Agro-forestry in the African Humid Tropics

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An identity and strategy for agro-forestry

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Abstract

The fact that agro-forestry land-use systems are location-specific makes it difficult to design models adapted to all circumstances. It is therefore proposed to pursue the development of new methods applicable to the description of both existing and conceptual land-use systems. The aim is to identify constraints that can potentially be overcome by the application of an agro-forestry approach.

It is also argued that the development and implementation of agro-forestry systems may benefit from the institutionalization of such an approach to land use.

Introduction

Agro-forestry is the new word for an age-old practice—that of having trees in the agricultural landscape. It has become more refined in meaning and now connotes trees with a purpose such that the land-use system yields both a food product and a tree product, each meeting the needs of the user of the system. At the same time, the agro-forestry system should be stabilizing in its impact on the environment and stable in its output of products.

The modern concern for agro-forestry arose among the foresters. They saw the forested lands being threatened by a growing population demanding more food and hence by farmers seeking more land upon which to grow that food. Their reaction was rational—find a way to accommodate some aspects of agriculture within forestry. In contrast, conventional agriculture, and here I include both crop and animal agriculture, has made virtually no contribution to alleviating the concern for the pressure that its activities are placing on the non-agricultural tree-covered areas.

To leave the concern and the development of agro-forestry with the foresters would deny to it the body of knowledge that exists outside forestry, while to delegate to agriculture the responsibility for agro-forestry would not correct the situation but merely reverse the wrongs and accomplish nothing. The need is to institutionalize agro-forestry; to establish it independently of both agriculture and forestry so that it can develop its own concepts, body of knowledge, and principles, not engulfed by either of its antecedents but able to draw upon their resources as is deemed necessary. The International Council for Research in Agro-forestry (ICRAF) is such an institution.

There is ample precedence for the efficacy of institutionalization. Statistics, for instance, with its approach to design and analysis of experiments, began to emerge from mathematics when R.A. Fisher started his classic work at Rothamsted: he was, literally, the institution. Genetics, likewise, did not establish a clear identity until it separated from biology, be it botany or zoology. In many universities today that separation has not been effectively concluded. Agro-forestry is much less clearly defined than either statistics or
genetics and is thus even more in need of its own institution. I hasten to add, however, that if in establishing the institution—whether agro-forestry or genetics—one divorced it from all those areas that have relevance to it, then that would be a retrograde step.

**The Systems Approach**

The establishment of the institution is merely the first step in establishing an identity; the next critical move is to develop the focus, the raison d'être, the strategy. With this, one would then develop the approach to the problems and the activities deemed most appropriate to provide answers. Further, the kind of staff would be identified and the targets for the activity would become clearer.

The key word is systems. Agro-forestry is a system of land use. It is, at the same time, a food and tree-product production system. It is not a single commodity nor a single management practice but rather a complex interacting set of subsystems, components, and practices suited to a particular environment and needs.

The systems approach implies, first, that one does not engage in piecemeal consideration of problems, and, second, that there is an analytic rather than merely intuitive approach to land-use systems. The analytic approach is the diagnostic method that enables one to analyse the state of the system, to identify the critical subsystems, and to determine the problems or operative constraints as well as the potentials for improvements of system performance. From the diagnosis will then flow the capability to identify existing agro-forestry technologies that are appropriate to system needs. From it will flow the definition of the research and development problems that must be solved if one is to generate new agro-forestry technologies that possess the specific capacities needed to improve system performance. The International Council for Research in Agro-forestry (ICRAF) has adopted this approach and aims to focus agro-forestry research and development on real world problems and conditions.

**The Cycle of Development**

The basic logic of ICRAF's research programme is dictated by the cycle of development (fig. 1). Each phase in the cycle embraces a series of research activities. Each situation to which the cycle is applied will require a different mix of the particular activities in order to complete the cycle. The cycle takes its starting point from the inescapable conclusion that the process of developing a solution to a problem begins with the capacity to analyse the problem, in this case the land-use system in which agro-forestry technology is deemed to have a role. The diagnosis of existing land-use systems is aimed at discovering the agro-forestry-related constraints and potentials. This is the deductive, analytic, or diagnostic part of the technology development cycle.

One of the main conclusions to come from the agricultural development research of the past decade is that the conditions under which the majority of farmers operate often bear little resemblance to those on agricultural research stations, with the consequence that, unless a special effort is made to take account of these conditions, the resulting technology is often inappropriate for the majority of farmers. To identify the full set of operant constraints and potentials that govern decision-making with regard to land-use practices in a given area, it is essential that the multidisciplinary expertise of a team of biological and social scientists be assembled to diagnose factors ranging from climatic constraints to cultural values.

One important outcome of the first phase of the land-use system diagnosis will be the identification of land-use subsystems. In this effort, ICRAF is developing a "basic needs" approach to the identification of production subsystems in terms of output categories that answer the universal human need for food, energy, shelter, cash, and community integration. In this way it is ensured that what is analysed is highly relevant to people's needs.

How it is analysed, in the second phase of the diagnostic research, is also a subject of intense methodological interest. Agro-forestry, by definition, is equally concerned with production and conservation. In this respect it differs from most other branches of plant science, in which conservation aspects of production systems are frequently of secondary, if any, concern. This difference in purpose
requires a difference in methods. ICRAF is now exploring analytic techniques to diagnose the performance of basic output subsystems in terms of both their productivity and their sustainability, thus encompassing both aspects of its diagnostic objective.

FIG. 1. The Cycle of Technology Development

The final output of the diagnostic part of the cycle will be a set of general design specifications for agro-forestry technologies in terms of functional or end-use requirements. These then become the primary input for the inductive, synthetic, or R&D part of the cycle of agro-forestry development.

Two courses of action are possible in the first part of phase three. One is to identify existing agro-forestry technologies that are generally appropriate to local needs and that can be used directly to bring about an improvement in the immediate situation. The other is to generate, through research, new technology that is specially designed to meet the diagnostic specifications. These two courses of action are not mutually exclusive; in fact, the most likely situation will be that in which a temporary improvement is gained by the use of existing technology while new technology is being developed. The cycle of development is a continuous iterative process. One seeks the best technology but settles for one that is merely better, hoping to continuously improve it.

Phase four in the cycle of development encompasses the research necessary to synthesize a new land-use system that incorporates the new agro-forestry technology into the existing pattern of land use in a manner consistent with local and regional production purposes and constraints. Finally, the cycle is completed by a new round of diagnostic research to identify the set of constraints and potentials now operating. These must be addressed by a new round of technology generation if the system is to be further optimized. The four phases of the cycle of technology development define the scope of ICRAF's research activities. Each situation in which the cycle is applied will require a different mix of the particular activities to complete the cycle. An interdisciplinary approach will be pursued throughout (fig. 2).

Research Activities

The implication of the adoption of the strategy is that there will be two distinct but complementary research activities. These are:

- The development of the diagnostic capability for the identification of agro-forestry needs and potentials. This will be done through on-farm studies of the system used by the smallholder. This will also treat "communities," particularly when land use and environmental impact is of major concern. This research will initially be carried out in Kenya but later extended to other countries.
- The identification of methods to develop new agro-forestry technology. These may range from methods of evaluating multi-purpose trees to design of experiments to test new systems. This research will be carried out at the Machakos field station in Kenya.

The appropriate relationship between these two activities is for the diagnostic research to identify the problems of highest priority for the development of the methodology. There will undoubtedly be some technology generated as a consequence of this research activity but that is not the objective per se; rather it is a spin-off from the development of the methodology.

Agro-forestry, as implied, is both a system of land-use/resource-management and a production system with multiple outputs of food products-plant and animal-and tree products that may range from food to fuel. When fuel is the aim, the target will almost invariably be the farmer: generally, the small farmer.

The technology will most likely be relatively labour-intensive. The objective, however, is not to develop a low-input system but rather one that uses inputs efficiently and achieves a stable and sustainable output.

Where one is dealing with an agro-forestry solution as a resource management/land-use system, the target goes beyond the individual user. Thus, where an agro-forestry system is deemed to be the solution for water/erosion control on sloping land, then the catchment area becomes the target. The individual farmers
will use the technology, but the complete area must adopt it if they are to benefit. Inherent in such a situation will be the individual farmer's food/tree-product production but all predicated on the primary objective of resource management.

Mention has been made of trees in the landscape. This is probably a more rational approach than to consider "trees in crops." The latter will tend to force one to think in terms of tree crop mixtures that, in the majority of cases, will result in lowered productivity of the crops. In contrast, to consider trees in the landscape will tend to accord to trees the dominant role where that is necessary and to crops the dominant role where that is appropriate. One would then seek to find the relationship that defines the role for each, yet achieves the stability that is sought and the productivity that is needed.

Institutionalization

Finally, I return to the question of institutionalizing agro-forestry. I believe it is important to seek institutionalization at both international and national levels. At the international level is ICRAF. At the national level, one is concerned not only with the generation of appropriate agro-forestry technology but also with the testing and transfer of that technology to the user. In this task, agro-forestry will draw on many areas of knowledge in forestry and agriculture as well as many disciplines basic to them. In addition, it must draw on the social sciences if it is to become relevant to the needs of its users. There are many examples of recent institutionalization, most prominent being the creation of ministries of energy. Why not of agro-forestry? Surely the urgency of the problems that face us demands effective action. ICRAF will seek national institutions with which to co-operate. Which shall they be? I am not seeking a means to proliferate institutions but, rather, a way to place agro-forestry as a major actor in the struggle to meet the increasing food and fuel demands for human beings while minimizing the impact on the environment.

FIG. 2. Implementation Flowchart for the ICRAF Research Strategy
Tree crop farming in the humid tropics: Some current developments

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Abstract

Tree crop farming systems in the humid tropics are in an active state of development. In Sri Lanka, Nigeria, and Latin America, attention is being devoted to improvement of traditional tree food crops. In larger-scale rubber and oil palm cultivation monoculture is still the norm, but in the small-farmer sector there is increased interest in intercropping with food crops. In coconut, the introduction of high-yielding hybrids, complemented by the development of multicropping systems, is leading to a major upward revision of this crop's potential. Studies of taungya farming have confirmed the value of food cropping in young forest tree crops.

So far research has concentrated on the commodity crops and many lessons have been learned which could be applied in the future development of agro-forestry.

Introduction

Spurred by increasing social, population, and economic pressures, tree crop farming systems in the humid tropics are in a state of very active development. In the commodity sector, rubber, oil palm, coconut, and cocoa plantations are being extended; there is greater use of high-yielding material, more productive methods of management, and shorter replanting cycles, together with increased interest in intercropping. In the traditional multicrop farming sector, there are attempts to establish more productive crop mixes, and the improvement and cultivation of food tree crops are being encouraged. So far, the bulk of detailed research on tree crops has been concentrated on commodities, and many lessons have been learned of possible application in the production of forest and food crops.

Traditional Tree Crop Farming Systems

The traditional farming system of the humid tropics typically involves, in small plots of not more than a few hectares, a mix of trees in association with a variety of perennial and annual crops. Together, they provide food and income for the smallholder farmer. In Indonesia, there is the homestead farm, with multistoreyed crops: the top storey of coconut, middle storey of cloves, citrus, cinnamon, jackfruit, bananas, and pepper, and ground storey of ginger, groundnuts, maize, patchouli, cucurbits, and others. In the West African compound farm, the tree component includes oil palm, coconut, cocoa, grown with an understorey of cassava, plantains, yams, groundnuts, and vegetables (Lagemann et al. 1975).

Perhaps the most intensive tree cropping system is found in the Sri Lankan Kandy gardens. These are small farms based on a close association of coconut, kitul, and betel palms with cloves, cinnamon, nutmeg, citrus, mango, durian, jackfruit, rambutan, and breadfruit, with a lower storey of bananas and pepper vines, and a peripheral ground storey of maize, cassava, beans, pineapples, and others, often supplemented by an outside field of paddy rice (McConnell and Dharmapala 1978).

Such gardens provide the farmer with a mix of food and cash crops that can offer a large degree of self-sufficiency. Harvests and consequent income are dispersed throughout the year and provide greater stability than is possible with only one or two annual crops. Furthermore, the mix of trees offers almost complete protection to the soil, sustains the nutrient cycle, and eliminates the need for cultivation implicit in the production of annual food crops.

In Sri Lanka, a major programme is under way to develop such gardens on neglected and abandoned tea
areas on erosion-susceptible land (The World Bank Tree Crop Diversification Project, Tea, 1). The old tea bushes are slashed heavily, and then planting holes are dug to accommodate a mixture of coconut, cloves, nutmeg, durian, rambutan, avocados, breadfruit, mango, jackfruit, coffee, and pepper. House plots are established at the same time to provide an area for vegetable production and accommodation for a milk cow. Where possible, improved varieties of the different crops are used, and, eventually, the productivity of these plantings should be high compared with that of traditional gardens where only a proportion of the crops yields at any appreciable level.

**Food Trees**

The humid tropics is the home for many hundreds of potentially important food trees that have traditionally provided starches, sugars, proteins, oils, salts, and vitamins to indigenous peoples. In some territories, a limited number of fruit species have been subject to selection and propagation for organized production, but the potential of other species as suppliers of basic food stuffs has been largely ignored. With increasing population pressures, however, and a greater realization of the limitations in the cultivation of crops such as maize and rice, more attention is now being paid to these crops.

Particularly noteworthy is the work in Nigeria, where Okafor (1977) has been developing vegetative propagation techniques for Irvingia gabonensis (African mango), Treculia africana (African breadfruit), Pentaclethra macrophylla (African oil bean), and Chrysophyllum albidum (star apple). Buddings of the first two species have produced viable fruits in 3.5 and 4 years, respectively. Acceptance by the local population has been good. (See the paper by Okafor in this volume, pp. 103-107.)

