of Results by Crops 1967/68

Region and Fertilizer Treatment $N-P_2O_5-K_2O$ (kg/ha)	Yield Increase kg/ha	Yield Increase %	Net Return $/ha	Value/Cost Ratio

Major Season 1968

Yam (16)

Region and Fertilizer Treatment $N-P_2O_5-K_2O$ (kg/ha)	Yield Increase kg/ha	Yield Increase %	Net Return $/ha	Value/Cost Ratio
Forest				
Control (16)	5632	-	248	-
22.4 0 0	2051	36	84	15.4
0 22.4 0	1979	35	80	12.7
0 0 22.4	2369	42	102	38.8
22.4 22.4 0	2226	40	85	7.7
22.4 0 22.4	2298	41	93	11.8
0 22.4 22.4	2525	45	102	11.6
22.4 22.4 22.4	2573	46	98	7.3
44.8 44.8 44.8	2980	53	100	4.3

Main effects, mean responses to N = +569; P_2O_5 = +646; K_2O = +877

Cassava (7)

Region and Fertilizer Treatment $N-P_2O_5-K_2O$ (kg/ha)	Yield Increase kg/ha	Yield Increase %	Net Return $/ha	Value/Cost Ratio
Forest				
Control (7)	7527	-	60	-
22.4 0 0	1686	22	8	2.3
0 22.4 0	2219	29	11	2.6
0 0 22.4	1531	20	10	4.6
22.4 22.4 0	1473	20	1	0.9
22.4 0 22.4	3062	41	16	2.9
0 22.4 22.4	272	4	-7	0.2
22.4 22.4 22.4	2714	36	6	1.4
44.8 44.8 44.8	2578	34	-10	0.7

Main effects, mean responses to N = +1228; P_2O_5 = +100; K_2O = +550.

Table 5. Sierra Leone. Demonstrations: Regional Averages of Results by Crops 1967/68

Region and Fertilizer Treatment $N-P_2O_5-K_2O$ (kg/ha)	Yield Increase kg/ha	%	Net Return $/ha	Value/Cost Ratio
	Upland Rice (191)			
Yonibana (12)				
Control	1094	-	95	-
0 22.4 0	176	16	11	3.5
22.4 22.4 0	285	26	15	2.6
Western Area (19)				
Control	834	-	73	-
0 22.4 0	365	44	27	7.2
22.4 22.4 0	593	71	42	5.3
Makeni (31)				
Control	1070	-	93	-
0 22.4 0	287	27	21	5.7
22.4 22.4 0	644	60	46	5.8
Port Loko (31)				
Control	888	-	77	-
0 22.4 0	323	36	24	6.4
22.4 22.4 0	630	71	45	5.7
Rokupr (12)				
Control	1603	-	139	-
0 22.4 0	910	57	75	18.0
22.4 22.4 0	1244	78	99	11.2
Moyamba (15)				
Control	1273	-	111	-
0 22.4 0	423	33	32	8.3
22.4 22.4 0	836	66	63	7.5
Bo and Pujeun (31)				
Control	1215	-	106	-
0 22.4 0	225	19	15	4.4
22.4 22.4 0	564	46	39	5.1
Menema (35)				
Control	1324	-	115	-
0 22.4 0	333	25	25	6.6
22.4 22.4 0	697	53	51	6.3
Bonthe (5)				
Control	1235	-	107	-
0 22.4 0	209	17	14	4.1
22.4 22.4 0	398	32	25	3.6

Table 5. Sierra Leone. Demonstrations: (cont'd)

Region and Fertilizer Treatment $N-P_2O_5-K_2O$ (kg/ha)	Yield Increase kg/ha	%	Net Return $/ha	Value/Cost Ratio
		Swamp Rice (83)		
Menema (43)				
Control	2088	-	182	-
0 33.6 0	478	23	35	6.3
33.6 33.6 0	798	38	55	4.8
Western Area (8)				
Control	1673	-	146	-
0 33.6 0	600	36	46	7.9
33.6 33.6 0	839	50	58	5.0
Moyamba (11)				
Control	2243	-	195	-
0 33.6 0	550	25	41	7.2
33.6 33.6 0	911	41	65	5.4
Port Loko (15)				
Control	1045	-	91	-
0 33.6 0	354	34	24	4.7
33.6 33.6 0	639	61	41	3.8
Bo and Pujeun (3)				
Control	2077	-	181	-
0 33.6 0	1477	71	122	19.4
33.6 33.6 0	1439	69	111	8.6
Makeni (3)				
Control	2057	-	179	-
0 33.6 0	65	3	-1	0.9
33.6 33.6 0	226	11	5	1.4
		Boliland Rice (24)		
Yonibana (6)				
Control	1351	-	118	-
0 44.8 0	529	39	37	5.2
22.4 44.8 0	924	68	66	5.7
Makeni (18)				
Control	994	-	86	-
0 44.8 0	361	36	23	3.6
22.4 44.8 0	582	59	37	3.6

Table 5. Sierra Leone. Demonstrations: (cont'd)

Region and Fertilizer Treatment $N-P_2O_5-K_2O$ (kg/ha)	Yield Increase kg/ha	%	Net Return $/ha	Value/Cost Ratio
Groundnuts (119)				
Port Loko (7)				
Control	602	-	48	-
0 22.4 0	223	37	13	4.0
0 44.8 0	762	127	51	6.8
Western Area (15)				
Control	937	-	74	-
0 22.4 0	123	13	5	2.2
0 44.8 0	297	32	15	2.7
Kenema (21)				
Control	832	-	66	-
0 22.4 0	308	37	20	5.5
0 44.8 0	696	84	46	6.2
Yonibana (6)				
Control	1011	-	80	-
0 22.4 0	81	8	2	1.5
0 44.8 0	307	30	15	2.7
Moyamba (15)				
Control	461	-	36	-
0 22.4 0	253	55	16	4.5
0 44.8 0	506	110	31	4.5
Makeni (23)				
Control	767	-	61	-
0 22.4 0	179	33	10	3.2
0 44.8 0	401	52	23	3.6
Bo (12)				
Control	425	-	34	-
0 22.4 0	79	19	2	1.4
0 44.8 0	142	33	2	1.3
Pujeun (8)				
Control	479	-	38	-
0 22.4 0	158	33	8	2.8
0 44.8 0	319	67	16	2.9
Bonthe (12)				
Control	730	-	58	-
0 22.4 0	86	12	2	1.5
0 44.8 0	216	30	8	1.9

FERTILIZERS IN THE IMPROVEMENT OF SHIFTING CULTIVATION

by

Adetunji, S.A.* and Agboola, A.A.**

Introduction

Farming in Nigeria and in some other parts of Tropical Africa is maintained by a system of ''shifting cultivation'' - the system whereby a piece of land is cultivated for a few and left to rest for some years. The period of rest is related to the population pressure on the land.

This system which is considered primitive has certain merits. It involves minimum disturbance of soil for the production of crop. Regeneration of vegetation does not take long, as a result the nutrient reserve is built up rapidly. The fallow provides control ever erosion, weeds, pests and diseases and requires no great skill of management and high investment. Above all it is an effective and practical means of maintaining soil fertility as long as ample land permits a lengthy fallow period. In the past, the maintenance of soil fertility by this method was comparatively easy, because the population was not large and a reasonable fallow period was possible. Presently the problem of maintaining soil fertility by shifting cultivation is becoming difficult as rapid growth of population is placing more strain on the resources of the land and getting the fallow period reduced - consequently there is decline in the general level of fertility, which is made worse during subsequent cycles.

In most areas where shifting cultivation is practised land is still rather abundant and therefore the yield per unit area is still not very crucial. The low yield per unit labour is however a big setback. However, the business of cutting and burning of bush each time a new plot has to be cropped, the high proportion of land under fallow and the fact that the system is stable, only as long as the fallow periods can be maintained for an adequate period are also big defects.

The soil under shifting cultivation has been exhaustively discussed by Nye and Greenland (1960) and Vine (1965, 1968). Vine (1965) mentioned some points that should be borne in mind, when considering more general aspects of shifting cultivation: That the organic matter content of tropical soils can be rapidly restored to fairly high levels when depleted after periods of cropping and that the accumulation of nutrients is more rapid under forest regrowth than under the regrowth of grasses. That the formation of soil structure by grasses is relatively unimportant and the physical condition of soil is poorer under natural savannah than it is under forest regrowth.

When land is continuously cultivated without manure or fertilizer yields are usually found to decline rather gradually and decreased supplies of nitrogen, phosphorus, or potassium are more important than other factors. The mineral nutrients which the fallow growth collects and makes available in the top soil by leaf-fall and rain wash and in the ashes after burning are partly ''pumped up'' from the subsoil and partly accumulated from difficult available forms in the top soil, but the relative importance of these sources is uncertain as yet.

The Nigerian former who crops his land without fertilizer knows from experience when the fertility of his soil is declining. He realises that high yields of crops are no longer obtainable without restoring the soil fertility which has been depleted by a period of continuous cropping. Crop yield is the yardstick for ascertaining when the fertility of his soil is becoming depleted.

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The farmer maintains the fertility of his soil by:

(1) Natural fallow

(2) Ashes from clearings and weeds. The burning of the bush may lead to an increase in the mineralisation of the organic matter Birch (1960) and a temporary state of partial sterilization. Whilst there may be losses of some nutrients like nitrogen and sulphur as a result of burning, some nutrients like Ca and Mg are returned to the soil. There is not much work yet to indicate the effect of burning of fallow or cover crop on some soil properties like soil structure. Where the intensity of burning is very great crop may not be able to grow for some years after. Because of the above effects of burning, it has been assumed to be deleterious.