A similar process is beginning in Brazil, with Brazil nuts (Bertholletia excelsa), guarana (Paullinia cupana), and the pupunha palm (Bactris gasipaes) all being brought into improvement programmes and tested in mixed cropping regimes (Watson 1980). In Latin America the pupunha or pejibaye palm may be particularly important. This palm is indigenous to the entire humid tropical zone of Central and Latin America and traditionally has provided a staple food for Amerindians. A great range of genotypes exists, producing fruit with various levels of starch, protein, and oil; palmitos (palm hearts) are obtained from young basal shoots, and the wood is of value for parquet flooring and production of canes, fishing rods, etc. Some 300 ha of small plantations exist in Costa Rica, and there are plans to expand this to 1,000-2,000 ha producing palmitos for export. Work on propagation and selection is under way in both Brazil (Arkcoll 1979) and Costa Rica (Urpi 1979), and precocious fruiting at age two years has been recorded. Some fruit yields have been as high as 35 t/ha a year, and, if they can be maintained at this level in large-scale plantings, this palm may become a major staple food for the tropics. As such, and in common with other food trees, it would have major advantages over annual food crops. It can be sown directly into uncultivated land and be kept in continuous production for many years without any soil cultivation, thus eliminating one of the major limitations facing the small farmer of the tropics.

**Commodity Plantations**

With commodity crops, operators in both the public and private sectors face great pressures; in many areas there is a shortage of labour for plantation operations. Costs for labour, land clearing, and crop establishment are rising, yet prices must remain in line with competitive materials. Increasing financial pressures and market fluctuations must be offset by great flexibility and sophistication in cropping practices. To improve productivity, farmers must increase inputs and accept the consequent additional technical and administrative problems. A similar situation is likely to be encountered in the development of agro-forestry schemes.

**Rubber**

In rubber, the main drive toward increased productivity is for a shortening of the time before the tree reaches tapping size. Measures include use of advanced planting materials, leguminous groundcovers, and fertilizer applications based on a diagnosis of the local soil requirements. Also used are highyielding materials, chemicals to stimulate latex flow, and quicker replanting schedules that allow advantage to be taken of improved planting material as it becomes available (Lim et al. 1973; Abraham 1978; Mohamed...
Intercropping with food crops is possible in the early years of establishment of a rubber plantation but is not favoured in the large-scale operations because of management problems. In such cases, local food supplies are obtained from areas set aside for the purpose: house plots, ravine and "waste" areas, or paddy fields running through the rubber areas but unsuitable for the tree crop.

In the smallholding sector, however, intercropping has been a traditional practice, with pineapples, bananas, cucurbits, and others as cash crops, and with maize and upland rice for subsistence. Data are available from West Africa (Mellis 1978), Malaysia (Wan and Chee 1976; anon.1973) and Thailand (Templeton 1974; de Vries 1974; Speirs 1974; anon. 1974) but possibly the most comprehensive are from Indonesia by Reed and Sumana (1976). They quote the results of a survey of 100 farms in an organized smallholder development scheme (NSSDP), and a further 20 independent farmers from a local village, Babussalam. All farms in the NSSDP had 1 ha of rubber planted at a density of 500 trees/ha intercropped in the wet season but only a portion intercropped in the dry season.

Yields of wet-season rice and rice interplanted with maize were satisfactory, but there was a great deal of variation between farms. The average yield of maize in 45 NSSDP blocks was only 462 kg/ha of rubber, whereas yields of 1.52.0 tonnes should have been possible. The average yield of green gram (Phaseolus aurea) was 261 kg/ha in the NSSDP blocks and only 114 kg/ha at Babussalam. Yields of 400 - 600 kg should have been possible. Reed and Sumana calculated that, to break even, the farmers would need maize yields to rise to 942 kg/ha, rubber yields to 1,077 kg/ha of intercrop, and, for green gram, in Babussalam and NSSDP, respectively, to 449 and 342 kg/ha of rubber. These levels should be achievable if the farmers use good-quality seed and adequate quantities of fertilizer.

At the Aek Nebara smallholder development scheme in Sumatra, it has been shown that, with central assistance involving mechanical cultivation of the interrow areas, large-scale intercropping with rice can be successful. In this scheme, over the years 1974-1977, the area of rubber intercropped annually with rice rose from 447 to 8,133 ha for a total production of 25,555 tonnes, with an average yield of about 1,500 kg/ha in the later years (Matondang and Rangtuki 1978). Even this scheme was not without its problems, however; at the end of rice cropping, the smallholders left the area to cultivate food crops elsewhere, and a massive lalang (Imperata cylindrica) invasion developed that threatened the rubber crop and required extensive use of herbicides.

This incident highlights a problem that is likely to occur with the intercropping of rubber and other long-term tree crops: the main crop becomes neglected in favour of the food crops. In development schemes in the Ivory Coast, for example, there is a policy of rubber monoculture with leguminous creepers used as groundcovers. However, farmers unfamiliar with rubber have insisted on intercropping with tomatoes, aubergines, maize, and even sugar cane.

The soil is sandy and infertile, and the results will be that rubber growth will be poorer than expected, the time until tapping will be extended, and the viability of the project as a whole will be affected.

In Brazil a major new planting programme is under way with rubber, but few of the farmers are familiar with plantation rubber and they now are testing systems that stem from alternative cropping traditions. At Belem, for instance, where vine pepper has been traditionally grown as a monoculture, the crop became badly affected by Fusarium, Phytophthora, and nematodes. In an effort to maintain production, trials have been carried out on the intercropping of pepper with rubber: disease incidence is said to be lower but the economic potential of the association has yet to be assessed (Viegas et al. 1980).

In jungle colonizing schemes in north-west Brazil, in an attempt to gain early income and supplement official subsidy payments, farmers are intercropping rubber with upland rice, maize, beans, and pineapples, as well as with coffee. Formal experiments are under way involving coffee grown in different spacing combinations with rubber, and these seem reasonably promising. But, in the farmers' fields, competition between the annual crop, coffee, and rubber, compounded by the absence of fertilizer application and general know-how, indicates that any short-term advantages are unlikely to offset the
long-term loss in productivity of the rubber.

**TABLE 1. Projected Total Income per Hectare of a Typical Crop Association with Rubber (Ouro Preto, Brazil) (in cruzeiros*).** Crop association: rubber with coffee and rice-beans, maize-beans rotations in the 1st, 2nd, 3rd, and 4th year respectively after planting.

<table>
<thead>
<tr>
<th>Year after planting</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sacks/ha</td>
<td>Coffee</td>
<td>-</td>
<td>15</td>
<td>35</td>
</tr>
<tr>
<td>(Cr/ha)</td>
<td></td>
<td>(30,000)</td>
<td>(75,000)</td>
<td>(50,000)</td>
</tr>
<tr>
<td>Sacks/ha</td>
<td>Rice</td>
<td>30</td>
<td>-</td>
<td>15</td>
</tr>
<tr>
<td>(Cr/ha)</td>
<td></td>
<td>(15,000)</td>
<td>(7,500)</td>
<td></td>
</tr>
<tr>
<td>Sacks/ha</td>
<td>Beans</td>
<td>6</td>
<td>4,5</td>
<td>3</td>
</tr>
<tr>
<td>(Cr/ha)</td>
<td></td>
<td>(24,000)</td>
<td>(18,000)</td>
<td>(12,000)</td>
</tr>
<tr>
<td>Sacks/ha</td>
<td>Maize</td>
<td>-</td>
<td>25</td>
<td>-</td>
</tr>
<tr>
<td>(Cr/ha)</td>
<td></td>
<td>(17,500)</td>
<td>(7,000)</td>
<td></td>
</tr>
<tr>
<td>Total Cr/ha</td>
<td></td>
<td>39,000</td>
<td>65,500</td>
<td>94,500</td>
</tr>
</tbody>
</table>

* UN rate of exchange in July 1979 was: US$1 = Cr 26; in July 1981: US$1 = Cr 87.

A common practice in the colonizing schemes is to rotate rice with maize and beans, between the coffee and rubber. The income from a typical mix of these crops, over the first four years after the rubber was planted, has recently been estimated at 264,000 cruzeiros per hectare (approximately US$7,000) (table 1). Such an income is likely to be dependent, however, on the co-operative efforts in several holdings, because there is a labour shortage in the area. Moreover, visual observation of typical rubber in the area suggests that at least eight to nine years are likely to be required before tapping can begin, so there must be serious doubts over the viability of mixed cropping under the local conditions.

**Oil Palm**

The great bulk of plantation oil palm is grown in monoculture, and maximum productivity is ensured by use of high-yielding materials, assisted pollination, and heavy fertilizer programmes. In West Africa the oil palm is an important constituent of the compound farm and would need to be incorporated in any mixed cropping development in the area. It has been shown that on good soils, intercropping of oil palm with food crops is quite possible and may even be advantageous. Sparnaaij (1957) has described how, in one major experiment, intercropping for as long as possible with a mixture of yams, maize, and cassava, followed by cocoyams as the palm shade developed, gave a net increase in yield of palm fruit as well as significant production of the food crops. Intercropping stimulated palm growth in the early years after planting and thereafter gave increased fruit production for 12 years of harvesting.

Soil fertility levels, however, impose some limitation on the potential for intercropping in oil palm. In one experiment at Nkwele in eastern Nigeria, on a degraded soil, continuous intercropping with yams and cocoyams was included as one treatment, with household waste and other fertilizer materials applied in the second, fifth, and seventh years after planting. In the first three years of production the continuously intercropped plots yielded twice as much as the control plots, but the effect was not lasting. Whereas the yield in the control plots continued to rise slowly, that for the intercropped treatment declined.

It would seem that the small nutrient reserves in the soil and the original vegetation, which were released by the clearing and cultivation for arable cropping, were quickly exhausted. As a result, soil fertility dropped to such a low level that the intercropped palms, although much taller and better developed than the control palms, could not maintain their yields.
The conclusion drawn from these experiments is that intercropping of oil palm is perfectly feasible on the good soils (and so is compatible with local traditions), but that on poor soils there is a clear risk of nutrient exhaustion and eventual decline in productivity of the palms.

**Coconuts**

Traditionally a subsistence crop with low input, coconut is now moving into a phase of active development. The productivity of old stands is being raised by the introduction of intercropping, and new hybrids, the progeny of crosses between Asian dwarf palms and certain West African and Asian tall varieties, show promise of bringing the profitability of coconut up to that of oil palm.

Coconuts are particularly suitable for intercropping by the small farmer. In the early years after planting, and at about 812 years when shade lightens with increase in height, the palms do not fully utilize the soil, water, and light resources available. Accordingly, intercropping has been traditionally practiced in some parts of Indonesia, Malaysia, Sri Lanka, and India, and formal studies on cropping combinations have been carried out in India (Nair et al. 1975).

Crops tested included tuber and rhizome species, upland rice, cucurbits, bananas, and pineapples. Most promising were the rhizome species, but performance of pulse crops was not good, probably because of inadequate light penetration. Among perennial crops, cocoa, cinnamon, nutmeg, cloves, and peppers grew well, with cocoa showing the greatest promise.

The beneficial association of cocoa with coconut has been recorded elsewhere and is probably due to weed control and improved nutritional conditions following introduction of the cocoa. In Malaysia the cocoa-coconut combination is considered to be the most profitable of all crop combinations (Yaacob Tunku Mansur and St. Clair-George 1979) and is being adopted rapidly by both the estate and smallholder sectors.

Intercropping of coconuts will present some of the same limitations as those with oil palm, but the coconut is more adaptable than the latter and has a much wider geographic application. For instance, coconuts are often grown on sandy coastal soils where little else that is profitable will grow. Under these conditions, cashew, passion fruit, jackfruit, and guava may provide suitable middle storey crops (Denamany et al. 1978), and cattle and sheep may be grazed successfully on the thin pasture that develops. With improving soil and moisture conditions, cropping intensity can be increased until peak productivity is reached, as with the cocoa coconut combinations of Malaysia, which are generally sited on fertile, marine clay alluvium.

Of particular interest to agro-forestry is that coconut traditionally has furnished fibre, leaf, and wood for a range of local cottage industries. In the Philippines a large-scale replanting programme in coconut has provided the stimulus for the design and production of saws capable of handling large quantities of the tough coconut wood, which hitherto was wasted material. Similarly, intensification of the Malaysian rubber industry has led to the use of rubber timber for charcoal, construction, and household and ornamental articles.

**Cocoa and Coffee**

Coffee production has stabilized in general, because of fear of over-production, and the only technical development worthy of mention is the production of "arabusta" hybrids and of rust-resistant varieties in Latin America. In cocoa, high yields are sought by use of selected hybrid seed, and in preliminary fashion by the development of high-yielding clonal material. Both crops are often grown together with shade crops, with yield being very dependent on incident light.

Of particular interest is work in Costa Rica studying the local traditional practice of growing cocoa, and particularly coffee, in association with the leguminous tree "poro" (Erythrina poeppigiana) as a shade and mulch-providing tree, together with the naturally regenerating timber laurel (Cordia aliodora). Caturra and other low-growing varieties of coffee are normally planted at about 7,000-8,000 plants/ha, with taller-
growing varieties at 3,000-4,000 plants/ha. The poro shade trees are planted at about 200 trees/ha, with laurel occurring as self-sown trees at densities of up to 300 trees/ha. This combination proves highly compatible; the poro is pruned twice a year, with slashed branches and leaves returning nitrogen of up to 80 kg/ha at each pruning (Molleapaza 1979). The laurel is a fast-growing tree and is self-pruning; it has a straight trunk with a narrow, open crown. Although it does not produce heavy shading, its roots will compete with coffee. It is a valuable timber tree, and, with the natural forest now distant from the cocoa-coffee areas, timber costs are high, so that the value of annual production by typical stands of laurel is estimated to be US$644/ha (Combe and Gewald 1979). The trees are generally cut in small numbers as the farmer requires, either for sale or for construction use.