(3) The utilization of refuse from domestic sources for farms around the village or hut.

Attempts to improve the existing system of local food production and encourage a more permanent system of Agriculture dates from the end of the first World War (1914-1918). These attempts will be discussed under the following headings:

I. Organic manure

(a) Green manure;

(b) Farmyard manure;

II. Inorganic manures or fertilizers.

Green Manure

The main research efforts from 1921-1951 particularly on the Moor Plantation, Ibadan was directed towards replacing natural fallows with suitable leguminous cover crops such as mucuna in an arable rotation (Lewin 1931, Faulkner 1934 and Vine 1953). As a result of the findings, the Federal Department of Agricultural Research advocated the introduction of Mucuna as a source of fertilizer. This system was not accepted because the peasant farmers considered it unprofitable to grow a crop for a season only to dig it into the soil without any immediate return either in term of cash or food and as well an unnecessary labour ploughing in the green manure annually.

In more recent works (Amon and Adetunji, 1968, 1970, 1973) Crotolaria juncea has been included in the maize, yam and cassava rotational experiment as it was found that the yields of the crops in the rotation could not be maintained indefinitely using inorganic fertilizer. Table 1 gave an idea of the amount of nitrogen, phosphorus and potassium that could be added to soil as a result of ploughing-in of Crotolaria juncea.

Table 1 - Yields of Crotolaria juncea and amount of nutrients added to soil

Site	Dry Wt. lbs/Ac.	N lbs/Ac.	P lbs/Ac.	K lbs/Ac.
Fashola	5 609-5 859	89.2 -100.0	14.9-16.2	21.5-33.8
Ilora	1 897-3 470	40.8 - 65.5	6.4-10.9	30.9-42.0
Eruwa	362- 483	11.00-14.40	0.8- 1.15	4.6- 6.9

Further investigations do show that a lot of nitrogen was lost between the time the Crotolaria juncea was usually ploughed in in October and the time maize is planted in March/April. Comparing the effect of Crotolaria juncea, Crotolaria spectabilis, cowpea and Stylosanthes and the time of ploughing-in on the crop of maize following showed that Crotolaria juncea gave the best results compared with the other and the difference between the other legumes and the different times at which the legumes were buried were not significant. (Table 1b)

Table (1b) - The yield of Maize in lb dry grain per acre following the different legumes buried in at different stages of growth

Summary of yield in lbs/acre dry grains

	Main plot	sig. at 5% level
V_1	Crotolaria juncea	1 827
V_2	Crotolaria spectabilis	1 507
V_3	Stylosanthes	1 527
V_4	Cowpea	1 593
	S.E. 53.3	

Sub plot treatments

Time of ploughing in		N.S.
T_1	October	1 577
T_2	November	1 667
T_3	December	1 596
	S.E. 53.3	

Control (no cover crops/no fertilizer)

Interaction V x T (N.S.)

V = variety of legume

T = time of ploughing in

	V_1	V_2	V_3	V_4
T_1	1 917	1 440	1 416	1 534
T_2	1 921	1 637	1 504	1 606
T_3	1 642	1 442	1 661	1 641

Work by Headchote (1965) at Samaru comparing yield of crop following burnt and unburnt cover crop (or of applied organic matter) in this case Hyperrhenia grass showed that in the drier North, the most significant yield response in the first year is due to the phosphate in the ash whilst in the second year, the most significant but lesser response is to the nitrate released by the slow mineralisation of the unburnt material incorporated the previous year. The work using Andropogon gayanus in Northen Nigeria (1945-1965) as cover crops gave similar results to those mentioned by Vine (1953) and Amon and Adetunji (1968, 1970). The works of Watson and Goldsworthy (1965) in experiments with different types and different lengths of fallow have shown that where only a short fallow can be allowed Cajanus cajan or Andropogon gayanus as planted cover were more efficient than natural regeneration.

Bromfield (1967) suggested another method of improving the fertility under shifting cultivation. He suggested that grain legumes such as cowpea could serve as a food crop while performing the same function of guaranteeing a nitrogen supply to the succeeding maize crop. The work in Agege indicated that maize following a cowpea crop unfertilized gave higher yield than even maize crop fertilized directly (Amon and Adetunji (1968)). The difficulty in the inclusion of cowpea in rotation as a fallow crop however is the question of disease build-up and control and the fact that presently farmers do not practise sole cropping.

Other works on the use of planted fallow to improve shifting cultivation include those of Moore (1962); More and Jaiyebo (1963) which showed that grasses or grass-legume mixture do increase organic matter and that the natural fallow has an advantage over the planted fallow. Most of the results indicate that the crop following immediately after the fallow crop benefit most from it.

Organic Manure

Recently farmers have started using organic fertilizer - the big question is can the use of organic fertilizer replace fallow in shifting cultivation or in Agricultural practices in the tropics. The quantity of farmyard manure needed to raise and maintain the soil fertility is high as it will be evidenced below.

On soils that are inherently poor organic manure (farmyard manure) have given good results. Amon and Adetunji (1968) found that 2 tons/acre of farmyard manure was optimum for maize at Agege. Hartley and Greenwood (1933) found that in Northern Nigeria dressing of 1 ton/acre of organic manure gave a considerable increase in the yield of sorghum. Dennison (1961) concluded from long-term trials in Nigeria that three tons of farmyard manure per acre is required each year to maintain the yields of sorghum and millet at a reasonable level.

On the University of Ibadan Farm Soil organic manure has been used to improve the condition of a run-down soil. In the experiment 10 tons of organic manure was added per acre. This increased the soil organic matter, soil pH, C.E.C. The C.E.C. changed from 9.61 me/100 g to 46.20 me/100 g while soil organic matter content changed from 0.25% to 7.5% after twelve week Table 2. The soil samples in Table 2 were obtained from the plough layer and maize was grown as the test crop.

The acid soils of the Mid-Western State of Nigeria in a pot experiment, had better yield when it was treated with 10 tons of organic manure. Table 3 indicates that organic manure was as good as lime in improving soil pH and better than lime in increasing soil organic matter while Table 3 indicates that organic manure increases yield better than lime on acid soils of Mid-Western State of Nigeria.

Chemical investigations suggested that the increase in yield was due to phosphate release from the farmyard manure, Goldsworthy (1966). Amon and Adetunji, (1968) showed that the 2 tons of farmyard manure used in Agege could add as much as 60.48 lb N, 24.64 lb P, 89.6 lb K, 0.58 lb Fe, 3.05 lb Mn, 34.94 lb Ca and 61.38 lb Mg. per acre; and an increase in organic matter was noted as well. Soil nutrients are correlated with soil organic matter. The increases in the yield of crops as a result of addition of farm yard manure could be due to a combination of the following: increase in nutrient reserve, improvement in soil structure and an increase in water retentivity of the soil.

Inorganic fertilizers

Quite a number of fertilizer experiments have been carried out in Nigeria by Governmental and International bodies. The chief aim of all these trials is to increase food production as a result of improvement of yield of crops and also to collect information needed to promote efficient use of fertilizers as food crops; thereby indirectly increasing the length of time for which a piece of land can be cultivated and reducing the length of the fallow crops. The amounts of fertilizer generally used in Nigeria on most of the crops are much lower than the amounts of fertilizers being used in more industrialised countries like the United States of America, Holland etc. (Goldsworthy 1965 and Heady and Pesck, 1954). But by and large farmers using fertilizer and any of the innovations have been able to double the yield of their crop as shown in Table 5.

Table 2 - Effect of liming and organic manure and Soil organic matter, CEC and Soil pH in a soil low in pH

Treatment	pH		CEC meg/100 gm		% O.M.	
	Initial	Final	Initial	Final	Initial	Final
Control	3.18	3.48	9.61	7.25	0.26	0.24
Lime	3.17	6.86	9.56	6.47	0.29	0.32
Organic Manure	3.17	6.42	9.61	46.20	0.25	7.20

N.B. Duration of experiment was 12 weeks. 10 tons of organic manure composition of 0.620% N, 0.531% Pm, 1.269% K, 0.860% Ca and 0.420% mg was applied per acre. One ton of lime having 100%mersh was applied per acre to the lime plot.