Other tree species often found within the coffee plantings of Central America, at times growing as living fences, along steep banks or in hedges, and used for construction or firewood, are Alnus acuminate (a nitrogen-fixing tree which is also planted with pastures in the highlands), Inga spp. (a legume which produces shade and fuelwood), and Erythrina berteroana, E. costaricensis, and Gliricidia sepium (all of which are used for live fence posts and fix nitrogen). Laurel (Cordia alliodora) and Spanish cedar (Cedrela odorata) are often found and tended in coffee and cocoa plantations or in pastures, and they are both very valuable timber trees. The pejibaye or peach palm (Bactris gasipaes or Guilielma gasipaes) is also included for food and shade. Work is under way at CATIE in Costa Rica on all these combinations, seeking to determine the interactions of species and so help to develop optimum combinations.

**Taungya Farming**

The taungya system of forest establishment is practiced in many areas of the humid tropics, particularly in the Far East, with teak plantings, and in West Africa, with Gmelina arborea Except that the system operates on a more extensive basis, it has many similarities to intercropping systems with rubber, oil palm, or coconut, with labour cultivating annual food crops in the interrow and helping to keep the plantation free of weeds.

Ball (1977) has detailed the Nigerian system and estimates that whereas direct planting with no food crops may cost the Forestry Department N525/ha (1 naira = US$1.8), with traditional taungya, when food crops are grown and belong to the farmer, costs may be reduced to N212.5/ha. If the Department retains the food crops and merely pays the farmers for their labour, costs are further reduced to N117/ha (see the more recent paper by Ball and Umeh in this volume, pp. 72 - 78).

In Costa Rica, CATIE staff have been studying taungya systems since 1962 and conclude that production of a food crop during the first one to two years of tree establishment can offset substantially the costs of reafforestation, particularly if fertilizers are not used and if high value annual crops (maize and beans) are grown (Combe and Gewald 1979).

In applied work from Surinam, Vega (1979) also determined that the growing of food crops in the early years of establishment is of real value but distinguishes between schemes run with farmers owning the food crops and those run under the control of a state service with the farmers acting purely as paid workers. He supports Ball in concluding that the latter is the more economically satisfactory alternative for the state.

There is an interesting analogy to this from the commodity sector in Malaysia, where the Federal Land Consolidation and Rehabilitation Authority has been running land development schemes. They have found that in peripheral areas with relatively low infrastructure, an allotment of 4 ha of rubber per settler is necessary to achieve a satisfactory level of income. This amount, however, is more than can be handled properly by family labour, at least in the establishment phase, and accordingly it is recommended that the rubber be managed on a shared basis, with the family effectively receiving a wage for their labour rather than a land entitlement (Ti 1977, Mustapha Juman and Gan Teng 1980). Other peripheral areas of tree crop development, such as occur in a number of territories, could conceivably be candidates for the same treatment.

**Agro-forestry and Its Development**
In the whole spectrum of farming systems of the humid tropics, ranging from primitive shifting cultivation to the intensive commodity crop plantation, traditional taungya farming perhaps represents the first step towards formal cropping, and agro-forestry its updated and more intensive development. With intensification, inputs and production will both rise, and agronomic and management problems must be expected to increase in proportion. Some lessons that the commodity sector has learned will be of interest in this respect.

In the first place, management can only deal competently with a small number of main crops. The provision of high-yielding material, development of nursery techniques, planting maintenance, and harvesting schedules are all simplified by concentration on a few planting materials.

Care in the establishment phase, particularly in the degree of shade permissible, the use of fertilizers, and maintenance of weed control, can exert a lasting beneficial effect on the main crop. The need for fertilizer applications sufficient to supply both production and immobilization requirements by tree crops is of major importance, particularly during the years of establishment and on poor soils (Watson 1964; Baule and Fricker 1970; Ng 1977; Sanchez 1979).

The use of leguminous groundcovers during the early years of establishment of a tree crop can have major beneficial effects on soil conditions and tree growth, while at the same time permitting significant savings in nitrogen fertilizer use (Soong and Yap 1976; Ng 1977). However, the cultivation of short-cycle leguminous food crops is unlikely to confer such benefits because they require complete fertilizer applications, including nitrogen, to produce satisfactory yields (Oelsligle et al. 1976).

To obtain satisfactory production of food crops in the interrow areas, without damage to the tree crop, the secondary crops must be kept well away from the young trees; improved varieties should be used; fertilizers applied for both tree and intercrop; and some system of pest control will also be required (anon. 1974; Templeton 1974; Wan and Chee 1976; Reed and Sumana 1976). In addition, if large areas are to be intercropped, mechanized cultivation is essential for adequate planting and harvesting schedules and control of weed problems.

As shade from the developing tree crop canopy causes a cessation of food cropping, provision must be made to prevent any major weed invasion. The best and cheapest way of protecting against weeds is to encourage vigorous tree growth by good husbandry and use of fertilizers.

In the replanting of tree crops, productive cropping can be maintained by staggered felling and introduction of a following crop under the decreased shade (Black and Hubbard 1977).

Just as some commodity crop development schemes have set land aside for food crop production, so Ball (1977) foresees the allocation of areas within any agro-forestry project so that raising of trees, animals, and food crops may separately be intensified. Wetter soils in valley bottoms might be cultivated permanently with rice and vegetables. Steep slopes and catchment areas need to be retained under natural forest that serves as a source of traditional products, including bush meat. Shallow soils on moderate slopes may support short-rotation forest crops, with slightly sloping sites with deep soils being cultivated by mechanical means with short fallow periods. Soil derived from sedimentary deposits on level sites is suitable for forest production with short agricultural cropping periods.

One can see that such developments in time could lead to the establishment of relatively intense cropping systems for each soil unit in a given project. Egger (1978) foresees the same type of longer-term development but with the emphasis on ecofarming techniques, largely based on tree crops, and with only the minimum necessary inputs, such as fertilizers, from external sources (see the closely related paper by Behmel and Neumann in this volume, pp. 92 - 98).

In Costa Rica and Brazil, among other places, attempts are being made to compare different cropping treatments on small-scale experimental sites. The trials involve a variety of tree crops mixed with lower storey annual and perennial crops or pastures. Although these are likely to give useful indications of the effect of different cropping systems on soil conditions, their application may otherwise be very limited. It
is extremely difficult to reproduce field conditions in small plots; edge effects are large, and microclimatic effects caused by wind and insolation differ appreciably. It is virtually impossible to extrapolate the cost of weeding, pruning, harvesting, and other operations in small plots to field conditions; pasture plots have no animal interaction and so on.

These experiments need to be complemented by production-oriented, large-scale field studies of the more promising systems, on a number of locations, if they are to be meaningful to the farmer and the planner. Such studies do not require that one relearn all the basic facts of tree-annual crop-soil interrelationships. Much is already known, or can be inferred, from related commodity crop studies. Field work should concentrate instead on the selection of the most promising associations for any given location and then on the development of methods for maximizing productivity within the resources available.
Applicability of agro-forestry systems

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Abstract

At present agro-forestry is suffering from oversale and wishful thinking rather than being based on an objective analysis of what it can and cannot offer. To build up the scientific credibility of the discipline and to provide a useful instrument for those who want to promote agro-forestry practices, researchers should always compare the potential of agro-forestry with that of monocultures. Such comparison must carefully weigh the advantages and disadvantages of each system from both biological and socio-economic perspectives. To facilitate such a comparison, a recapitulation of qualitative and a few quantitative assessments, based on Costa Rican experiences, a literature review, and discussions with practicing agro-foresters, is presented. It is hoped that these assessments-to be refined on a continuous basis-will serve as guidelines to research themes, for promotion and extension campaigns, and for evaluations a posteriori.

Introduction

In a recent consultative meeting of the International Council for Research in Agro-forestry, held in Nairobi and which concluded only nine days before the initiation of this workshop, I had the privilege of participating in one of the four working groups, with the aim of producing an appraisal as well as guidelines on plant management in agro forestry systems. The discussions and the resulting conclusions, soon to be published together with the background papers, all proved to be extremely useful to the subject that had been assigned to me by the organizers of this workshop, and it was inevitable that it moved me to rewrite the paper which I had prepared in Turrialba, Costa Rica, in March 1981.

The lesson is, of course, that agro forestry is in a dynamic state of knowledge and reappraisal, full of pitfalls and often grossly overrated in its role to help rural populations. As the draft conclusions of the Nairobi working group forcefully state: "agro forestry should not be considered as a panacea to cure all evils of land management nor is it of uniform applicability. In specific areas agro-forestry is useful, e.g. in reclaiming land which has been degraded by defective other uses, or in augmenting production on good land in high input systems, by managing suitable plant associations. In other areas, other land use systems are to be preferred" (ICRAF 1981).

A similar word of caution was voiced in a recent paper by the new director-elect of ICRAF, Dr. Bjorn Lundgren (Lundgren 1979:526): In the promotion of the agro-forestry concept, there has been no limit to the alleged positive influence of trees. Sometimes this has achieved almost mystical dimensions—the frequent talk about 'miracle trees' is one aspect of this. Although it may sound like a lack of imaginative thinking, it must be flatly stated that there exist no miraculous influences of trees on soils. It is often mistakenly supposed that any tree crop has the same stabilizing effect on the soil as the natural forest. This is as wrong as to say that a managed maize field is ecologically equivalent to a savanna.

Moreover, there are other stereotyped images that must be clarified concerning agro-forestry. Is it practiced only by the rural poor? Is it restricted to marginal land? Can it be true, as stated in a famous report to IDRC (Bene et al. 1977:43), that "more than half of all land in the tropics, although too dry, too steep, too rocky to be classified as arable land, is suitable to the practice of agro-forestry"?

The more one learns about agro-forestry, the more one discovers that it includes productive and stable systems on all kinds of climate, soils, and under various social conditions. Many of these systems are very old, covering centuries of empirical knowledge. People who have been exposed to various agro-forestry
practices as a result of training in this field are actively reporting (or rather discovering) systems, along routes they had previously travelled without ever noticing them before (Budowski 1981a).

Although agro-forestry has mostly been reported to be practiced by the rural poor (Michon 1981; Nao 1981; Avila et al. 1979; Bishop 1979; Fuentes Flores 1979; Wilken 1977), good case studies are also coming forth concerning highly productive systems by small farmers (Beer 1981; de las Salas 1979). After all, coffee, tea, and cocoa, when cultivated under one or several strata of "shade" trees (that also produce timber, add organic matter, recycle nutrients, diminish weed growth, and provide a variety of other products and services), can be legitimately regarded as part of agro-forestry systems, whether they are raised on small or large farms, or in very huge enterprises, such as Jari Florestal in Amapa, Brazil (Briscoe 1981).

It is, therefore, possible to see agro-forestry as a land-use technique that applies to both low-capital, low-input farming where self-supply is aimed at, and high-input, capital-intensive operations where the highest possible yield is aimed at; both systems having in common that they must be sustained; that is, productivity must be maintained.

Actually, as many authors have pointed out, notably Lundgren (1979), "agro-forestry as a form of land use is primarily considered as a desirable replacement or improvement of land use systems that are degrading under the pressure of increased population densities in areas with low inherent potential for intensive agriculture." He adds: "In the humid tropics this is often synonymous with areas under various forms of shifting cultivation." For the American humid tropics one may reasonably replace "shifting cultivation" with "extensive grazing" because this is, in terms of area affected, the principal cause of land degradation, as witnessed by millions of hectares of worthless secondary brush that has reinvaded abandoned pastures, themselves carved out at the expense of the rainforests (Budowski 1981a).

Lundgren (1978a) in a report for West Africa makes the additional point that "the economic and nutritional output from the land must not only be sustained at present low levels but must be substantially increased to meet the requirements of an increasing population and increasing demands for social and economic development"—a generalization that is valid for all the low-input agro-forestry practices throughout the tropical world.

**A Yardstick to Judge Applicability**

To be justified, the practice of agro-forestry must equal the performance of any alternative, notably monocultures. It should be judged according to both economic and social, short- and long-term aspirations; depending on the feeding requirements and land-use patterns, the areas devoted to agro-forestry can cover a small or a large part of the land used by rural communities.

Basically, agro-forestry involves agricultural systems where trees are added in time or space or both to annual or perennial crops or grasses or combined with animals (Combe and Budowski 1979); the combinations are many.

For adequate assessment they need to be compared with monocultures of either annuals or perennials without these trees (or for that matter the same trees in monocultures). Comparison may by no means be easy because often the monocultures have no parallel in agro-forestry or vice versa, or, if they exist, they may not be found side by side under comparable conditions. Moreover, such evaluation is complicated by various short- and long-term economic projections concerning, for instance, the value of wood or the present and future estimations of environmental damage (for instance, erosion, use of pesticides in monocultures) and, even more so, by the appraisal of social and cultural factors, themselves complicated by a dynamic evolution in time that is difficult to foresee.

Nevertheles, this evaluation is considered a most useful exercise for all those who want to promote agro-forestry and eventually transfer various of its forms to other areas, without unduly preaching on the basis of faith instead of careful scientific appraisal. As described by Steppler and Raintree (1981) at the recent ICRAF consultative meeting on plant research and agro-forestry: "ICRAF considers itself as an
honest broker in promoting agro-forestry. If other land-use practices are better qualified, it implies that ICRAF will make this clear and refrain from introducing agro-forestry practices where they are not warranted." This approach should become a credo for all those working in agro-forestry. With this objective in mind, a list, with emphasis on the humid tropics, of advantages and disadvantages of agro-forestry practices as compared with monocultures, has been compiled in the present paper. Its purpose is to serve as a basis for discussion and future evaluations. The compilation is based on discussions with practicing agro-foresters and on a review of the literature (notably, de las Salas 1979; Chandler and Spurgeon 1980; Beer 1981; Mongi and Huxley 1980; Raintree 1981; ICRAF 1981).