Table 3 - Top growth of maize in gm/pot as affected by lime and organic manure treatment in soil low in pH

Treatment		Locations		
	Effurum	Agbaro	Nifor	Oluku
Control	3.71	14.56c	13.94c	3.34e
Lime	7.03d	15.05c	14.79c	5.01de
Organic Manure	26.98b	38.75a	27.8 1b	22.89b

Table 4(a) - Simple correlation coefficients for the relationships between the soil variables pH, organic matter, available phosphorus, available potassium, exchangeable calcium and exchangeable magnesium

Soil Variable		Correlation coefficient			
	pH	P	K	Ca	Mg
OM	.375**	.185*	.325**	.687**	.365**
pH		-.157	.349**	.533**	.164
P			.139	.258**	.145
K				.323**	.226*
Ca					.358*

* Significant at 5%

** Significant at 1%

Table 4(b) - Simple and multiple correlation coefficients and F values for the relationships between the concentrations of each of nine elements in maize tissue and six soil variable - elements in Plant tissue

Soil	N		P		K		Ca		Mg		B		Cu		Zn		Mn	
Variable	Simp r	Part F	Simp r	Part F	Simp r	Part F	Simp r	Part F	Simp r	Part F	Simp r	Part F	Simp r	Part F	Simp r	Part F	Simp r	Part F
pH	.073	0.020	x .218	1.33	xx .363	3.69	.117	2.57	-.174	0.00	-.029	xx -2.28	-.106	xx -3.56	-.136	4.37	xx -.235	0.90
OM	.093	0.10	.132	0.72	xx .339	3.14	-.173	xx -5.57	-.287	-5.28	-.121	0.08	-.021	-1.61	-.126	1.68	-.376	-3.99
P	.004	0.16	xx .189	xx 1.82	.104	0.01	.041	0.40	-.062	-0.01	.092	0.38	.001	0.06	.149	xx 2.55	-.120	0.08
K	-.011	0.83	.123	0.01	xx .415	xx 11.93	-.040	0.14	-.166	xx -1.40	.119	1.21	.085	x 1.40	-.070	0.65	-.051	xx 2.21
Ca	.115	0.11	xx .243	1.35	xx .316	0.05	-.007	0.82	xx -.265	xx -2.20	.132	xx 1.08	.053	xx 1.80	.072	0.30	xx -.360	1.03
Mg	xx .247	xx 6.49	xx .212	xx 2.46	.038	xx -2.78	-.101	0.44	xx .213	xx 19.81	.065	0.01	.151	xx 2.38	.031	0.05	xx -.264	xx -2.32
R^2	.071		.109		.268		.082		.231		.047		.068		.083		.193	
F	x 1.44		xx 2.31		xx 6.90		xx 1.69		xx 5.69		.932		x 1.39		xx 1.72		xx 4.57	

x Significant at 1%

xx Significant at 5%

Table 5 - Yields of crops on research plots compared with yields of crops on farmers plots

Crops		Guineacorn	Maize	Millet	Upland rice	Swamp rice	Yam	Cassava	Cowpea	Cotton	Groundnut
Yields in lbs. per acre	Farmers using old methods	610	535	450	500	1,100	5,740	3,500	200	375	620
	Farmers adopting innovations	1,100	1,375	775	1,280	1,800	9,500	4,750	430	765	1,150
	Research	3,000	6,000	1,670	2,000	4,000	40,000	11,200	2,000	2,000	2,000

Quite a number of experiments using different inorganic fertilizer on different crops have been carried out in Nigeria. Fertilizer additions to soils have been found to increase the yield of crops generally (Agboola 1968; Amon and Adetunji, 1968, 1970, 1973; Bredero 1962; Fayemi, 1966; Goldsworthy, 1963, 1966, 1967; Goldsworthy and Heatdrote 1963, Greenwood 1954; Meredith 1962, 1963; Tewari 1965, 1968 and Vine and Kowal 1952). Fertilizer response is more frequent in the savannah than in the forest areas (Adetunji; 1972 unpublished date). Where there has been no response, this may be due to some other factors like inadequacy of rainfall and deficiencies of other nutrients, rather than high level of fertility. Nitrogen is the most important of the major nutritients followed by phosphorus. Response to potash is less common except in the high rainfall areas of the forest zones. Positive interactions have been noticed for nitrogen and phosphorus on maize and groundnut (Amon and Adetunji 1968, 1970, 1972; Goldsworthy 1966; Richardson 1965). Responses to trace-elements have been found in the rainforest areas on the sedimentary soils and in the savannah where no responses were found with the addition of N.P.K. only. The six trace-elements used in the mixture were Mo, Fe, Zn, Cu, B and Mo. The attempts to separate and find conclusively which of the six trace elements are responsible for the increase in yield were not successful particularly on the sedimentary soils.

Long-term rotational experiments involving maize, yam and cassava (Amon, 1965; Amon and Adetunji 1968, 1970 and 1973) showed that high yield cannot be maintained with the use of inorganic fertilizers indefinitely without a fallow period, hence Crotolaria juncea was included as a fallow crop and only stays on the ground for about four months.

Limitations of the previous works were:

1. No soil maps were used in siting some of the experiments including those for the Freedom From Hunger Campaign of the FAO.

2. No attempts to find out the residual effects of the fertilizers applied and how over the years this can affect the amount of that nutrient or others required as fertilizers.

3. The number of sites for some of the experiments were too few for the areas for which their results were required for advisory service to farmers; and as a result the advice given to farmers was not yielding fruitful results.

As a result of these limitations present work particularly in the Western State has been designed to have wide coverage and to correlate soil tests with yield of the crops and fertilizer requirements.

Conclusions

So far no alternative fallow vegetation has been shown to be much better and acceptable to the local farmers in Nigeria. Even if it were, it would require planting. No farmer as of now with a small capital outlay and a small holding will be prepared to plant fallow crop to be ploughed under. The result of these poor economic conditions and lack of adequate knowledge on the part of the farmer is that all the recommendations for the use of the fallow crop have not been acceptable.

One of the virtues of natural fallow is its variety and the speed with which, under forest condition at least, both new weeds and new regrowths from existing stumps and roots ensures a rapid upsurge of growth and immediate cover. Artificial fallows, however, are easier to clear and to plant mechanically.

The results so far showed some of the planted fallows were better than the natural fallow, but more work is still required to see whether legumes that could fetch some income, but with other desirable qualities like disease control, e.g. nematode control, heavy vegetative growth within a short period and easy of establishment and management can be introduced.

The fertility of the soil can be improved and maintained by the use of organic manure. The difficulties involved in translating all the research results into practice include:

(i) the difficulty of obtaining enough organic manure for use. Where one considers two tons farmyard manure as being adequate, these applications are as much as twice as farmers put c heavily manured farms in the Northern Nigeria where rearing of animals is good. In the sout production of farmyard manure is even smaller (when it is produced at all) - this is because of the difficulty in keeping the animal healthy from tsetsefly attack. In the rainforest area, the farmers keep few goats, sheep and chickens. Their grazing is not controlled; the droppings are generally more around the village compounds than on the farms.

(ii) It is not possible to consider transporting even one ton of farm yard manure; something much more than this, or it will be highly uneconomical.

With the use of fertilizer, higher yields have been obtained and maintained although not for an indefinite period. With the use of fertilizer and a good fallow crop in the rotation, continuous cultivation can be achieved. More work is required however on fertilizer need of each crop based on soil tests and the sequences of cropping.

Work done so far on mix cropping indicates that legumes that are early maturing like the green grain could safely be interplanted with early maize and that this could serve as a source of fertilizer. Furthermore a later matuing green grains like Calapogonium muccunoides could be intercropped with early maize (Agboola and Fayeni 1972).

Mix farming is another way of reducing the problems of shifting cultivation in preference for more stable and permanent agriculture. Large acreage and mechanized systems will have to be introduced as opposed to peasant farming whereby individual farmers only own one to two acres of farm at a time. Let us assume that a farmer has a 50 acre piece of land. The piece of land can be divided into two 25 acre plots. On one plot of 25 acre he could have a grass-legume or grass pasture, while the other 25 acre plot carries a four to six year crop rotation. These two plots can be alternated for grazing and cropping - thereby integrating crop-rotation, fallow and grazing which provides farm yard manure.

This proposed system of alternating crop rotation with planted pasture can be practised in the savannah, or in other areas by the use of animals that are adopted to the conditions prevailing there. Other problems that may have to be looked into in this type of proposition however are socio-economic e.g. the land tenure system, capital outlay, the use of labour displaced from land, fragmentation of holding and legal aspect of ownership at the death of the farmer etc., etc.

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PROBLEMS ASSOCIATED WITH A CHANGE FROM SHIFTING TO PERMANENT CULTIVATION ON A LIGHT SOIL IN THE KILOMBERO VALLEY, TANZANIA

by

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Introduction

The Kilombero Valley is part of the upper Rufiji basin in southern Tanzania. It lies at an altitude of about 250 to 300 m and covers an area of about 20 000 km^2. It is situated in a forest savannah transitional zone where the average temperature is 26°C, the annual rainfall amounts to 1 200-1 400 mm, and the dry season is of six months duration. The low lying centre portion of the valley is swampy, but surrounding it is higher lying land which can be used for agriculture and where the population density is 20-23 persons per square kilometre. The soils, some of which are alluvial and others have been developed _in situ_ from the parent material, show a wide range of fertility.

Shifting cultivation

Shifting cultivation is carried out in the valley. In the less densely populated areas some of the farmers shift their dwellings when they move to another piece of land, but probably more commonly the house is not moved. The farmers clear and cultivate an area of bush for a period of 3-5 years and then abandon it in favour of another area which in turn is cleared and cultivated. After two to four such cycles, the farmer returns to the land which had first been cleared which in the meantime had lain under bush fallow for 10-20 years. The length of the fallow period is mainly dependent on the type of soil, and the farmer often judges it to have been sufficient to restore soil fertility when the original _Hyparrhenia_ grass has again become the dominant species of the vegetation.

Rising population indicates the need for further research into permanent cultivation. An interesting feature is that farmers have not always preferred areas of fertile soil. The relatively less fertile, sandy soils have been attractive, the lower labour input required for clearing, weeding and cropping compensating for cropping a larger area giving lower yields. It could be expected, therefore, that areas of poorer soil hold considerable potential for future research.

Permanent cultivation on a groundwater laterite

One of the poorer soils which is widely used for shifting cultivation in the Kilombero valley is a groundwater laterite. It is a pale, sandy soil overlying a hard pan of manganese-iron concretions which has been formed _in situ_ at a depth of about 80 cm. During the rainy season the soil is often waterlogged, but during the dry season the water table is at a depth of about 1.5 m.