**Biological Aspects**

**Advantages**

- A larger amount of solar energy is captured;
- A better utilization of the vertical space is achieved and, up to a point, natural ecological models are simulated as to form and structure;
- There is greater resistance against adverse rainfall conditions (both excess rainfall and unseasonal droughts);
- Temperature extremes are mitigated (lower maxima and higher minima), benefits particularly affecting plants and animals close to the ground; the lower maxima reduce the speed of decomposition of organic matter;
- The damage caused by strong winds and raindrops with high energy is reduced;
- A larger amount of biomass returns to the soil as organic matter through fallen leaves, fruits, flowers, and branches. There is greater efficiency in recycling nutrients because tree roots capture nutrients that move through the soil profile or to areas far away from the annual or perennial crop plants; in this connection the long, superficial horizontal roots of trees may play an extremely useful role, as was pointed out by Lundgren (1978a): "the superficial root system (of trees) will reduce nutrient and soil losses by leaching and erosion and improve porosity, infiltration and aeration properties, and their deeper roots will bring up nutrients from depths to be incorporated into the biomass";
- Trees and their roots tend to improve the soil structure by producing a higher amount of stable aggregates and avoiding (also dismantling) various types of hard pans; percolation is thus favoured and there will be less stagnant water on the soil surface;
- There will be less proliferation of weeds because less light reaches the ground and there is the possible suppressive effect of mulching;
- Mulch production—particularly if trees are pruned or pollarded—reduces water evaporation from soil, adds considerable organic matter, and reduces (or eliminates) the need for tillage;
- Most trees are better able to extract available nutrients from the soil through the activities of mycorrhizae. In the case of most legumes (and representatives of a few other families), nitrogen from the air can be fixed through the action of specialized bacteria and other micro-organisms and incorporated in the plant tissues;
- Erosion is prevented (up to a point) by most trees, particularly on slopes;
- Manipulation of the arboreal strata through pruning (particularly to control crown density) can become a tool for better control of phenological processes like flowering or fruiting, for the benefit of associated plants; moreover, the trees themselves can be selected for appropriate phenology (Huxley 1981b), particularly their deciduousness (Budowski 1981b).
- A greater diversity of fauna is promoted because trees provide a variety of niches for animals (a source of protein), birds, and other beneficial predators of harmful insects or rodents;
- The diversity of plant species and their spatial arrangement can deter insect proliferation; and - Trees may serve as supports for climbers of economic value (Okigbo 1981).

**Disadvantages**

- Trees compete for light with associated plants in the lower strata, and thus may lower the yields and the quality of crop plants;
• Trees may compete for space with associated plants, both above and below ground, and this competition can be a handicap for either or both components;
• Trees compete for nutrients, store them in stems and branches, and, hence, make them inaccessible to associated crops;
• There is a loss of nutrients when the wood is harvested or "exported" from the area; this is, of course, equally true when fruits or seeds from the trees are harvested;
• Trees compete for water in the soil in times of water stress, the more so if they keep their leaves (and transpire) instead of shedding them;
• Trees keep part of the rain in their crowns; this fact can be important when there are light rains; stemflow can adversely redistribute rainfall;
• The harvesting of trees may cause mechanical damage to the associated crops;
• Mechanization becomes more difficult or impossible;
• Micro-relief manipulation of the soil surface (furrowing, building of mounds, etc.) to benefit certain crops is more difficult or impossible;
• Air moisture close to the associated crops may be increased (partly because of less air movement), favouring fungal diseases;
• Large water drops that coalesce and drop from the higher parts of the tree crowns may cause damage to the associated crops (for instance, in times of flowering);
• The different environment produced by the addition of trees can favour the proliferation of noxious animals; and
• Some trees have allelopathic effects on crops.

**Economic and Social Aspects**

**Advantages**

• Farmers obtain, at least in part, direct economic benefits from the trees that satisfy their needs for firewood, posts, poles, sawn wood, certain fruits, feed for cattle, flowers for honey, medicinal products, etc.; they do not need to buy these products or transport them from far away;
• Trees that produce saleable wood constitute "standing capital," an insurance against emergencies in case of immediate cash needs;
• Dependency and catastrophes associated with a single crop are overcome or mitigated, particularly in the case of irregular rainfall patterns, market fluctuations, pest outbreaks, difficulty in acquiring imported products such as pesticides, fertilizers, machinery and spare parts, concentrates for cattle, etc.; moreover, the price of such imported products may (and often does) drastically increase;
• The economic investments required to establish tree crops may be considerably reduced because of the benefits obtained from annual crops at the early stages of tree growth; in some cases the number of years devoted to annual crops can be increased if thinning, pruning, or upper crown manipulation is undertaken, and additional economic benefits can be obtained (posts, firewood) at the early stages of tree development;
• The presence of trees usually reduces weeding costs;
• Trees can be used to mark property boundaries and constitute a safeguard against land usurpation;
• There is more flexibility to distribute the work load during the course of the year;
• Wildlife can be favoured and may be harvested for protein;
• Some schemes allow a gradual change from destructive land-use practices towards more stable systems without diminishing productivity; and
• There is obviously considerable scope to improve on existing stable systems and to design new systems with higher production and productivity by associations of the most desirable plant species (and animals), in space and in time, by drawing on local and worldwide experience.

**Disadvantages**

• In some cases, over the same area, yields of crops (or pastures) can be lower than for monocultures; even if the combined value of crops and trees is higher, it may taken a number of years for the trees to acquire economic value;
More manual labour may be required, a negative factor where labour is scarce and expensive and mechanization appears to be a better alternative;

Agro-forestry is often associated with land-use systems of poor people, where little effort is made to adapt improved agronomic practices such as selection of improved varieties or use of fertilizers, and there is usually a complete neglect of pest control; in this connection, it is often argued that many current agro-forestry practices do not stimulate farmers to abandon their present socio-economic status associated with poverty and subsistence levels;

In depressed areas, economic recuperation may take a longer time (than with profitable cash crops) because of the time lag in cropping trees;

In areas of high population density and scarce land resources, where survival is based on the next crop, there may be considerable resistance against the planting or tending of trees. The particular case of taungya, when cheap labour is used to establish trees with the collaboration of itinerant farmers that do not own the land, may be considered socially inadequate or a vestige of colonial or other practices linked with exploitation of the poor;

There is considerable scarcity of trained personnel to handle or improve existing agro-forestry systems, devise new systems, and install demonstration plots;

Agro-forestry is more complex and less understood than monocultures, and thus may be unattractive to scientists, extensionists, or farmers with a higher agricultural education; also, any experimental designs involving complex associations (in space or in time) and subject to statistical analysis are likely to be much more difficult; they can hardly be done in existing plots because of the impossibility of controlling, let alone manipulating, the variables; testing agro-forestry practices and comparing them with monocultures may thus become a lengthy, difficult, and costly task that apparently can only be carried out efficiently by selected experimental stations where appropriate land, funds, and specialists of different disciplines are available; and

There is a lack of knowledge among decision-makers about the potentialities of agro-forestry and this results in a lack of funds for land-use planning, research, and extension programmes; backlashes resulting from false promises (e.g., "miracle" trees) may compound this rather depressing picture.

Conclusions

These appraisals of advantages and disadvantages are obviously incomplete. Moreover, they cannot pretend to cover the whole array of agro-forestry possibilities. However, they can provide a framework for the evaluation of existing systems and for the design of new ones, particularly in assessing their applicability and chances of success. They could constitute a basis for a series of questionnaires when the promotion of certain agro-forestry practices is desired. Finally, they can help to define a series of possibilities for research. Then, as new and more homogeneous descriptions of agro-forestry systems enter the literature, these preliminary appraisals may be considerably refined, enlarged, and used to help, at least in part and where applicable, in the quantification of those systems, including their testing, validation, and continuous evaluation.

Agro-forestry and forest laws, policies, and customs

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Abstract

Agro-forestry is an evolving land management technique. Two of its antecedents, taungya and agristlviculture, derived from the foresters' desire to retain substantial portions of their countries' land area for their enterprise. Therefore, these systems have for a long time been restricted to the estates managed by the forest services. The increasing popularity of the systems with the foresters was due largely to the availability of cheap labour for plantation establishment in addition to the palliatives of
the systems against the protagonists of forest dereservation. However, because of the narrow but
overriding forest regeneration values attached to taungya or agrisilviculture, and also because the
policies were incoherent, the forest departments were unable to elaborate the objectives and regulations
into attractive development schemes. Changing socio-economic factors, particularly the land-use
resource base, compel a meaningful review of the erstwhile incompatibility of the various sectors.
Agro-forestry seeks not only to realign the two major land-use sectors with revamped output per unit
area but also to offer alternative development strategies for rural areas. This new enterprise will
succeed only if the objectives are clearly identified, policy guidelines formulated, and practical laws
and regulations enacted. Inevitably, the forest services must improve their institutional capability and
introduce genuine incentives to enable them to realize the potentialities of the emerging enterprise.

Introduction

By their nature, policies and laws are concerned with the future. Decisions are never made about past
actions. Rather, one is always deciding what to do now or in the future. Similarly, laws are usually made
to curtail, if not prevent, the occurrence of anti-social behaviour. In contrast, customs are based on
historic norms and often provide valuable background for policy decisions and legal frameworks. The way
in which agro-forestry is influenced by policies, laws, and customs is both historic and contemporary.

As an enterprise, forestry must change its objectives from time to time. In the early stages, foresters had
limited objectives, largely concerned with forest reservation, wood production, and establishment of
efficient forest services. In recent years, there has been a sharp distinction between goals, means, and
processes of forest policy to the extent that ideas such as the maintenance of efficient forest services,
creation of forest research organizations, and public awareness of the benefits and value of scientific
forestry, previously regarded as important policy objectives, are now correctly classified as part of the
means and processes for the attainment of goals. For the realization of objectives or goals, forest laws and
agro-forestry must be construed, respectively, as regulatory tools and resource management techniques.

Land upon which agriculture and forestry are inseparable, together with its related institutions, is
significant to a country not merely for economic reasons. It is also important in terms of the individuals
who use it and who, in turn, affect the prevailing political institutions. There can be no doubt that in the
tropics private ownership of land by families, clans, or ethnic groups has been the bane and strength of
agriculture and forestry. Thus, agro-forestry, which combines these two enterprises sequentially or
simultaneously on the same piece of land, is probably a palliative in the short run but also a potent land
management technique if backed by pragmatic policies and regulations.

Forest Regeneration

Forest laws are relatively new in most tropical countries; in some, they are non-existent. Some particular
beliefs have prompted them in areas where they exist. The first was that a large portion of the superficial
area of each country should be secured-consecrated, as it were-forestry. Although this concept may
have derived from the notion that forestry was incompatible with other land uses, in recent decades this
belief has been justified by the proven environmental and scientific benefits of the natural vegetation. The
second belief was that, because of the long gestation of the principal crop *timber), an exclusive land
management or monoculture for production was needed. This belief was consistent with the prevailing
level of technology and phytological knowledge. Because the idea of cultivated forests and industrial
plantations was still far-fetched and the wood-processing plants were designed for huge logs, the forestry
policy-makers had to propagate a legal framework that could secure a freehold and pre-empt the claims of
other rural land users. Thus forestry became insulated and an opponent for many land users. The fact is
that where they have been promulgated, forest laws have been seen as a once-and-for-all exercise; they
were imposed on traditional communities who did not fully comprehend the reservation of large parcels of
land for the sole purpose of timber production.

Slowly, it dawned on foresters that the age of blanket forest land reservation must give way to intensive
management of the land as justification for a hold on the prime resource (land). In this connection, forest
regeneration, the continuity of the resource, or the creation of new crops became the new focus through
which economic factors have been brought to bear on forest laws and regulations. Thirty or forty years ago, most tropical countries depended solely on natural regeneration, so forestry policy-makers introduced regulations that were designed to ensure natural regeneration. The Tropical Shelterwood System (TSS), adopted in Nigeria with modifications from a Malayan system, was pursued with a network of instructions that became entrenched almost as codes.

The problem was that the policies on natural regeneration of heterogeneous forests were founded on economic grounds, but only a few forest crops were economically viable. Therefore, the vast majority of the species did not benefit from the regulations. Also, the policies presumed a technological standstill. Thus it became necessary to shift emphasis from natural regeneration to artificial regeneration.

Most francophone countries have constituted artificial regeneration into a separate entity called fonds forestier, with its own statutes, regulations, and specialized staff. In contrast, the anglophone countries have tended to establish regeneration funds administered by their respective forest services and dependent upon the parent ministry and the central treasury. In the latter, the lack of autonomy or special recognition of the peculiar needs of forest regeneration has been exacerbated by the ad hoc disbursement of pertinent funds. The result is that, whereas the francophone countries have elevated forest regeneration programmes into parastatals able to carry out a fairly schematic forest replenishment, the anglophone countries have come to rely heavily on cheap but restricted techniques without any substantive legal framework. It is no surprise then that taungya, agrisilviculture, and agro-forestry, which have been more widely accepted in the English-speaking countries than elsewhere, developed as a socio-economic palliative rather than a well-designed and formalized means of resource generation.

In other respects, the French and British viewpoints on forest protection and regeneration were, during colonial times, very close if not identical. For instance, the British introduced laws and regulations for the protection of forests and forest products against trespass, theft, and fire. They compelled exploiters to establish seedlings to replace felled trees. Moreover, individual farmers were obliged to nurse, maintain, and protect seedlings of classified species on their farmlands. This particular obligation not only lacked incentive but also raised the fundamental question of land ownership and sharing of benefits, which is crucial to the agro-forestry concept.

Similar regulations were introduced in many francophone countries. For example, in the Republic of Niger, 15 species of special economic interest to the colonial administration were protected, even though they were growing on peasants' farmlands. The consequence of the somewhat arbitrary forestry regulations in Niger is that the trees are without effective protection despite the heavy penalties for harm done to them. In Nigeria, Niger and elsewhere, these or any other laws that control the use of property of private owners without providing compensation for the control are a negation of cooperative development. Such laws are counter-productive and have missed a great opportunity to propagate agro-forestry.

Over the last 15 years or so, several countries have received substantial loans from the World Bank and other financial institutions for the establishment of forests. These new investments are accompanied by regulations that compel loan recipients to guarantee as far as possible a desirable level of technical inputs for the establishment of tree crops and their maintenance until the end of the rotation when they can be put to economic use. Due to the specific objectives inherent in these foreign investments, the production of multiple goods and services characteristic of agro-forestry is hardly feasible. Thus, although more and more countries are now able to regenerate vast areas of degraded forests with international financial assistance, the possibility of agro-forestry is not enhanced. However, it has been proved in Kenya, for example, that the returns from agricultural production in the World Bank industrial plantations have a minimal effect on the financial rotations of the forest stand.

**Policies and Customs**

Agro-forestry policies and customs are, at present, not definitive; they are evolving gradually in response to a variety of physical and socio-economic constraints. There are policy elements and trends that favour multiple use of forest lands and the spread of such practices to production systems previously viewed as
incompatible with forestry. However, the rapport between agriculture and forestry is neither sudden nor
novel. Indeed, to some extent, it is an old solution to a new set of problems.

Hill cultivation, or taungya, as practiced in Burma, is the precursor of tropical agro-forestry. Its
development had its roots in the desire of foresters to exploit the valuable teak in its natural habitat while
causing little damage to the economy of the peasants. This necessitated replanting the forest to minimize
soil erosion; and for this the cooperation of the farmers was needed.

Agrisilviculture as practiced in lowland African forests is a variant of taungya. Again, the policy element
derives from the desire on the part of forest services to provide rewarding vocational opportunities to local
communities experiencing shortened fallow periods with decreasing agricultural productivity. To curtail
farmers' destruction of the forests and also retain their hold on the land, forest services have had to resort
to a give-and-take policy. In other words, foresters concede temporal tenurial rights to farmers on forest
lands in exchange for labour inputs for forest crop establishment. The underlying policy decision was
largely political, although the economic advantages to the forest services in terms of availability of cheap
labour for forest regeneration have become overwhelming.

Taungya and agrisilviculture were intuitive in concept and therefore fortuitous in the long run. Although
the antecedents and inspiration for agro-forestry, they were far less deliberate and purposeful. The reasons
for the recent development of agro-forestry are many (Adeyoju 1980). One is that the increasing rural
population has experienced agricultural land shortages that compound food supply problems. Because of
the population growth, land-use practices have become less rational, and in many locations the
monocultural practice of agriculture or forestry has become increasingly untenable.

On the basis of resource allocation, it is now generally agreed that the realization of benefits in one
economic sector may be harmful to that of another. There are, for instance, pertinent questions about
opportunity costs and the time-scale of resource allocation that cannot be ignored. Thus, in developing
countries the case for reserving land exclusively for forestry or agriculture is not always justifiable if, in
the critical short run, the land can be made to yield a variety of goods and services. In an era when food
shortages are growing and when international food aid is losing its appeal even among recipients, the
choice between agriculture and forestry land uses, or between food and cellulose production, is becoming
sharper, direct, and unassailably in favour of the former.

In such situations, agro-forestry proffers an alternative. It is noteworthy because, in general, the resource
inputs are aimed at a production mix of goods and services that will cater to many members of a
community. Also, because agro-forestry is an enterprise that is not intended solely for the forest estate, it
can be aided by changes in agricultural laws and customs that permit a revitalization of misused lands. In
this regard Uganda's experience with forestry interludes on private farmlands is interesting as the
interludes have been observed to ameliorate the harmful affects of fertilizers and pesticides on agricultural
production. In such situations, forest crops provide not only biological protection but also a critical balance
in otherwise deteriorating ecosystems.

Agro-forestry policies must be deliberate and geared toward the elimination of competition between two
enterprises. The central policy issues must be the unifying factors. These may be determined through an
examination of the physical state of the land and the general economic objectives for the country. Perhaps
cost-benefit analyses of agro-forestry in different locations versus those of single uses would reveal the
main ingredients of policy and permissible customs.

The recent trend in Nigeria, and elsewhere, of establishing villages primarily for forest regeneration and
maximum food crop production during the first two years of forest plantations is a policy breakthrough.
The capital outlay on low-cost housing and basic social infrastructures is more than compensated by the
volume and variety of food crops produced, the low failure rates in nursery work and seedling
transplantation, the provision of regular employment for a large and increasing labour force, and the
unparalleled opportunities created for ethnic harmony (Adeyoiu 1978). Although a similar policy of
allocating housing estates in urban areas to large employers of labour such as banks and industrial firms
also has benefits, the policy within the forestry setting is especially enviable because it seeks to redress the imbalance between the urban and rural areas. Agro-forestry villages constitute a viable alternative to development schemes, many of which introduce heavy machinery, create unemployment, ruin the ecosystem, alter the basis of traditional societies, and turn ordinary people into strangers in their environment. Forest villages may well be a trump card for policy-makers.

**Law and the System**

The implementation of agro-forestry systems can and has been aided through contracts, agreements, permits, and licences. The legal implications of these terms differ, but they are all based on a relationship between the forestry department, which to all intents and purposes owns the forest land, and the farmer who is the tenant of the forest. Generally, they include clauses that govern the entry to, and use of, forest land by farmers and also reserve the forestry department's power to punish defaulting farmers.

In a comprehensive study of agrisilviculture, King (1968) examined the legal framework in vogue. He classified the terms of agreement first into those acceptable to the forester and second into those expected of the farmer. On the face of it, it may appear that the tenurial conditions are generous, but these conditions restrict cultural practices to those that cause minimum biological impairment to the forest crop establishment and exact maximum labour input from the farmer. For instance, some of the clauses typical of licences require that the cultivators not plant specific crops; not plant crops within specified distances of the tree crop; replace seedlings that have not survived at the farmer's expense; undertake work in other parts of the forest estate on other jobs for a specified period; not engage in certain weeding practices; not construct houses or buildings in the forest reserve without authority; not transfer rights or sub-let the land allocated; and deposit a certain amount of money against breaches of the agreement.

However, on the credit side, there are provisions for the farmers to hold forest land free of rent; plant farm crops among forest trees; cut, collect, and remove free of charge from the area allotted all timber and firewood less than a certain size for personal use; make charcoal free of charge; be given due notice for termination of the agreement; and for competent cultivators to be paid rewards and bonuses.

The fact that the terms of various agreements are overwhelmingly in favour of the forester can be easily understood because the prerogative of the rulers or lawmakers is to provide for those actions that are compatible with their objectives. As the landowner, the forest service has unequal rights with the cultivators. Nevertheless, the rights of use conceded to the cultivators should be expanded by special considerations rather than by strictly legal principles and precepts. Moreover, the cultivators of forest land generally live below subsistence level and deserve flexible and practical concessions in the choice of crops to plant and the spacing used. Foresters should appreciate the need for reviewing the terms, conditions, and incentives to arrange, where and if possible, more equitable conditions.

**What Should Be Done**

Agro-forestry policies and laws hinge critically on the nature of land tenure. The three aspects of tenure - economic, social, and political-are not only interrelated but are also the customary points of view from which the performance of land-use sectors is evaluated. However, a more meaningful evaluation of land-tenure institutions can be made from the viewpoint of agro-forestry production.

Certain aspects of forest tenure are oblivious of agro-forestry both as a regeneration technique and as an enterprise outside the forest estate. The present forest tenures and laws do not permit private investment, let alone encourage the adoption of agro-forestry by private individuals. Yet in the land-use sectors, such as agriculture and livestock production, the record of achievements by public agencies, even in socialist countries, has been most unimpressive. In many tropical countries, particularly in the dry and arid zones, there is increasing evidence that within the limits of existing village technology, people are now interested in family plantations. But, given the present laws and codes, the villagers are uncertain whether the wood they produce will belong to them. A clear and positive relationship between effort and reward is a necessary condition for local participation in agro-forestry. This is part of what the new policies and laws should seek to ensure.
The laws that compel farmers to take care of trees on their farmlands and for such trees to yield income to government when harvested must be rescinded. Full ownership of trees must be vested in those who own the land. This should be a long-term arrangement whereby villagers have some security so that investments are encouraged not only in individual trees but also in afforestation of deforested or fallow lands. The farmers will then be free from legal factors influencing their judgement of what trees are appropriate as well as from the frequent harassment by forestry protection staff for noncompliance with the law. Also, they will be able to take the initiative in private plantation establishment; they will have incentives to work with the forest service in finding ways to manage the local woodstock for diverse goods and services.

Lesotho, a small, hilly, highly eroded country whose economy is primarily based on livestock, has succeeded in operating a set of incentives for agro-forestry. Under the Anglo-American Woodlot Project initiated in 1973, the chiefs who own the land have become increasingly receptive as a result of certain strategic provisions. First, the project (otherwise the Forestry Division) made a solemn pledge to sell the harvested firewood to the local community in the first instance at the subsidized rate of one-third of the price of firewood imported from South Africa. No firewood is sold until the needs of the local community have been fully met, after which the rest may be auctioned at economic prices. Second, section 18 of the Forest Act 1978 states, inter alia: . . . (1) all monies collected under this Act whether from tariffs, fees, charges or otherwise shall be paid into a special fund; and . . . the Minister may after consultation with the Minister of Finance, determine, by order, that such percentage as may accordingly be determined of the monies received under subsection (1) from a forest reserve be allocated to the benefit of the community of the area within which that forest reserve lies.

Indeed, it has been determined that 20 per cent of all revenue collected shall be set aside for the development of the chiefdom in which the plantations are situated (D.F. Davidson, personal communication). These incentives are so popular that the project staff are now inundated with offers of land, and the critical limiting factor is the executive capacity. Moreover, because there is a willingness to surrender land for woodlots, it is now relatively easy to constitute and gazette such plantations into permanent forest estate in a country that previously had no state forests of any kind.

The understanding of policy as setting a course of action implies that policies affect resource use over time, but it does not necessarily imply that the use will be uniform or continuous over time. This aspect of resource policy is not fully appreciated by those who have responsibility for land-use policies in tropical countries. Both agriculturalists and foresters have rigid viewpoints and fear losing a metre of their territory to other uses. Although they are policymakers/advisers, they are not well-disposed to change. In view of how difficult it is to read the future and to make significant changes in land use, flexibility is an absolute essential in forest and agricultural policies. Gould (1962) has therefore stressed: "permanence and stability may create a false air of security while really leading to obsolescence and irrelevance in an expanding economy. A process of continuous planning is needed to balance the use of forest resources." This process should be predicated on the meeting of evolving needs and on the flexible combination of labour and capital with land in an expanding economy. Because agro-forestry has demonstrably unique technical and socio-economic roles to fulfil, it is compelling for the policy-makers in the main sectors concerned-agriculture and forestry-to make it work.

Two decades after independence, most countries are still operating with colonial forest policies and laws. During this period most developing economies have been restructured through numerous development plans, and, of course, forestry activities have expanded considerably. Yet, most forest services still retain a colonial structure lacking planning units. Invariably, the director or chief conservator of forests is in charge of forest policy and laws formulated long before he or she joined the service and with which the staff are largely unfamiliar. Published and up-to-date policy statements and laws do not exist, and thus forest services have operated for years without declared objectives, work programmes, and implementation strategies. In these circumstances, the approach to agro-forestry is ad hoc and sporadic. Forest services need to take urgent steps not only to strengthen their structure with planning and policy co-ordination units but also to enunciate categorical policy guidelines on forest land tenure, regeneration strategies, and the role of private investment. Perhaps it is not too early to suggest that in the rapidly
expanding economies there should be challenging career opportunities for full-time legal experts in the forest services.

A statement or pronouncement that some particular course of action should be, or will be, followed does not of itself establish a policy. It is merely a policy recommendation or the expression of what some individual or group feels should be followed. It will only become the policy of the larger society if enough of the members accept this course of action and actually follow it. The choice of courses of action and their acceptance by enough people to establish them as actual policies is a gradual, incremental, and, in some respects, evolutionary process. What appears to be an abrupt policy decision may actually be the culmination of a number of gradual changes in knowledge, viewpoints, and objectives on the part of many people. In these respects, the consensus would seem to be that agro-forestry has evolved in one form or another with generations of foresters and that it is being increasingly accepted as having a special role as a management technique with particular reference to vast areas of misused lands. Our real need is, therefore, not to search for an entirely new and different process but to make the existing process more effective. That is why we need to improve the appropriate policy and legal framework so that it consolidates the gains that have been made.
Agro-forestry research for the humid tropics

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Abstract

If the principal aim of agro-forestry is to meet the needs of human communities, then research should be directed towards preservation or modification of the undisturbed habitats, rehabilitation of the disturbed ones, and rational use of the improved ecosystems. The goals of agro-forestry should be food production, forest production, and environmental conservation. Within the forest ecosystem, taungya offers particular scope for research, especially the determination of how long the forest land can sustain food crops before complete canopy closure, and the identification of optimal spacings that maximize food production without interfering with the form and the rate of tree growth. Within the agricultural production system, research should be devoted to the introduction of trees that rejuvenate soil fertility by nutrient recycling within the shortest possible time and that produce forest products to increase the farmers' income or satisfy their needs.

Introduction

This presentation does not undertake the definition of agro-forestry practices and systems, because much has already been written and said in this regard. The term agro-forestry is used here as defined by King and Chandler (1978), i.e., a sustainable land management system that increases the overall yield of land. There seem to be two main reasons for the growing interest in a sustainable land management system: the first is that there is a serious degradation of the ecosystem as a result of deforestation; the second, which is a consequence of the first, is that the global forest resources and arable land areas are diminishing at an alarming rate. The environmental aspect of agro-forestry necessitates planting trees in such a way as to bring about conservation and improvement of the ecological factors that influence the production systems. In addition, the trees should provide one or more of the forest products, such as wood, fodder, and food, that are needed for the improvement of the living conditions in the rural areas.

The term agro-forestry should thus imply land management systems in which forest management, food production, and conservation form integrated components, i.e., a multidisciplinary exercise.