When clearing this land, the farmers leave the larger trees and roots undisturbed. The crop most commonly grown is upland rice, but maize and cassava are also grown. All crops are planted on ridges, the last two mentioned being on even higher ridges to avoid waterlogging. Weeds are removed and laid in the furrows where they serve as green manure after splitting the ridges for the next crop. Farmers cultivate soil of this types for three to five years, using only a hand hoe.

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In an attempt to bring this soil under permanent cultivation with annual crops, about 30 ha were cleared at Katrin Research Station and cultivated in the normal fashion with tractor plough and disc harrow. The crop rotation differed somewhat from field to field, but generally the sequence was: maize, rice, soyabean, rice or sesame, rice, rice. Dressing of artificial fertilizers were given to all crops; rates of application to rice were usually 20 kg of N (as ammonium suplhate), 26 kg of P (as triple superphosphate) and 40 kg of K (as potassium chloride) pee hectare.

Despite the dressings of fertilizer, yields decreased gradually, but it was not possible to determine to what extent it could be attributable to the effect of season or to an ever increasing amount of weed growth which could not always be handled properly.

During the sixth year of cropping, large patches of plants in the fields grew extremely poorly and no seed was harvested. On one field, soyabeans suffered considerably, remaining small before finally dying. In another field devoted to a rice variety trial, all 16 varieties germinated well, but few tillers and even fewer ears were produced before the plants died without a single grain being harvested. As there was still some little time left before the end of the season, a soyabean trial was immediately laid down on one of the worst patches in order to seek a clue to the cause of crop failure. A basal dressing of NPK was applied and followed by five treatments; (1) Control; (2) Ammonium molybdate at 25 g/ha; (3) Agricultural lime at 2 t/ha; (4) Cattle manure at 30 t/ha, and (4) Agricultural lime at 2 t/ha plus cattle manure at 30 t/ha. Owing to the short period of time before the end of the season, no beans could be harvested, but the weight of dry matter produced and other parameters showed clearly the beneficial effect of cattle manure and also of lime. Molybdenum had but a small effect.

Soil analyses showed that during the six year cropping period the pH of the soil (as measured in $CaCl_2$ solution) was reduced from 5.4 to 4.1. This reduction was a very large one, taking into account the relatively low rates of application of N and P. Lime applied to the final soyabean crop raised the pH from 4.1 to 4.9, but rice sown as a test crop on the site of the same experiment in 1973 was destroyed by wild animals and no crop was harvested. The remaining land was put down to fallow.

Research work in progress

Leaf and soil analyses of a detailed nature are being undertaken, but no results are available yet.

Several trials have been laid down in an attempt to find a sound cropping system for this type of soil. One long term experiment is being used to compare 12 different crop rotations in which rice is the main crop and leys are also included. Other experiments are being used to compare high and low rates of fertilizer and the effect of lime. In one trial Mo significantly increased the yield of rice straw and narrowly failed to do so for grain yield.

Conclusions

The results obtained so far from trials on the long-term cultivation of annual crops with mechanization on a pale sandy groundwater laterite soil have not been encouraging. After six years cropping, yields fell to zéro, despite reasonable dressings of NPK. The application of cattle manure and lime markedly improved the crop but neither seems to be a practicable proposition because little cattle manure is produced and the cost of lime is uneconomically high. Liming might also aggravate the problem by increasing mineralization of organic matter.

At the present early stage of investigation, no improvement can be suggested on the customary method of shifting cultivation as practised by farmers on soil of this type.

CLASSIFICATION OF LAND FOR ITS USE CAPABILITY AND CONSERVATION REQUIREMENTS

by

F.R. Moormann*

The intensification of agriculture on land used for shifting cultivation requires in most cases a thorough knowledge of the edaphic and other attributes of such land. Modern techniques such as mechanization, higher-yielding varieties and the use of fertilizers can transform the extensive form of land use under shifting cultivation to a more intensive one with a considerably higher agricultural output per unit area. Introduction of such techniques can, however, lead to failure if soil conditions are not suitable or if other environmental factors are adverse. Many examples of failure to use shifting cultivation land for a high input, temperate zone type of agriculture can be cited from various countries in the lowland tropics. Determination of correct intensified land use thus requires a study in depth of the land and and evaluation of factors which are limiting in view of such intensification.

The technique which makes it possible to determine the most suitable use for any area of land is Land Classification. A great number of systems of Land Classification are in use, varying in approach mainly according to the purpose for which the land is classified. Land may be classified according to its present land use, to its suitability for a specific crop under the existing forms of management, to its capability for producing crops or combinations of crops under optimum management, or to its suitability for non-agricultural types of land use.

Land capability classification

The purpose of land capability classification systems is to study and record all relevant data, which will lead to a decision as to the combination of agricultural use and conservation measures which permit the most intensive and appropriate agricultural use of the land without undue danger of soil deterioration.

The best known of these systems is the United States Department of Agriculture system (Klingebiel & Montgomery, 1961), which has been adapted and modified for use in a number of countries, including, those in which shifting cultivation is widely practised. The USDA system is an interpretative system, using the soil survey map as a basis and grouping the individual soil map units into groups that have similar management requirements. The capability grouping is designed to help land users to use and interpret soil maps and to make possible broad generalization, based on soil potentialities and on limitations in use and management. The system is primarily concerned with the risk of erosion and to a lesser extent with other management hazards such as wetness, shallowness and salinity or alkalinity of soils. In the highest category, eight classes are distinguished, i.e.

Class I. Soils that have few limitations that restrict their use. Erosion hazards on these soils are low; they are deep, productive and easily worked. For optimum production, these soils need ordinary management practices to maintain productivity, both as regards to maintaining soil fertility and favourable physical soil properties.

Class II. Soils that have some limitations that reduce the choice of plants or that require moderate conservation practices. Limitation of soils in Class II include singly or in combination the effect of gentle slopes, moderate susceptibility to erosion, less than ideal soil depth, somewhat unfavourable soil structure, slight to moderate correctable salinity, occasional damaging overflow, wetness correctable by drainage, slight climatic limitation. Soils in this class require more than ordinary management practices for obtaining optimum production and for maintaining productivity.

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Class III. Soils that have severe limitations that reduce the choice of plants or require special conservation practices.

The limitation of soils in this class are those of Class II, but in higher degree; including as additional possible limitations, shallow depth, low moisture holding capacity and low fertility which is not easily corrected. Class III soils require considerable management inputs but even so, choice of crops or cropping systems remains limited because of inherent limiting factors.

Class IV. Soils having very severe limitations that restrict the choice of plants, require very careful management or both.

Restrictions, both in terms of choice of plants and of management and conservation practices, are greater than in Class III to such an extent that production often is marginal as regards the inputs required. Limiting factors are of the same nature as in the previous classes, but are more severe and more difficult to overcome, while several of the limitations, such as steep slopes, are a permanent feature of the land.

In the USDA system, the soils of classes V to VIII are generally not suited to cultivation, although certain of them may be made fit for agricultural use by costly reclamation measures.

Class V. Soils that have few or no erosion hazards but have other limitations, impracticable to remove, that restrict their use to pasture, range, woodland or wild life food and cover. Many of these soils are subject to inundation, are ponded or are stony or rocky, though level or nearly level.

Class VI. Soils having severe limitations that make them generally unsuited to cultivation and limit their use largely to pasture or range, woodland, or wild life food and cover. This class is a continuation of Class IV with very severe limitations that cannot be corrected. They may serve for some kinds of crops, such as tree crops, provided unusually intensive management is practised.

Class VII. Soils with very severe limitations that make them unsuited to cultivation and that restrict their use largely to grazing, woodland or wild life. The limitations, are such that these soils are not suited for any of the common crops.

Class VIII. Soils and land forms that preclude their use for commercial plant production.

In the second level of generalization of the USDA system, the sub classes the kind of limitation is specified. Four kinds of limitation are recognized at this level, i.e. risk of erosion, wetness, drainage or overflow, rooting zone limitations and climatic limitation. The third level, that of the capability unit, provides more specific and detailed information for application to specific fields on a farm. In tropical countries where the framework of the USDA system has been introduced, adaptations and changes have been made. Examples of such adaptions for Rhodesia and the Philippines were discussed by Hudson (1971); for the monsoon area of Thailand reference may be made to Gallop et al. (1967). One of the main reasons that the USDA system cannot be used without substantial revision for local conditions is the premise that the system assumes a moderately high level of management, one that is practical and within the ability of a majority of the agricultural land users in the United States. It is, therefore, of particular use for areas where the mechanized, moderate to high input types of agriculture are practised. It caters to a much lesser degree to the areas, under discussion in this seminar, where the level of management under shifting cultivation is particularly low. The use of the system in such areas most often has to be based on interpretation of soil characteristics only, without the benefit of relevant agronomic data or of the knowledge of the dynamics of soils under intensified management. Whereas shifting cultivation is frequently adapted to the ecological and socio-economic conditions of the land, intensified cropping especially of annual food crops, is not. While environmental parameters, leading to classifying land in classes V to VIII are commonly easy to discern by field studies alone, this is not so for classes I to IV where such parameters have to be tested for their effect on agricultural productivity in order to be of value in the determination of the correct land capability class of a given piece of land.