Some of the recognized agro-forestry practices have been in use for centuries in many parts of the world (King 1968). They were evolved in the rural areas when demands for specific tree products were not easily met from the natural forest or when a tree species proved useful and important to food crops. Gum arabic production in the Sudan and the cultivation of crops under Acacia a/bide in West Africa are two of the known examples of agro-forestry practices today two of the better-known examples of agro-forestry practices today (Self el Din 1980). The continuation of these practices is threatened by the problems caused by the growing human populations, for example, over-cultivation of the land and, hence, the gradual elimination of the tree component from the system. The task of agro-forestry research is, therefore, to find the best system within physical and biological limitations and communal or individual socio-economic requirements.

One of the important tasks of agro-forestry research workers should be to find ways to maintain stability in ecosystems that have not yet been seriously interfered with, to render them more productive of human needs. The painful reality is, unfortunately, that there is very little left of the natural forest to maintain. Consequently, agro-forestry research programmes should be directed towards tackling the immensely difficult task of rehabilitating degraded lands and devising land management systems that will fulfil the objectives of agro-forestry.
The gravity of the problem is apparent in the rapid disappearance of the tropical moist forests. Myers (1980) has given the global rate of conversion of these forests into other forms of land use as being 40 ha/minute. He states that up to the mid-1950s, about 1 million km² of tropical forests were lost in Africa alone, and that 40,000 km² of forest are annually disappearing on this continent. The Ivory Coast is estimated to have lost nearly 40 per cent of its forests between 1966 and 1974, and in Nigeria it is reported that only about 25,000 km² of forest exist today, representing less than 3 per cent of the total area of the country. Addo-Ashong (1980) states that of the original 82,000 km² of tropical rainforest in Ghana, only 20,500 km² or one-quarter, remain today.

Research Proposals

If the principal objective of agro-forestry is to meet the immediate and future requirements of the human communities living in the region concerned, then the approach should be directed towards the preservation or modification of undisturbed habitats; the rehabilitation of disturbed ones; and rational utilization of the improved ecosystems.

In other words, agro-forestry should be viewed in the context of food production, forest production, and environmental conservation, which is similar to what has been suggested by Combe (1979) as being economic, ecological, and silvicultural. The result of an agro-forestry approach should be a new environment, dissimilar but strongly related to the natural one in its basic features, so that it is reasonably stable and productive enough to satisfy human requirements. It should offer, as stated by Wassink (1977), "a reasonable and acceptable permanent way of life to the people that dwell therein."

Several workers have suggested the essential elements of an agro-forestry system (Greenland 1977; Grinnell 1975; Combe and Budowski 1979; and Reategui 1979). Most people agree that an agro-forestry system should cater to:

- diversification of species per unit area;
- permanent soil protection;
- continuous restoration of soil fertility; and
- control of weeds, pests, and diseases.

The next step is to consider the type of land and the combinations of plants and animals that constitute an agro-forestry system. There are considerable differences of opinion in this regard, for the simple reason that most of the ideas advocated in agro-forestry have not yet been subjected to systematic investigation.

In the Philippines, Kuo (1977) proposed three classes of land: forest land, agro-forestry land, and agricultural land. He places the forests on the steepest slopes with the shallowest soils, agriculture on the deepest soils with gentle slopes, and agro-forestry in the middle occupying a relatively small portion of the area. He points out, however, that the latter can be practiced on either side of the classification depending on land-use policy and soil characteristics.

In the example cited by Kuo, some of the forest lands are so steep that any cropping or grazing would endanger the entire landscape, whereas some areas are suitable for continuous cultivation of agricultural crops that can only be economically produced when cultivated in monocultures. The implication is that not all crops and not all lands can be included in agro-forestry systems. Consequently, there should be areas solely managed for crops, pastures, or pure forest stands. For the agro-forestry combinations, the broad classification of the systems proposed by Budowski (1977) and also by Torres (1979) are thought to be adequate, i.e., trees combined with farm crops; trees combined with farm crops and animals; and trees combined with animals. In order to arrive at the desired agro-forestry system, one must tackle research from both the agricultural and the forestry perspective. These two disciplines have, for a long time, had conflicting interests over land use, whereas livestock was, in most cases, completely neglected. Forestry and crop production systems should therefore be gradually modified independently toward a common end where both meet at a stage called agro forestry. Livestock production should be accommodated in both systems in such a way that optimum yields are obtained without adversely affecting the system, and even improving it. This, simply stated, means production of crops and livestock within forest land and
production of forest products and livestock on agricultural land.

Some agricultural research scientists view the subject of agro-forestry as merely involving the use of short-lived, fast growing tree species to improve soil fertility for food production and not as a source for forestry production. Still others view it as an introduction of new tree crops into farming systems to increase and diversify the food supplies of the rural people. The last point of view is similar to that of domestication of new animals as a form of agrosilvopastoral system. The danger of this approach to agro forestry is that very little is known about the biology and the environmental implications of the new crops and animals.

Some of the forest research scientists look upon agro-forestry as another name for the taungya system, in which a certain amount of food is produced at the treeplanting stages of forestry plantations. This group does not take into consideration the need for the use of the space available for food production at the time of tree establishment in even-aged plantations, at the stage of opening up the canopy for natural regeneration in what is known in West Africa as the Tropical Shelterwood System (TSS), and, finally, at the various stages of stand treatments such as thinning. With this understanding of agro forestry, the taungya system then forms only one step of the comprehensive system that calls for the use of appropriate combinations of plants and animals and the best spatial and temporal distribution for food and wood production as well as for the preservation of the ecosystem. Agro-forestry research on the taungya system should be devoted to the determination of how long the forest land can sustain cropping before complete canopy closure or the decline of soil fertility, and to the identification of optimal spacings that maximize food production without interfering with the form and the rate of tree growth as required in traditional forest management.

**Food Production within the Forest Ecosystem**

Various silvicultural systems were developed to regenerate the natural forests in the humid tropics of West Africa, but the most popular one at present is the TSS. This involves gradually opening up the forest canopy by killing and clearing the trees so that sufficient light is available for the growth of the natural seedlings of the desirable species. The degree of clearance depends on the forest type (density and composition by species), the available resources, and the status of the naturally occurring seedlings.

The agro-forestry research approach here should aim at food production by increasing the intensity of clearance and by the use of shade-tolerant food crops that do not endanger the tree species. Even though little experience is available to show the interactions between food crops and trees, it is possible that the latter would benefit from cropping because most of the undergrowth (bush) would be removed to provide space for the food crops and, hence, competition from weeds would be reduced.

It is desirable to test different crops at different stages of tree growth that entail changes in the environment, especially the amount of leaf litter and the sunlight reaching the ground surface.

Once forest stands pass the seedling stage, they are treated at different intervals by processes known as cleaning and thinning to create the best possible stand of managed forest. The intensity of these operations, especially thinning, depends again on the tree species concerned and the objectives set out for each plantation. Because the need for more food producing space is universally recognized, thinning itself can be modified to provide room for crops and livestock without jeopardizing the objectives of forest management. Appropriate avenues for research are the planting of food crops at different intensities of thinning, and fodder production at the various stages of thinning from both the planted trees and the natural undergrowth.

The main points to be considered when planning the research experiments are: (1) the types of food crops that will favourably respond to the newly created environment in the forest without endangering the trees; and (2) the potential for the introduction of browse shrubs and grasses to enrich the natural pastures for optimum livestock production.

**Forestry Production on Farm Plots**
Forestry production on farm plots is feasible only if there is demand for the forest products grown on the farm plots; otherwise there will be little incentive to the farmers to plant trees. However, if the gains in soil fertility are clearly demonstrated, farmers may be willing to introduce and maintain trees. This possibility is the basis for present efforts by researchers to adapt and optimize the traditional system of land rotation or shifting cultivation, where soil fertility is regained through the regrowth of the natural bush during the fallow period. The suggestion is that trees be planted on abandoned farm plots to rejuvenate soil fertility by nutrient recycling within the shortest possible time and also produce forest products to increase the farmers' income or satisfy their own requirements.

The tree species used in these efforts must be fast-growing to produce marketable products in a short time, i.e., the farmer does not lose time when he again requires the land for food production. At the same time, the tree plantation should be at least as good as - and preferably better than - the natural bush in restoring soil fertility.

Tree planting in conjunction with food crops entails producing forest products and food crops simultaneously on the same piece of land. In addition to their principal role, the trees should improve the soil. In this way the farming system can be prolonged beyond the current one to three years and perhaps lead to the development of a combination that will sustain permanent cropping. The combination aimed at is an extension of that occurring in certain dry tropical areas where food crops are cultivated under Acacia albida, but, in addition, the trees will be managed in such a way as to produce marketable products continuously or at regular intervals. The correct tree species and their spatial arrangements should be adequately investigated in research trials.

Some crops, like cocoa, coffee, etc., are known to tolerate a certain amount of overhead shading. A number of forest tree species have been successfully used to provide shade as well as produce wood. One example in South America cited by Fuentes Flores (1979) is what he calls "stratified tropical agriculture" to produce coffee, citrus fruits, plantain, beehives, and vegetables under scattered trees of Cedrela sp. In India, coconut plantations are intensively intercropped in ways that maximize the use of both aerial and subterranean space (Nair 1979). Okigbo (1977b) and Getahun (1980b) have compiled comprehensive lists of woody plants, including forest trees, which are of nutritional importance in the traditional farming systems of Africa.

It should be pointed out that neither the use of shrubs solely for soil improvement nor the introduction of new tree crops on the farm as additional food sources serves the purpose of agro-forestry. Instead, the research should be directed towards finding the tree species that create favourable environmental conditions for optimal production of crops and livestock in addition to wood production.

The research topics outlined are by no means exhaustive. Instead, they should be considered as a basis for discussions leading to a comprehensive agroforestry programme with long-and short-term objectives. Some of these proposals are likely to apply to the drier tropics where agro-forestry is just as important, in fact even more so, especially when livestock production becomes a more prominent landuse factor.

Before an agro-forestry research programme is worked out, sufficient basic information must be obtained. There should be a survey of the existing land-use practices in the region in a manner similar to that carried out by Getahun (1979a) in southern Nigeria. This will enable researchers to understand the way in which the rural people operate so that they can aim at improving the existing land-use systems rather than designing entirely new ones that would not be easy to implement. The survey should include evaluation of the soil characteristics, the existing vegetation and its effect on soil protection! and the needs of the local communities in terms of food and forest products. The next step is to identify the crops that grow best under trees and the forest trees that will provide protection and soil improvement on farm plots. The research activities should be designed in such a way to find the optimum combinations of trees, crops, and animals to ensure maximum productivity and improvement of the environmental conditions. Finally, a strategy for agro-forestry research should be outlined and methods for its implementation be developed. One such strategy has been proposed by Steppler and Raintree (1981) and provides the basis from which to start (see paper by Steppler in this volume, pp. 1 - 5).
Summary of discussion: Principles of agro-forestry

The presented papers stimulated extensive discussion, and this focused mainly on the institutional and socio-economic constraints to the dissemination and adoption of agro-forestry techniques. Several speakers emphasized that one must begin with the needs of the farmer, and that if proper attention had been paid in the past to their perspective, much misunderstanding and trouble could have been avoided. Scientists must be realistic and should not expect farmers to adopt agro-forestry practices just because of the value of trees in terms of soil and water conservation. There must be more direct benefits for the farmer, especially if they do not own the land. In short, conservation must be designed as a spin-off of agro-forestry and cannot be considered as a selling point on the farm level.

With reference to the planting of tree crops, it was recognized that the most successful method of persuading farmers was through financial inducements, with two basic elements being free seedlings and appropriate extension services. It was pointed out that the farmer may occasionally receive conflicting advice from different extension agents or institutions. In this sense agro-forestry should not consider setting up a third layer of extension services, but should be integrated into existing programmes.

Particular attention was paid to the fact that current legal systems have been primarily designed to protect forests and, if anything, serve to discourage farmers from growing longterm tree crops, especially for timber. Even if a compensation system does exist, these are generally for growing plantations (e.g., in a taungya system) and are not applicable to other agro-forestry situations. Land tenure plays a decisive role, for if the farmer is in a forest estate or forest reserve, or if he is only leasing the land, there is no incentive for him to grow or protect trees. In many cases the farmer is liable for any merchantable trees, so it may be easier for him simply not to allow any trees to become established.

With regard to the design of agro-forestry systems, the theme which ran throughout the workshop was that we must begin with existing systems. An urgent need was felt to catalogue existing systems-successes as well as failures—and then try to quantify them. It was pointed out that ICRAF’s approach will follow this basic methodology of assessing structure and function of existing land-use systems, particularly those which show signs of deterioration, and will then try to formulate alternative systems. Both the conceptual and methodological problems of comparing farming systems were brought out. The sheer number of variables puts agro-forestry into a dilemma, for full quantification and exhaustive testing of agro-forestry systems is generally impossible, yet one cannot try to disseminate an unproved system to the farmers. Some balance must also be found between the in-depth investigation of single systems on the one hand, and the fact that there will be an infinite variety of systems due to both environmental factors (soil type, rainfall, etc.) and socioeconomic factors (access to market, cash crops vs. subsistence crops, etc.).

In evaluating agro-forestry systems, it was generally reaffirmed that the most valid standard would be a comparison with monocultures, and one should not automatically expect that agro-forestry systems would be more successful. For one thing, the management of farms with mixed crops is more difficult, and this impedes mechanization. It was also pointed out that trees may be able to bring more nutrients into the system by bringing up deep nutrients and lowering leaching rates, but they also may immobilize certain nutrients for a long period of time and eventually export large quantities of certain nutrients in the form of fruits, leaves, or wood. Performance must therefore be qualified in terms of factors such as time-span, economic return vs. subsistence, biological productivity, sustainability, etc. It was noted that since agro-forestry systems might be successful in marginal areas unfit for traditional agricultural systems, a comparison with monocultures would not always apply. A cautionary note sounded by several speakers was that we cannot regard agro-forestry as a panacea, but as an alternative land-use system which must be adequately tested and impartially evaluated.