Land evaluation for agricultural land use planning

A new standard framework for land evaluation by means of land suitability classification is presently being developed under the aspices of FAO (FAO, 1972), based on experiences in developing countries and to a large extent on the work of Beck and Bennema (1972). As in other systems, the land suitability component of land evaluation is based on the survey of the physical attributes of the land (soils, climate, vegetation, topography, hydrology, etc.), and consequently requires interpretation of these attributes. The proposed land suitability classification represents the first stage in the evaluation process for rural purposes; a further step is the economic suitability classification which integrates relevant social and economic factors with the technical suitability classification. At the present stage, the system mainly concentrates on the technical suitability classification of land.

The system recognizes the fact that land suitability depends to a large extent on the purposes which the land is required to serve. Hence, the notion of land utilization type is introduced. Land, according to this notion, can only be evaluated within the context of a given utilization type as defined by its produce, capital intensity, labour intensity, farm power, technical knowledge, farm size and land tenure. Of these factors, produce is certainly the most important when evaluating the potential of land under shifting cultivation for increased and sustained agricultural production. Land utilization types can be defined in broad terms, based on differences in agricultural use (e.g. rainfed arable farming, tree crop farming, horticulture, etc.) but also in more narrow refined terms of crop rotations, single crops or even single varieties. This approach implies that evaluating land under shifting cultivation for its suitability for intensified agriculture will require consideration of a number of alternative land utilization types.

The suitability classification proposed recognizes the fact that intensified land use requires inputs, whether recurrent or minor inputs such as tillage, fertilizers which are applied by the land users themselves, or major capital inputs such as the introduction of irrigation, land shaping or terracing or, as in the case of shifting cultivation in forest areas, land clearing. A range of suitability classifications is proposed, referring to actual land utilization on to potential land utilization requiring major capital inputs.

The same structure of interpretative groupings proposed would be used in all of the interpretative classifications, each grouping retaining its basic meaning of suitability in relative terms within the context of the different classifications and in relation to each land utilization type. Four categories of generalization would be recognized, i.e. land suitability order, land suitability class, land suitability subclass and land suitability unit. Three orders are proposed:

Order 1. Suitable

Order 2. Conditionally suitable

Order 3. Unsuitable

In the classes, degrees of suitability would be indicated in order of increasing limitations. For Order 3, a two class subdivision is proposed, i.e. Class 3.1 presently unsuitable for practical or economic reasons, but with the possibility that it may become suitable in future, and Class 3.2 unsuitable, when no such possibility would exist.

The subclasses are divisions within the classes, according to the nature of limitations, whereas units would be recognized according to minor differences in production characteristics and/or management requirements.

In order to arrive at a satisfactory diagnosis of the suitability of land for a specific purpose, the FAO system introduces the notion of land qualities. Land qualities are groupings of attributes of the soil and environment which determine, alone or in combination, the suitability of a given piece of land for a specific type of land utilization. The land quality ''Resistance to erosion'', for instance, could be seen as an integration of single land attributes such as erodibility of the soil, degree and length of the slope, erosivity of the climate. Major land qualities in relation with agricultural use are grouped according to the kind of requirement they serve. They are related with requirements of plant growth, animal growth, natural product extraction or with management practices in plant production, animal production, or extraction. Determination of land qualities, sufficiently precise to be used as diagnostic characteristics in the land suitability classification process, is possible if reliable agro-ecological data are available. This is mostly not the case in wide areas of shifting cultivation, particularly in the lowland humid forested areas of the tropics.

Parametric methods of soil and land evaluation

The parametric method consists of evaluating separately the different properties of soils and their environment and of combining these factors according to a mathematical model taking into consideration the relationships and interaction between the single properties. The outcome is an index of performance which is used to rank soils in order of (agricultural) value A summary of the major parametric methods was given by Riquier(1972). As quoted by Riquier, a multiplication method for soils of the humid tropics has been worked out by Sys & Frankart (1971, unpubl.). The criteria considered as factors are: profile development, parent material, depth of the soil, colour, drainage, pH, base saturation and development of the A1 horizon. In this method, improvement measures are taken into account but without computing their influence on productivity. Moreover, no climatic factor is used in the formula which is established for use in the warm and very humid tropics where recurring droughts would not be limiting for productivity. Parametric methods have a number of advantages, the major one being that the indices chosen and the arithmetic procedure used can be standardized, thus eliminating a certain element of subjectivity common to other methods. Nevertheless, the choice of the indices is, of necessity, often subjective in as much as it is difficult, if not impossible, to evaluate the action of certain factors used in the equation on plant growth and crop productivity. Hence, parametric methods usually are empirical and of application for specific crops in limited agro-ecological areas only. In the meanwhile, the ideas which they embrace are likely to form a usefully objective basis for determining the place of individual land units within a standardized framework of land suitability classification.

Conclusions

Different methods of land capability and/or suitability classifications have been in use in many countries, including those where, at present, shifting cultivation is an important form of land utilization. In areas where shifting cultivation predominates, the type of land suitability classification should preferably be one which takes into account the desirability of developing a more intensive type of land utilization. Potential land suitability classification is thus clearly indicated for such areas.

Determination of land use alternatives to shifting cultivation requires a thorough knowledge of crop performance in the areas under study. In most countries, considerable amounts of agricultural data are available from experimental farms and stations, from field experiments and demonstrations witn fertilizers and new varieties, and from records of commercial farmers. In certain cases, notably where tree crops and certain annual commercial crops are concerned, enough is known of crop perfomance in function of environmental factors to enable the land classifier to make pertinent predictions of the suitability of land for such a specific land utilization type. This, however, is generally not the case for various food crops. The principal shortcoming of the available agricultural research data is, in general, the lack of a solid quantitative description of the physical environment in which experiments are carried out. Climatic data of the sites are often not available or, if they are, very frequently only mean values are given. Soil data, if mentioned at all, are commonly insufficiently precise and are unrelated to the general soil conditions of the area which the experimentation is required to serve. Quite often, results of experimental work are not very accessible. Even more alarming is the fact that negative results of experiments are most frequently not published, even though such adverse results are of great importance for the land classifier because they may inform him on the nature and severity of factors limiting production. With all their shortcomings, however, the results of agronomic experimentation are of eminent importance for the land classifier. Such data should be integrated and, where possible and feasible, made more meaningful by adding the lacking data on soils, on climate and on other physical environment parameters. Quite frequently this would entail a detailed study of the physical environment of selected experimental sites.

A further step would be the establishment of experimental fields or farms on selected soils or soil associations representative for larger land areas. Agronomic experimentation on such bench mark sites should be directed towards the determination of the soil potential under improved management while studying, at the same time, physical production limiting factors and the ways and means to overcome such limitations.

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AGRONOMIC ASPECTS OF SOIL CONSERVATION

by

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It is intended to focus the topic of this paper on shifting cultivation; however, at times aspects will inevitably overlap practices concerning cropping systems of a more complex nature. These latter systems are considered more intensive but is is suggested that, in fact, they are often only more intensive in capital investment.

Of the factors contributing to a system of shifting cultivation (social, ritual, environmental and demographic), environmental change is certainly the most important. Long-term modifications in climate lead to a movement of people which is more a migration than a shift, but along rivers in particular annual seasonal shifts occur. These are related to flooding which releases land for cultivation when the water recedes and are combined with genuine shifting cultivation with rainfed crops on the unplands. Nevertheless, it is thought that the most important environmental contribution to shifting cultivation is soil deficiencies, and here also it helps to distinguish between short and long-term moves; the former permit soil regeneration while the latter indicate an acceptance of apparently irremediable destruction of valuable soil properties.

The traditional farmer commonly regards farming as a way of life rather than a profession; even so, he has a great capacity to assess the level of soil fertility, yet is hampered in determining the relative importance of each factor contributing to change in soil fertility. For example, he seldom realizes that sheet erosion can be a means of soil degradation because he recognizes erosion only in its most severe forms (gullies and landslides). Farmers are still reluctant to adopt any measures to control erosion or to adopt ley farming; bush fallowing is accepted as a simple and cheap method of regenerating soil fertility. Hand in hand with this reluctance, the traditional farmer retains a high degree of skill in interpreting the natural flora as an indicator of restoration of fertility, plant communities giving an accuracy for this purpose at least as good as laboratory methods.

A very broad view is essential when assessing traditional farming practices or when contemplating the introduction of far-reaching changes (such as the replacement of shifting cultivation with permanent cultivation), without which serious damage could be done. In Lesotho, for example, settlement of the population led to a complete change in social and economic behaviour, and because there was no indigenous technique for farming under the new conditions large areas of forest disappeared and spectacular, destructive erosion was widespread.

In countries such as Rwanda and Burundi, which have by far the highest human and animal population densities in Africa, it is surprising to find relatively little damage from erosion caused by water. Both countries are mountainous, and intensively cropped (land use factors varying from 2-3 for semi-permanent to 3-5 for recurrent cultivation). Erosion is mainly caused by cattle overgrazing the fallows, thus reducing any regenerating effect. Incidentally, this is an example of conflict of interests between the Hutu crop producers and the Tutsi herdsmen which might have been resolved by a social integration of the two ethnic groups, and thus maintained a balanced system of agriculture seemingly well suited to the environment.

It is astonishing that a non-mechanized agriculture could have developed cultivation techniques which enable all crops to be grown on many different soils without lasting loss of soil fertility. The chief traditional way of controlling erosion is to plant very small plots of different crops, so giving the landscape a patchwork appearance; the land tenure system did

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not facilitate contour cropping. This persists even to the present day, despite the introduction of more methods such as contour hedges and ditches. For a long time, farmers did not accept the planting of grass in contour strips, even though these were more efficient for controlling erosion than continuous or discontinuous ditches, because it limited their cultivation methods and interfered with their land tenure system. A compromise was reached by the introduction of fodder crops for strip planting following the tardy acceptance by farmers of the principle of feeding their livestock.

Owing to their structure and texture, many soils are very susceptible to erosion under heavy rainfall even on very gentle slopes. Even small modifications to planting methods, such as planting on ridges instead of on individual mounds, would be of some value in reducing erosion while in no way detracting from the performance of the plants.

While loss of soil fertility is, in part, brought about by erosion losses, some plant nutrients are permanently removed from the soil when the crops are harvested. Such remedial measures for both as have evolved from research have not been widely accepted by the rural population as often they are too costly in labour and materials for farmers of limited means.

In the savannah areas, ley farming has been successful only when combined with the production of fodder for livestock, and then only when cattle were appreciated as a new source of energy for soil cultivation and when it was realized that better feeding resulted in faster growth rates and more rapid cash returns. As a principal source of green manure, ley farming has not been a success, and the very long grass fallow, although less efficient, is still general. Both the somewhat difficult propagation of cultivated grasses and the effects of uncontrolled grazing are deterrents to the adoption of ley farming, as also are the practical difficulties of removing stumps and the burying of organic matter.

In the Sahelian and Sudan zones, and to a lesser extent in wetter areas, the incorporation of organic residues into the soil has very often greatly reduced crop yields during at least the first year. This effect cannot wholly be attributed to nitrogen deficiency developed during the rather slow breakdown because of the lower microbiological activity of soils in dry areas, since heavy dressings of nitrogenous fertilizer do not fully restore crop yields. It seems probable that large quantities of organic matter tend to insulate the topsoil, reduce capillarity and create a shortage of water for the plants, so aggravating the effect of temporary nitrogen deficiency. In these ecological zones, where the water balance of the soil is highly important, the largest programme of research is being carried out by forestry research workers, and agronomists, who should have an approach more orientated towards crop production, have taken second place. Nevertheless, some of their early work has yielded some remarkable data which could possibly lead to revision of the usual concepts of soil preparation and fertility conservation.

As population pressures have increased, so have farmers in the wetter areas been compelled to accept a shorter form of weed fallow in substitution for the former longer-term forest fallow. This shorter fallow may not be long enough to regenerate the soil, and has an added disadvantage, common to ley farming, that soil preparation is less easy than under a tree cover.

Traditional apathy towards weeding may or may not be justified, but the fact remains that those who express it have, until very recently, been able to meet their subsistence requirements with little more than selective weeding. It has been said by farmers that weeds fall into three categories: those that are directly harmful to the current crop; those that have little effect on the current crop but will be helpful to the following crop, and those that grow slowly and late and are helpful to all crops. This classification seems to be mainly related to the rooting systems and speed of growth of both crops and weeds, and knowing that the traditional farmer is more inclined to seek an optimum return for the longest period of time rather than a maximum return, it seems possible that he has developed a cropping system with a type of 'intercrop fallow' which supplies an intermediate green manure or mulch. The same considerations may have contributed to the general practice of mixed cropping.

Agronomists have much to contribute to soil conservation and to the improvement of shifting cultivation; equally, they have much to learn from indigenous farming methods.

SOIL AND WATER CONSERVATION PRACTICES PARTICULARLY IN AREAS OF SHIFTING CULTIVATION

by

B.T. Datiri*

Introduction

Soil and water conservation could briefly be described as the wise use of land and water by adopting a planned management programme of these natural resources so as to prevent their exploitation, destruction or neglect through man's activities. Conversely, as Wrigley (1961) stated, misuse of land is that stage when the soil becomes exposed to the elements of erosion and exhausted by overgrazing. thereby sacrificing its fertility to the wind and the rain. He also pointed out that erosion of the Ethiopian highlands was the source of the legendary fertility of Egypt.

In considering soil and water conservation practices under shifting cultivation, one must first define the term 'shifting cultivation' which embraces a large variety of primitive forms of agriculture. Unesco (1952) defined shifting cultivation as the movements of farmers' settlements as well as the fields the farmers cultivate. Where farmers live in fixed villages or communities and only move their fields, Unesco referred to it as 'land rotation'. The two systems could exist within the same farming community.

Permanent works for soil and water conservation are expensive, and when installed by a farmer they imply a degree of permanence of land occupation without which the investment would not pay a return. Formerly, there was a balance between human population, soil fertility and restricted soil erosion, but today in Nigeria erosion is now much greater as a direct result of the introduction of new cash crops and an increase in the human and livestock populations. All these factors have led to a greater demand on the soil.

Today in Nigeria soil erosion has significantly increased as a direct result of the introduction of new cash crops and a rise of livestock and human population through improved medical knowledge. All these factors have lead to the greater demand on the soil.

Ecological zones in Nigeria

In Nigeria, there are two main ecological zones, forest and savannah, where shifting agriculture is practised. The forest zone is divided into evergreen and semi-deciduous zones, while the savannah zone is divided into original and derived savannah zones. For the purpose of this paper, the Sahel zone, which is limited to the area around Lake Chad in the North-Eastern State of Nigeria, will be treated as part of the original savannah zone. All the zones run in an east-west direction, and in sequence from north to south they are: original savannah, derived savannah, semi-deciduous and evergreen.

The types of crop grown in each zone tend to follow the same pattern of the main vegetation within each zone; all are governed by the rainfall pattern. Farmers in the original savannah zone grow mainly grain and other annual crops such as sorghum, millet, rice, wheat, beans, soyabean and maize, while those in the forest zones grow mainly root and tree crops such as yams, cassava, oil palm, citrus, banana, plantain and cocoa. In the derived savannah zone there is a mixture of those crops grown in the original savannah and the two forest zones.

Differences between the ecological zones and differences between soils result in the cultivation of different crops.

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In general, shifting cultivation is similar throughout the country except perhaps for the tools used which vary in type according to the environment, custom and the crops to be grown. The size of each farm depends on the size of the family, ranging usually from less than one acre (0.4 ha) to about 4 acre (1.6 ha) on the average. In the north where the rainfall is low and the vegetation is mainly composed of short grasses and a few scattered trees, simple tools such as a small hoe are used. Land clearing is, therefore not costly. The crops to be grown are planted on the flat and the first cultivation is done after they have germinated. In the centre of the country where the rainfall is higher, the soils are heavier and the grasses are tall, ridges are made before the crops are planted. This calls for larger farm tools for the preparation of ridges. Further south, where the rainfall is even heavier, and grasses have been almost completely replaced by trees, cultivation of the comparatively loose soil is only possible when the forest has been cleared and the tree trunks have been burnt. In this area only root crops are planted on ridges. Tree crops are inter-planted with annuals until it is no longer economic to do so. The farmer then leaves the tree crops to take care of themselves and moves to new farm land to repeat the process.

Cropping and fallow periods vary greatly in their duration, depending on the crops grown and the type of soil. Other reasons for variations seem to be the direct result of the farmer's family, customs, beliefs and religious practices.

Farmers seldom apply fertilizers to other than certain cash crops which produce some income, but even so the quantity applied may be inadequate or the benefits may be reduced by poor management.

Soil erosion problems

Shifting cultivation as has been described is no longer in equilibrium with the ecological environment. Because of increased population the demand for land has increased, and consequently the cultivated land is not left long enough under fallow to regenerate fertility nor are enough fertilizers applied to balance the large amounts of nutrients removed at harvest by farmers each year. Some farmers own no good farm land and depend on renting farm land for the minimal fees set by their tribe or community. Under such conditions the farmers are only interested in how much produce they can obtain from the land regardless of the consequences. They are free to change landlords when the first land becomes economically unproductive.

As a result of shifting cultivation many steep slopes which used to be cultivated are now deeply gullied and subject to bush fires and wind erosion. The Nanka - Agulu gullies of the East Central State are typical examples.

The soils of the savannah region which generally range from loose to gravelly hard soils, covered with short to medium sized grass vegetation and scattered trees, are often subjected to torrential rainfall of short duration. Depending on the topography, the infiltration rate of the soil, and the type of vegetative cover, such rains are liable to be followed by rapid highly erosive run-off.

Under shifting cultivation when the fields are bare, the erosive effect of early rainfall could be great, more especially where the land is sloping and the area has been previously affected by wind erosion. Cultural practices also affect the extent of soil erosion; the construction of ridges up and down a slope as practised by many farmers has rendered farm land useless for any purpose.

In the forest zone of the south, the soils are generally more permeable and are therefore better able to absorb the high rainfall which is usually evenly distributed over a long period of time. Where there is a protective cover for the soil erosion is not serious. However, erosion becomes serious when large areas are cleared of forest and new crops (trees or annuals) planted in lines that ignore the contours.

The stage of soil erosion reached in Nigeria could be generalized in the words of Paton (1962): ''Red hills stand desolate and the earth has torn away like flesh. The lightning flashes over them, the clouds pour down upon them, the dead streams come to life, full of the red blood of the earth''.

Recommended soil and water conservation practices under shifting cultivation

Permanent engineering structures for soil and water conservation are costly to construct, and timeliness in their installation is clearly important. With regard to areas where sheet erosion had removed much of the top soil, Kohuke and Bertrand (1959) stated that while improved methods of agriculture may increase the productive capacity of a worn-out soil, the same methods would have resulted in much higher yields if the soils had not been impaired in the first place. With this background, the following recommendations for soil and water conservation practices are made:

a) Soil and Water Conservation Practices that could only be applied if subsidised by Government:

Major soil and water conservation works usually have to be installed to protect all cultivable land within a unit area, regardless of the number of farm holdings. Government involvement is necessary because the farmers usually have neither the technical knowledge nor the equipment required. Methods applied in Nigeria with remarkable success include:

1. Flood Control

Used for the protection of farm land which is periodically flooded in the wet season.