Another theme which ran throughout the discussion was the need to approach agro-forestry in a multidisciplinary manner. Agronomists or foresters working alone would not be able to fully develop the potential of agro-forestry systems, and some participants felt that this meant a new institutional
framework had to be created. Other participants stressed the need to revamp the heretofore narrow training of both scientists and extension workers to take account of the multidisciplinary approach demanded by agro-forestry; this was pragmatically described as taking food crops into the forest and trees into the fields. The idea of integrating farmers into the forest was recognized as anathema to most traditional foresters, but necessary to meet the needs of the local inhabitants. This integration could also be the basis for a more cordial relationship between farmers and foresters than has been the case in the past.

Finally, it was pointed out that the simple mixing of trees and crops was not sufficient, as the improvement of yields would probably require improved varieties, weed control and fertilizers. To be truly effective in improving living standards, agro-forestry should form part of an integrated rural development programme and thereby meet more of the farmer's basic needs.
Traditional agro-forestry systems: Prospects for development

The role of trees in farming systems in the humid tropics
Forest conservation strategies for tropical Africa
Impact of agricultural systems and rural development on Nigerian forests
Crop mixtures in traditional systems
Agricultural tree crops as a no-tillage system
Traditional agro-forestry systems in the central African republic
Prospects for agro-forestry in Benin
Summary of discussion: Traditional agro-forestry systems

The role of trees in farming systems in the humid tropics

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Abstract

The bush fallow-food crop rotation system has been the most popular and stable arable cropping system in the humid tropics of Africa. The system's stability is attributed to the presence in the fallow of deep-rooted woody plant species that are essential to soil fertility restoration. Population increases and the associated pressures on land have been threatening the stability and productivity of the system. As more land is brought in to production, the fallow period is shortened and woody species are eliminated or become ineffective.

A recent survey in southern Nigeria confirmed that the bush fallow-food crop rotation is still the dominant land-use pattern. Other important patterns are permanent tree crops (including plantain and banana), taungya, and permanent compound farming, in which trees are major components.

The role of trees in nutrient recycling, soil organic matter buildup, and erosion control has been recognized by the traditional farmers, who have identified and have been encouraging the most effective tree species in the fallow. With these selected species, the fallow period can be effective/y shortened. To exploit the potential of selected tree species in land and soil management further, we have been perfecting a system called alley cropping. This system embodies the agro-forestry concept of combining crops and trees and ensures the dominance of effective tree species during the fallow period.

Introduction

The tropics have about 50 per cent of the world's population and less than 40 per cent of the earth's land surface. It is estimated that by the Year 2000, the tropics will have nearly doubled their population as against a population increase of 20 - 30 per cent in the developed countries. By the year 2000, 60 per cent more food will be required to feed the world population (FAO 1977). Increasing agricultural productivity to meet this demand poses a special problem, as the greater proportion of the population increase is expected in developing tropical countries where food production is relatively low and, in many cases, falls below the demands of the present population. Alternative solutions to this problem can be found by expanding the area of production, increasing the productivity of the area under production, or a combination of both.

Expanding the area under food production is possible only in areas where suitable lands are available. Unfortunately, many developing nations are already utilizing fully the area regarded as arable, and further expansion would bring into production lands of marginal productivity (under existing local practices).

Increasing productivity per unit area can be approached by:

- Introduction of high-input management technologies based mainly on fossil fuel energy and inorganic fertilizers; the use of high-input technologies has been successful under certain soil, ecological, and management systems. These so-called modern farming methods have not generally been accepted in the humid tropics because of soil, climatic, and socioeconomic constraints. In many instances, these technologies have led to serious land and soil degradation (Uehara 1976; and
Development of more efficient low-input systems based on biological recycling of energy and chemical nutrients through use of fallow as already practiced by traditional farmers; this alternative may maintain naturally land and soil productivity in many areas of the humid tropics (Wilson and Kang 1980).

The bush fallow and related shifting cultivation system, which is still the dominant traditional food crop production system in many parts of the tropics, particularly humid tropical Africa, involves a few years of cultivation alternating with several years of bush following, with the main purpose of the latter being soil fertility regeneration (Ruthenberg 1971). This system has often been criticized as being wasteful and inefficient, and the major reason for degradation of soil and rapid decline in soil fertility and crop yield (FAO 1957). However, while land has been abundant, the bush fallow system has provided the traditional farmers with an efficient, balanced, and stable system for maintaining soil productivity. Problems only arise when land becomes limited due to increasing population, as has already been observed in several countries in humid tropical Africa, where fallow periods have become progressively shorter and fertility restoration becomes correspondingly less effective (Steiner 1973). Grinnell (1975) mentioned: "shifting cultivation though apparently wasteful, if not pushed to excess, has given man his livelihood in the humid tropics for centuries and is significant even now, when after a quarter century of experiment in tropical Africa, we have failed to introduce to the forest regions any method of food production superior to the natural fallow system." Because of the importance of trees and shrubs in fallows or in association with food crop production systems in land and soil management (ICRAF 1979), and also because of their roles in providing fuel, staking material, and edible products (Bene et al. 1977; Brewbaker and Hutton 1979), attention has recently been given to improving the bush fallow system and to developing improved land-based production systems for the tropics (Wilson and Kang 1980).

**FIG.1. Tropical Africa: Humid and Sub-humid Zones**

**Ecology of the Humid Tropics**

The tropics are usually referred to as the region of the earth between 23.5 north and south of the equator. They cover 4.96 billion ha or 38 per cent of the world's land mass. Forty-three per cent of this area is in Africa (Dudal 1980). Among the agroecological zones in tropical Africa, the humid and sub-humid tropics make up over 44 per cent of the total area and extend between 8°S to 8° N latitude (Fig.1).

The upland soils of low-altitude humid and sub-humid tropical Africa are dominated by low activity clay soils characterized by low cation exchange capacity (CEC) and low moisture-holding capacity (Moormann and Kang 1978). The soils can be grouped into two groups. The first is Ultisols and Oxisols (Sols ferrallitiques by INRA classification or Acrisols by FAO World Soil legend) and associated soils. These are strongly acidic and leached upland soils occurring in the perudic to udic moisture areas (with rainfall > 1800 mm). Ultisols are dominant in coastal regions. They are mainly coarse-textured, kaolinitic Typic Paleudults. The Ultisols (and some Oxisols) derived from basement complex rocks are mainly coarse-textured Plinthudults and Tropudults. The second group is Alfisols (Sols ferrugineux tropicaux by INRA classification or Luvisols by FAO World Soil legend). These are slightly acidic and less leached soils from the humid and subhumid zones. Most of these soils are derived from basement complex rocks or sandstone. In the drier forest zone, Oxic paleustalfs are the dominant soil types.

The biological environment of the humid zone, which consists mainly of infertile and fragile or easily degradable soils combined with abundance of moisture and radiation, provides a suitable and continuous growing season for the trees, which can also accumulate the largest amount of biomass. The traditional bush fallow system and its related land and soil management system is a direct adaptation to the prevailing physical and biological environments. However, the traditional system, which relies heavily on forest or woody fallows, is undergoing significant changes as a consequence of increasing population, agricultural land-use pressure, and over-exploitation of forest resources. The result is a steady decrease in the number of trees and shrubs in fallows and a steady increase in grasses and weeds which are less effective in soil rejuvenation.

**Dominant Farming Systems**

A recent survey of the humid and subhumid zones of southern Nigeria (Getahun 1979a; IITA 1978 and 1979a) showed that the traditional agriculture is predominantly upland and consists mainly of: (1) bush fallow-food crop rotation; (2) permanent tree crop farming; (3) taungya; and (4) permanent compound farming in the case of eastern Nigeria.

All are characterized and dominated by a tree component. In the bush fallow, the climax of the fallow is indicated by the presence and size of certain woody species. These woody species with their deep root systems play an
important role in enriching the upper soil layers by depositing litter on the soil surface. The litter decomposes and releases nutrients brought up from lower soil depths. The importance of trees or woody species in the fallow cannot be over-emphasized. Wherever the fallow has been shortened to a period inimical to the development of trees, land productivity in terms of food crop yields has declined. Shifting cultivation, in the classical sense of the moving of entire villages, may still be observed in isolated cases.

The reasons for the shifts have not been made clear and may not be directly related to factors influencing land productivity.

Tree crops, including plantain and banana (Muse spp.), accounted for up to 67 per cent of the land under cultivation, whereas arable crops accounted for only 25 per cent. Combinations of tree and arable crops, in mixtures, were common but were usually associated with farmers operating on small areas.

The taungya system is found only where forestry departments are establishing tree plantations. Food crop production takes place during the period between land clearing and plantation establishment phase. The system is not attractive to farmers and persists only where there is population pressure or when the diversion of land to plantations reduces the area available for land rotation as practiced in the bush fallow system.

Permanent compound farming represents an intensive management system in which soil fertility is maintained by addition of crop residues and household refuse. Both trees and arable crops are usually found in mixtures in this system. Plantains and bananas are of special significance in the system, as the high organic matter and mulching effect of the refuse increase the yield and productive longevity of these crops (Wilson and Braide, 1978). Fruit trees are generally found in these gardens and are readily accessible to the farm dwellers.

The overall picture reveals that outside permanent compound farms each farmer operates an arable crop (multiple cropping) and a tree crop enterprise. The arable crops supply food, and the tree crop provides cash income. The cash returns to labour from tree crops such as cocoa are often more than twice those from the food crop (Grinnell 1975). Land and labour with cash/credit as an occasional modifier are the important production factors in traditional crop production. Shortage of land invariably leads to reduction in the fallow period and expansion of the area under arable crops. Shortage of labour increases the area under tree crops but reduces the area under arable crops. Thus shortage of land appears the most serious factor threatening the survival of trees and ultimately that of human beings in the humid tropics.

The productivity of arable crop farming in traditional agriculture is positively correlated with the duration of the bush fallow. Thus, as the fallow length declines, it becomes more and more difficult to produce the food necessary to sustain the population. Therefore, to reduce the role of woody species in soil fertility maintenance and erosion control is to reduce the food output of the traditional food production system (Grinnell 1975). Tree crop production systems are suited to the humid tropics, but food is essential for human survival. Thus, if self-sufficiency is deemed necessary, as in the subsistence systems common in the tropics, arable crops are essential in the farming systems.

The survey indicates that, under high population pressure, systems are evolved in which special woody species capable of restoring soil productivity with relatively shorter fallow periods are relatively encouraged to dominate the bush fallow (table 1). Farmers recognize the potential of these species, which can achieve in two to four years that which requires six to eight years under uncontrolled regeneration.

There are no clear indications that the farmers are deliberately planting special species as fallow (Benneh 1972; Okigbo and Lal 1979), but it is encouraging to know that their awareness of the effectiveness of these species may enhance their acceptance of using woody species to reduce fallow duration while increasing land productivity in the humid tropics.

**The Natural Fallow**

A natural fallow is regarded as one in which recolonization by plants occurs without the interference of humans. The normal sequence of fallow development is defined by soil and climatic factors, local plant species, the agricultural technology in use, and the duration of the fallow. The general fallow regeneration pattern in the humid regions of West Africa has herbaceous grasses and broadleaved species as dominant during the first two to three years, during which they are interspersed with seedlings, root shoots, or coppice regrowth of trees and tall shrubs. According to Okigbo and Lal (1979), where the fallow period exceeds 15 years the climax vegetation includes large trees such as Albizia gummifera, Anthocleista vogelli, Diospyros con fertifolia, Funtumia elastica, Nauclea...
(Sarcocephalus) diderrichii, Lophira alata, Brachystegia spp., Khaya ivorensis, Triplochiton scleroxylon, Ficus spp., Cola spp., Celtis spp., and Antiaris spp. Elaeis guineensis occurs frequently in the less-crowded spaces. This type of fallow occurs only in areas of low population density where the cropping period is short and the fallow period long.

**TABLE 1. Vegetation Density and Botanical Composition of Three- and Seven-year-old Bush Fallows in Eastern Nigeria**

<table>
<thead>
<tr>
<th>Species</th>
<th>Akwa Density/ha (%)</th>
<th>Ikot-Ekpene Density/ha (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3-yr.</td>
<td>7-yr.</td>
</tr>
<tr>
<td>Dialium guineense</td>
<td>48.4</td>
<td>41.0</td>
</tr>
<tr>
<td>Anthonotha macrophylla</td>
<td>27.0</td>
<td>34.6</td>
</tr>
<tr>
<td>Pentaclethra macrophylla</td>
<td>2.4</td>
<td>-</td>
</tr>
<tr>
<td>Acioa barteri</td>
<td>12.7</td>
<td>23.9</td>
</tr>
<tr>
<td>Alchornea cordifolia</td>
<td>9.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Napoleona imperialis</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>MM (unknown)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>100.0</td>
<td>100.0</td>
</tr>
<tr>
<td>Total stems/ha</td>
<td>1,008</td>
<td>1,504</td>
</tr>
</tbody>
</table>

Source: Amaza, Akukwe, Getahun, Okafor, et al. (unpublished),

**TABLE 2. Effects of Clearing Techniques on Maize Yield, Soil Erosion, and Water Runoff**

<table>
<thead>
<tr>
<th>Clearing Method</th>
<th>Grain yield maize (t/ha)</th>
<th>Soil erosion (t/ha)</th>
<th>Water runoff (mm)</th>
<th>Soil loss/ grain yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional (partial clearing of secondary forest)</td>
<td>0.5</td>
<td>0.01</td>
<td>2.64</td>
<td>0.02</td>
</tr>
<tr>
<td>Manual, complete clearing</td>
<td>1.6</td>
<td>4.64</td>
<td>54.30</td>
<td>2.90</td>
</tr>
<tr>
<td>Mechanical, complete clearing</td>
<td>1.8</td>
<td>19.57</td>
<td>250.33</td>
<td>10.87</td>
</tr>
</tbody>
</table>

Water runoff and soil erosion losses before forest clearing were minimal.  
Source: IITA 1979 (b)

Where population density is high, the fallow is short, and a new set of species is dominant in what may appear as a climax vegetation. Obi and Tuley (1973) listed the dominant species as Alchornea cordifolia, Acioa barteri, and Anthonotha macrophylla. Other abundant species include Harungana madagascariensis, Dialium guineense, and Crestis ferruginea. These are interspersed with many other species.