2. Detention Dam and Gully Control

Similar to flood control but with the main function of preventing gullying of land below the dam which, otherwise, could threaten a farming community, their land or both.

3. Terracing

Used to regulate run-off water before it becomes erosive in areas of moderate to high rainfall. This method is also used to ensure maximum penetration of rainfall into the soil.

In the construction of terraces, provision must be made for waterways and outlets for the safe removal of run-off.

4. Windbreaks

Windbreaks are belts of trees planted usually on farmland to reduce the wind velocity and thus protect valuable topsoil from being blown away in the form of dust.

The Northern States of Nigeria, especially areas close to the boundaries with the neighbouring countries of Niger and Chad, are frequently affected by north-easterly winds, and areas such as Gusau and Kano have benefited greatly from planting of shelter belts.

5. Ponds and Earth Dams

The erection of small earth dams for the purpose of providing water for humans and/or livestock has been found very useful in Nigeria, particularly for the Fulani herdsmen in the low rainfall areas of the North.

6. Irrigation Dams

Irrigation dams are used to increase agricultural production, especially in the low rainfall parts of Northern Nigeria, and to provide farmers with a sure source of water for agriculture and domestic purposes.

7. Fertilizer

Since fertilizers were first introduced into Nigeria at subsidized rates, the quantity and types used have been increased with great benefit to shifting and settled agriculture.

b) Soil and Water Conservation Measures that could be applied by Farmers

The following simple soil and water conservation practices requiring a cash capital input or heavy equipment, could easily be applied, even under shifting cultivation, if the farmer is taught to do so:

1. Contour farming

Cultivation of crops along the contour, be it on the flat or on ridges, so as to reduce run-off which would otherwise cause erosion.

2. Plant Residues

Plant residues if not liable to harbour pests, may be retained in the field to reduce wind and water erosion.

3. Shadoof Irrigation

A simple primitive wooden structure with a bucket for drawing water is still very useful today in Nigeria for dry season vegetable production along the banks of perennial streams. or close to other sources of surface water.

4. Tree Planting

Trees may be planted on poor eroded areas to stabilize the soil and to provide fuel for sale and family use.

5. Controlled Livestock Grazing

Livestock such as cattle, sheep and particularly goats are frequently the cause of erosion if their number in a given area is not controlled.

6. Mulching

Mulching of cultivated land serves to control erosion in heavy rainfall areas. In low rainfall areas it will also conserve moisture. On decaying, the mulch adds organic matter and nutrients and improves the soil structure for subsequent crops.

7. Tie-ridges

Tie-ridging is a very useful practice in the low rainfall areas by which water in farmland is held between ridges and allowed slowly to enter the soil for use later by the crops.

8. Stop-Wash Lines

These are single, possibly permanent, strips of suitable grass, the purpose of which is to separate and retain much of the soil being carried by the run-off water. The practice is useful when farms are on gentle slopes.

Conclusions

Some major soil and water conservation measures in Nigeria have greatly increased crop yields where they have been applied and farmers now tend to concentrate their farming activities in these areas. As a result, other soil conservation measures have been adopted, and in time progressive farmers may reject shifting cultivation.

Unlike some of the major conservation works, the simple conservation measures take time for their effect to be felt, particularly if all the necessary steps are not taken at the same time. The widespread adoption of soil and water conservation measures under subsistence farming, where shifting cultivation is the accepted way of farming, will require extension workers with both the right expertise and good public relations if these ideas are to be accepted by farmers. Once farmers are convinced and have accepted new ways of agricultural production, these measures soon become part of them. In closing, our advice to farmers on the use of their land should be as Alan Paton (1962) put it: ''Keep it, guard it, care for it, for it keeps men, guards men, cares for men. Destroy it and man is destroyed''.

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INTRODUCTION OF CHANGES IN SHIFTING CULTIVATION AND OF SOIL CONSERVATION INTO PRACTICAL AGRICULTURE

(TRAINING, PRE-EXTENSION AND EXTENSION)

by
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Introduction

Innovations in farming systems, especially when radical changes are introduced, require thorough planning and preparation. Consequently, adequate and realistic education and training of the rural populations as well as the instructors are indispensable to success.

Pre-Extension

Before becoming the subject of extension work, improved or new techniques developed in research stations have to be tested in two ways:

i) by confirmation of their technical efficiency on land formed by the average farmer;

ii) by confirmation of their social and economic suitability to the average farmer.

Such tests are basic elements of a pre-extension phase in a development programme.

The results may lead to modifications, either for technical reasons, e.g. lower or higher response to fertilizers due to different ecological or management conditions, or because of socio-economic reasons, e.g. resentment against too drastic changes or lack of capital for necessary investments.

The degree of intensifications of a farming system is a matter of policy which may be influenced by factors of urgency such as demographic pressure having already exceeded the increase in food production.

Planning of both pre-extension and extension phases requires a careful and realistic approach. Whereas a stepwise intensification appears to provide a good chance for success with relatively limited means and investments, it should be borne in mind that more radical changes require greatly extended services to the rural population ranging from education and training, organization of input and output marketing to the availability of capital for the investments required.

For the execution of the pre-extension phase, pilot schemes organized in key areas would be efficient ways to confirm whether the new techniques can go into the extension phase as they are or have to be modified.

These pilot schemes should be organized and carried out in closest cooperation with research and extension so as to allow the researcher to see the problems connected with the introduction of the techniques developed by him and, if necessary, to find appropriate modifications.

The pre-extension phase would also be appropriate to familiarize the extension staff to be involved in the extension phase with the new techniques and to train them in ther application. Depending on the extent of these techniques it might be appropriate to foresee two categories of extension staff: (i) a number of subject matter specialists who could already have been basically trained during the research phase and (ii) unspecialized staff who would receive an overall training covering all subjects to be introduced. The operation would require a temporary transfer of such staff to the pilot scheme areas, probably in turns as it might be difficult to remove the entire extension staff from other areas. The experience gained during this operation would provide a sound basis for the planning and organization of the following phase.

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Extension

Before the inception of this phase, the plan and provisions for the organization or strengthening of input supply, output marketing and capital investment should be prepared.

Apart from their professional preparation, the extension staff should be spiritually motivated and ready for the action. Depending on prevailing conditions, material incentives for the extension staff will efficiently supplement the spiritual motivation. This also applies to extensionists in general, who usually live and work under less favourable conditions and often lack incentives, thus leading to a deterioration in the quality of the staff and even in the quantity. The extension staff should also be given the necessary equipment, adequate in quality and quantity, to enable them to fulfil the task.

Similar measures should be taken with the farming population. In their motivation the need for innovations should be reasoned and their interest should be promoted. This could be done through information meetings organized on the basis of existing social or administrative structures of various types. As in the case of the extension worker, material incentives help a great deal towards acceptance of new techniques, although care must be taken to avoid over optimism which would have an extremely adverse effect.

Practical demonstrations are the basic and classic weapon of extension. They should be carried out in sufficient number and quality, as a bad demonstration is worse than none. If demonstrations are to lead to acceptance by the farmer, he must be involved to the greatest possible extent, which in turn requires his own adaptation and training.

The organization of field days in connection with the demonstrations have an extremely valuable complementary effect. On field days at harvest the economics of the innovations are the main subject of discussion with the farmers. If a package of innovations is demonstrated, the effects of the various components, especially those requiring relatively higher and recurrent investments, should be demonstrated separately. This applies especially to fertilizers and pest control measures, as farmers often tend to be satisfied with improvements obtained through minimal efforts. The use without fertilizers of high yielding varieties which might not need annual replacement of seed is a striking example.

Another problem connected with demonstrations is whether the choice among different possible improvements should be left to the farmer. Were it so, it could lead to discontentment and/or the complication of follow-up actions and any choice should, consequently, be confined to the pre-extension phase if not altogether avoided.

Finally, if the extension phase is to last for a given period, e.g. five years, it should be the subject of an intensive and nationwide propaganda campaign involving all available audio-visual means. A realistic final target and intermediate targets should be set and all action, directly or indirectly involved, should be concentrated on the target.

Training

The effect of agricultural extension is greatly conditioned by the quality of training of all those involved in agricultural development.

Farmers in developing countries need to adopt new techniques over a relatively short period, to achieve which requires extensionists of high professional competence and outstanding personality. As university studies develop these qualities in the first place, it appears that graduates who are spiritually motivated are particularly required in agricultural extension work. On the other hand, in areas where agriculture is more advanced, farmers who have been in touch with technology from childhood have acquired technical skills which even a graduate would need very long practical experience to attain. Consequently, professional training at this level should closely combine theory and practice.

In many schools of agriculture in Europe it is a pre-condition of student entry to have experienced one or two years of practical agriculture and to have spent at least one semester doing practical work in their discipline. This method leads to better understanding of the problems, even for those later taking up appointments in laboratories or offices. It also facilitates the decision of those who acquire a dislike of the profession during these practicals to turn to other studies.

In lower grade agricultural schools the emphasis is mainly on the practical aspects, but occasionally the teaching staff give disproportionate attention to theory, with the result that extension staff are rather helpless in front of the farmer and have little to 'sell'.

The level of farmers' training depends on their background, but it is generally concentrated on practicals. For young unmarried farmers, training courses of one or two seasons' duration in centres away from their homes might be appropriate, whereas for the others, on-the-spot courses of short duration, possibly repeated, should be organized. Careful selection of instructors increases the chances and degree of success.

POSSIBILITIES FOR ASSISTANCE BY FAO

by

F.W. Hauck*

FAO's mandate for its role in soil development is based on Article I of its Constitution, from which the following may be cited:

The Organization shall collect, analyse, interpret and disseminate information relating to nutrition, food and agriculture.

The Organization shall promote and, where appropriate, recommend national and international action with respect to:

(a) scientific, technological, social and economic research relating to nutrition, food and agriculture;

(b) the improvement of education and administration relating to nutrition, food and agriculture, and the spread of public knowledge of nutritional and agricultural science and practice;

(c) the conservation of natural resources and the adoption of improved methods of agricultural production.

It shall also be the function of the Organization to furnish such technical assistance as Governments may request.

Within the organizational framework of FAO, the Land and Water Development Division, as a part of the Agriculture Department, is responsible, besides its work in water resources and use, for soil surveys and related fields (including Soil Map of the World) and for all aspects of soil development, including soil management, conservation and fertilizer use.

In FAO's short and medium-term plans, the seriousness and magnitude of the problems of soil conservation and traditional forms of land use emphasize the need for accelerated and continuing action programmes aimed at the restoration of lands which have been eroded, and the establishment of preventive conservation measures to combat the potential danger of soil degradation through erosion. New conservation techniques will be continuously developed which are adaptable to different and changing erosion conditions and conservation needs in different countries. Other soil conservation programmes will emphasize the implementation of practical and effective soil conservation legislation to promote agricultural development compatible with wise land use, and the study of the effects of shifting cultivation on agricultural production in face of the intensified population pressure.

FAO's activities in soil development are organized in the Field Programme and the Regular Programme.

Field Programme

The Field Programme works through field projects in cooperation with counterpart organizations in the recipient countries and is financed essentially by the United Nations Development

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Programme and Trust Funds. There are: large-scale projects, employing 5 to 8 FAO experts plus a number of consultants, each project lasting 5 or more years; small-scale projects with 1 to 3 experts usually dealing with specific problems; short-term missions consisting of 1 to 3 specialists and assisting countries, for instance, in preparing a plan for soil development.

In the fields of soil management, soil conservation and shifting cultivation, FAO is at present operating 12 large-scale and 20 small-scale projects. Eight projects are under preparation. Components of soil conservation and soil management are included in another 12 projects dealing with agricultural development in a more general way. It might be of interest that, in addition to these projects, the objectives of which are related directly to the subject of this Seminar, FAO is giving assistance also in 23 projects in soil survey. In soil fertility and fertilizer use, there are at present 25 projects financed by UNDP and 22 projects (FAO Fertilizer Programme) financed by Trust Funds.

The following examples show that in FAO projects dealing with soil development problems emphasis is so far placed on soil conservation matters. However, the problems of shifting cultivation are included increasingly:

In Malaysia, a soil management branch is now being built up with FAO assistance within the Agricultural Development Institute.

In Morocco, a large-scale project assists in organizing a countrywide soil conservation survey, including soil studies and land classification, studies of the factors related to soil erosion, reserach on methods of soil conservation and transfer of useful knowledge to practical agriculture and the development of soil management and soil conservation policy.

In Argentina, a soil conservation programme is being established by a large-scale project which has the following objectives:

(a) To assist the Government in the implementation of a National Soil Conservation Programme, through the establishment of a Soils Conservation Research Centre and the operation of a soil conservation demonstration area.

(b) To establish soil and water management programmes at a national level, through the Soils Conservation Research Centre, including a training programme for local technicians in the planning and application of conservation practices.

(c) To coordinate such activities in the field of an integrated watershed basis.

(d) To organize a field supervision programme.

In Korea, a project includes watershed planning, bench terracing, flood control, pasture and range development, bush farming.

In Botswana, a land development officer is being provided in order to establish a fully localized division of land utilization within the Ministry of Agriculture (OPAS expert). The expert is responsible for drawing up land capability plans and land use plans, for providing advice and extension on general conservation and anti-erosion measures, including the surveying and layout of contour farming schemes and also for dealing with other problems of land utilization.

In Lesotho, a short-term expert on soil conservation has been requested from the country to assist the Government in preparing an integrated plan for catchment stabilization and for farmer education in conservation techniques.

In Ghana, a UNDP project dealing mainly with soil fertility and fertilizer use also covers the establishment of suitable crop rotations and related management practices by the evaluation of different types of rotation and their introduction into practical agriculture. The project also deals with replacement of bush fallow by more permanent forms of agriculture.

FAO teams in soil management, conservation and development projects include experts, for instance, in: soil management (project manager), soil fertility, soil conservation, soil physics, soil chemistry, general agronomy and farm management. They may also include short-term consultants, for instance on soil conservation legislation, watershed management and specific crops.

Considering FAO's present activities in shifting cultivation and soil conservation in Africa, it would appear that, in accordance with the wishes of the countries and with the practical needs, an intensification of this type of work would seem highly desirable.

Regular Programme

The main purpose of the Regular Programme is to give technical support to field projects and additional advice and assistance as requested by the countries. These activities, financed by FAO's regular budget, are carried out by the expert staff in FAO Headquarters, in cooperation with the regional and project staff, with other organizations and with the help of consultants. They include:

- Seminars, consultations, conferences.

- A Consultation on Soil Degradation Problems was organized in 1971 and another, in cooperation with the United Nations Environment Programme, is being planned for later this year. The problems of shifting cultivation and soil conservation have also been discussed at Regional Soil Fertility Conferences, for instance in Addis Ababa in 1970.

- Missions: FAO services, for instance, a Regional Commission on Land and Water Use in the Near East, which is also interested in problems of soil conservation and shifting cultivation.

- Publications related to the subject of the Seminar. FAO has published recently Soils Bulletins on Land Degradation and Legislative Principles of Soil Conservation, and earlier a Guide to Sixty Soil and Water Conservation Practices.

- Soil data processing: FAO is developing a computerized soil data processing system which will also be made available to interested countries and which will facilitate the storage, analysis, evaluation and exchange of soil data with special reference to soil development.

- Environmental problems: Following the recommendations of the United Nations Conference on the Human Environment, held in Stockholm in June 1972, FAO envisages in its programme among other items, a global study of soil degradation hazards and the promotion of international cooperative research on soil capabilities and conservation. Support of national programmes of conservation of soil resources as well as the necessary action in soil regeneration are also included in the programme. In all environmental matters, FAO cooperates increasingly with the newly created United Nations Environment Programme (UNEP).

How to obtain assistance from FAO

The starting point for receiving assistance from FAO, as well as from other UN organizations, is a request from the country which is submitted through established channels.

The idea for the request within the country can come from different sources, for instance from an officer working in soil fertility, research or extension or from a high ranking officer in the Ministry of Agriculture. The request is usually discussed at an early stage with representatives of potential aid-giving organizations, for instance, with the FAO Country Representative and with FAO experts in the country. After the country has expressed its intention to ask for an assistance project (e.g. by a Letter of Intent to FAO or UNDP) a preparatory mission can be sent to the country. The mission assists the country in formulating the request in detail, including the technical, organizational and budgetary aspects.

As far as UNDP projects are concerned, it is also important to discuss with the UNDP Representative at an early stage how the project would fit in with the jointly established UNDP country programme, which contains not only the operational guidelines but sets out also the availability of funds within the Indicative Planning Figure (IPF). IPF indicates the amount of funds reserved for the country by UNDP for development projects for a period of five years. Once an understanding of the project, under the circumstances explained, has been reached, the respective authority (usually the Ministry of Agriculture, but in some countries the Planning Commission) submits the request to the local UNDP office for final approval by UNDP Headquarters, New York, with a copy to the respective UN Agency which in the case of agricultural projects is FAO.

When planning the request for a project it should always be remembered that in addition to the contributions requested from UNDP or FAO, the request should also give details of the counterpart contributions of the country to the project. This calls for provision to be made in the budget of the Ministry of Agriculture well in advance. Generally speaking, the development of an assistance project is a time-consuming procedure which might take up to two years or more from the first discussion of the idea to the actual start of the operations. The importance of the time factor should, therefore, not be overlooked.

Possible follow-up activities to this Seminar as part of FAO's assistance are:

- Wide distribution of the report, proceedings and country reports of the Seminar.

- Where requested and possible, inclusion of elements of shifting cultivation and soil conservation into current FAO assisted projects.

- New FAO assisted projects (small-and large-scale) on the subject, as requested by the countries.

- Assistance by short term consultant missions (one or more consultants) for instance for preparing plans for changes in shifting cultivation and soil conservation fellowships.

(Note: field projects, consultant missions and fellowships are elements of the country programme).

- Advice by officers of FAO's Regional Office for Africa and FAO Headquarters.

- Another Seminar on Shifting Cultivation and Soil Conservation after a certain period of time, subject to the availability of funds.

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1. Soils of the arid zones of Chile, 1965 (E**)
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3. Guide on general and specialized equipment for soil laboratories, 1966 (E**)
4. Guide to sixty soil and water conservation practices, 1966 (E**)
5. Selection of soil for cocoa, 1966 (E** F** S***)
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Availability: January 1978

E — English	* Available
F — French	** Out of print
S — Spanish	*** In preparation

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ISBN 92-5-100393-9

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