Among the many species that dominate natural fallows, farmers have recognized the superiority of certain species in restoring soil fertility and have encouraged these species. The preference given to some of these plants results in almost pure stands in some fallows. Benneh (1972) and Okigbo and Lal (1979) have reported planted fallows of Acioa barteri, Anthonotha macrophylla, and Alchornea cordifolia in eastern Nigeria. Observations by Kang (unpublished) at Onne in eastern Nigeria showed varying populations of Anthonotha ranging as high as 1,000 - 2,500 plants/ha. In Oyo State in south-western Nigeria Gliricidia septum dominates the fallow and could be regarded as an indirect planted fallow.

The effectiveness of trees in regenerating soil nutrients and land productivity is ascribed to their ability to absorb plant nutrients from the deep soil layers and contribute them to the upper layers through leaf litter (Lundgren 1978b; Nye and Greenland 1960). The conclusion drawn from these data is that tropical people have not yet devised systems of harnessing the nutrients derived from fallow without destroying or setting back the fallow.
The importance of trees in land management and particularly in soil-erosion control is clearly demonstrated by the results of a land clearing trial that was carried out at IITA (1979b) (Table 2). Complete removal of the tree cover and mechanical clearing greatly increased runoff and erosion.

The Planted Fallow

African farmers, renowned for mixed cropping, do not as a rule remove from their field any plants that are potentially useful. Thus a large number of the species seen in the field are not planted but are useful volunteers that are encouraged. This practice applies not only to food crop plants but also to plants that are known for their effectiveness in restoring soil fertility. The popularity of Acioa barter) and Anthonotha macrophylla in the bush fallow on acid Ultisols in eastern Nigeria does not result from direct planting but deliberate encouragement of volunteers. Farmers do not destroy the seedlings of these species, and this preference leads to their dominance in the plant population. In south-western Nigeria, especially around the city of Ibadan, farmers claim Gliricidia septum is an effective fallow species which restores land productivity for food crops after a fallow of only two years. Though the species was planted by farmers who have since accepted it as an effective soil-restoring plant, there is no evidence to suggest that it was ever deliberately planted for soil improvement. G. septum is usually established when green stems are used as yam stakes. These stakes grow, eventually providing the fallow that is maintained in a slash-and-burn system in which the base of the tree is never completely destroyed. Since G. septum readily coppices, it re-establishes itself once the pressure from cropping is removed.

Where planted forest becomes a part of the rotation, as in taungya systems in West Africa, farmers have reported their willingness to follow Gmelina arborea and Cassia siamea with food crops but have avoided lands that were planted to Tectona grandis. (See the paper by Kio, Bada, and Okali in this volume, pp. 108-110.)

Dilkman (1950) reported that prunings from the tree Leucaena leucocephala are traditionally laid among crops in Indonesia to provide nitrogen and that 1 ha of Leucaena provides nitrogen equivalent to that of 1 ton of sulphate of ammonia. Work in Hawaii (Guevarra 1976) has shown that 500 - 600 kg N/ha can be harvested from the foliage of L. leucocephala. Juo and Lal (1977) found that L. leucocephala was as effective as naturally regenerated fallow in restoring soil organic carbon and exchangeable cations. In addition to the nitrogen yield, the dry matter yield has an important role in preventing soil erosion when it is used as mulch. The nitrogen supplied by the leaves is the result of biological nitrogen fixation, as neither leaf nor nitrogen yield was affected by applied nitrogen (Kang et al. 1981). In a study of a single harvest at the start of the rains, the tree Gliricidia septum was shown to produce less leaf dry matter and nitrogen than the shrubs Cajanus cajan and Tephrosia candida (Wilson and Kang 1980). The low yield from G. septum resulted from its deciduous tendency, as the leaves are shed toward the end of the dry season.

Though there are many reports on the effectiveness of herbaceous fallow in the tropics (Webster and Wilson 1966), very little scientific information exists on the use of tree falls. Jaiyebo and Moore (1964) have demonstrated that a bush fallow is more effective than legume or grass cover crops in nutrient recycling and in increasing soil organic matter.

Guevarra (1976) examined the possibility of intercropping L. leucocephala with maize and concluded that reasonable maize yields could be obtained when the L. leucocephala prunings were used as fertilizer. We (Wilson and Kang 1980) have developed the "alley cropping" concept in which food crops, usually cereals and legumes, are grown in narrow alleys formed by fallow species (usually shrub or tree legumes). During the cropping period, the fallow is suppressed by regular pruning. This system is regarded as an improved bush fallow in which the fallow is formed by selected species and arranged to facilitate easier planting and crop maintenance, especially with mechanization. Though maize yields have not been as high as they are when inorganic fertilizers are added, crop performance in alley cropping indicates that sustained yields are obtainable in what appears to be a relatively stable system.

Maize-leucaena alley cropping at IITA has thus far proved to be successful on the Alfisols. On the acid Ultisols, where Leucaena has not grown well, other tree fallow species are being tested for inclusion in the alley-cropping system.

Though alley cropping appears feasible, there are fears that farmers accustomed to cleared land may not accept trees in their fields. In addition it may be some time before equipment is developed for the mechanization of the operations associated with alley cropping. To overcome these problems, IITA is looking into the development of a cut-and-carry form of fallow management. In this system the fallow species would be grown on land unsuitable for arable cropping. The leaves and other prunings would be harvested regularly and transported to arable lands where
they would be used as mulch and nutrient sources.

The alternative concept of establishing forest trees among food crops and continuing to crop the interrow spaces between the trees until the tree canopy closes could be regarded as a form of alley cropping in which suppression of the tree species occurs only after certain periods, say five to ten years, and regular pruning is not done during cropping.

With the shear-blade method of clearing land under tree fallow and with minimum tillage planting techniques, it is now possible to recover land from tree fallow and to establish certain crops without disturbing the soil. With these innovations, trees in the rotation may no longer be regarded as serious limitations to mechanization and largescale crop production in the humid tropics.
Forest conservation strategies for tropical Africa

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Abstract

Recent interest in agro-forestry practices has been generated against a background of rapidly deteriorating problems of forest exploitation and conservation in all forest ecosystems in Africa. The continent is faced with the possibility of timber and fuelwood scarcity towards the end of the century. Conventional methods of forest regeneration, such as improved natural regeneration, associated with less wasteful logging techniques, accelerated industrial plantation programmes under public and private ownership, and fuel plantations sited near urban centres, are ways of combating the problem of fuelwood and timber shortage. The best approach is through universal application of the agro-forestry system so that forest destruction is arrested at the source. Intensified agro-forestry research is required to anticipate the difficulties arising from the radical changes that the adoption of agro-forestry will induce in the life-styles of rural communities.

Introduction

The 1980s may witness widespread disasters arising from the misuse and over-exploitation of forest resources in the African region. Yet, for thousands of years and until the middle of the nineteenth century, human beings had little or no impact on the environment. A rich and varied vegetation, dominated by trees and an equally heterogeneous fauna, developed and maintained itself within a complex ecosystem—a balance between plants, animals, and the physical environment. In particular, the diversity of the African tropical rainforests and the rich genetic pool they contained provided a resource of vast potential that the metropolitan powers were later to recognize and exploit with little or no regard for their conservation.

Currently, the timber-rich zones of West and Central Africa contrast sharply in utilization and conservation patterns with those of the wildlife-rich zone of East Africa. In North Africa, desert and sub-desert conditions predominate north and south of the Tropic of Cancer. All the regions are faced with diminishing resources because of forest degradation, human and animal population pressures, mismanagement, and other forms of exploitation. It has been predicted that within the next 30 years, unless adequate measures are taken, most of the humid tropical forests will be transformed into unproductive land, and the deterioration of the savanna into desert will be accelerated.

Forest Destruction

Traditional agriculture in most parts of Africa has been shifting cultivation. This involves clearing a small piece of land by felling and burning most of the vegetation in the natural forest, secondary forest, or savanna woodlands. The area cleared is farmed for a few years (two to four, depending on the soil and climate) and is then abandoned to bush fallow. The disused farm land is gradually invaded by trees—at first by short-lived pioneer species, springing up amidst a tangle of creepers and shrubs, and eventually by true forest trees. Many years later the same, or another, farmer clears the area of secondary forest and harvests good crops for a few years before moving to another piece of mature or secondary forest. Many agronomists and soil scientists claim that this farming system has proved well adapted to the environmental conditions of most of tropical Africa (Nye and Greenland 1960). However, once population density reaches and exceeds certain critical limits, the fallow periods diminish and the soil-microfaunawildlifevegetation matrix that protects sensitive ecosystems suffers, perhaps irreversibly.

Obviously, in the process of eking out a meagre subsistence, shifting cultivators lay waste vast natural resources. Valuable timber trees are cut without being properly utilized. Foresters have long argued that shifting cultivation ought to be replaced by a more sedentary system. For instance, it is estimated that in the last 25 years tropical Africa has lost 100 million ha of moist forest to shifting cultivators, and the current loss is of the order of 400,000 ha/year (UNEP 1980).

Forest degradation is sometimes the least of the consequences arising from shifting cultivation. On sensitive sites, over-intensive utilization can damage the soil for long times, as visitors to the Agulu gullies in Awka Division of Anambra State in Nigeria can readily verify. Effects are especially pronounced in dry environments where the vegetation tends to recover more slowly than in moist environments. Protracted cultivation keeps the ground bare and vulnerable to wind and water erosion.
Fire is an important element in the conversion of the natural forests into simpler ecosystems. It is used in the first instance as a means of releasing some of the nutrients locked up in the biomass, and for creating a clean environment for the agricultural crops. In a dry climate, frequent use of fire kills fire-sensitive species of trees and shrubs and creates favourable conditions for the invasion of grass species, particularly Imperata cylindrica. Dry savannas provide very important pastures, but over-grazing threatens the natural pastures in Africa and, indeed, in the entire tropical world (Persson 1977).

Fuelwood and charcoal account for more than 90 per cent of wood consumption in Africa. The cutting of trees for fuelwood occurs in all ecological zones and does not adversely effect the environment as long as natural regeneration is possible and the population density is low. In many areas, the present population is so large that the existing wood resources are over-exploited. In many parts of Africa misuse of the bush and over-exploitation have led to complete disappearance of the wooded vegetation. In and around urban centres, shortages of fuelwood occur even in humid zones.

The level of nutrition of a community is sometimes linked to fuelwood availability and costs. It is claimed that there are now places in the Sahel where fuel (petroleum products, firewood, and charcoal) has become so expensive that it absorbs about half the budget of some of the poorer families (Poulsen 1978). With extensive deforestation, villagers are forced to walk long distances to collect firewood and eventually are tempted to substitute dried cow dung and crop residues for firewood, with serious consequences for local agriculture. Even in oil-rich countries, such as Nigeria, rural households that have not invested in modern oil- or gas-burning stoves purchase firewood in preference to kerosene, which in some parts of the country is half the price.

Apart from the deterioration in the quality of life associated with forest degradation, there are other more insidious effects that endanger the future of human beings on this planet. For instance, climate is determined by physical factors near the earth's surface, set in motion by the sun's energy. Vegetation influences the earth's surface in two ways: by reducing wind velocity and by intercepting the sun's radiation (albedo). But climate is one of the main vegetation-forming factors, causing differences in the vegetation cover of the earth. This relationship suggests that a feedback mechanism exists and that changes in vegetation, including those induced by humans, may result in irreversible changes in climate.

The Forest Resources

Vegetation type is mainly determined by climate, soil, and anthropogenic factors. In Africa the moist forest at low and medium altitudes is concentrated in Central Africa. It extends from the Congo Basin to southern Nigeria. A gap occurs in Togo, Benin, and south-eastern Ghana, and it then continues westward to Sierra Leone. The extent of the moist forest is about 256 million ha, of which 76 per cent (194 million ha) is found in Central Africa (Persson 1977) and 19 per cent (48 million ha) in West Africa.

This forest type occurs where the monthly mean temperatures rarely fall below 25 C, the mean annual rainfall is always in excess of 1,500 mm, and there is at most a short dry season.

The forest-savanna mosaic forms a belt around the moist forest. The drier part of the moist forest is described as semideciduous, and, in West Africa, it tends to be richer in desirable timber species than the true moist or rain forest. Shifting cultivation has destroyed the major part of the dry forest. The intermediate stage in the final degradation of the original continuous belt of semi-deciduous forest is the formation of a patchwork of high forests and savanna woodlands.

The savannas, both moist and dry, cover a total of 988 million ha, or 42 percent of the land area in Africa. Many ecologists believe that the areas now occupied by moist savanna were once covered by semi-deciduous forests that have been transformed artificially into savanna by centuries of shifting cultivation and annual fires. The limit for fire-induced savanna is believed to coincide with those areas enjoying three dry months or, alternatively, with those areas receiving an annual rainfall of 1,250-1,500 mm. Some remnants of the original forest remain, for example, in the Casamance region in Senegal and the Mambilla Plateau in northern Nigeria.

The moist savannas in West Africa are known as Guinea savanna, and the drier ones are designated Sudan savanna. Miombo woodland is found south of the equator, particularly in Tanzania, Zambia, and Zimbabwe. When protected from fire, the Miombo woodlands develop the characteristics of tropical high forests, particularly by the presence of climbers and dense herbaceous and shrub layers. Kalahari woodland occurs as a broad belt in the western part of Zambia and continues into the Kalahari sands of Angola. Mopane and Munga woodlands occur in the dry savanna south of the equator.
Wooded steppe with abundant Acacia and Commiphora is found between the dry savanna and semi-desert. It is characterized by the occurrence of widely scattered trees, and is typically known as Sahel vegetation in West Africa, where low thorny trees are the dominant woody plant. Unlike the savannas, over-grazing by animals is considered to be more a causal factor than is fire or shifting cultivation.

Grasslands occur as patches amidst moist and dry savannas and are predominant in steppes. Extensive grasslands occupy the central part of Madagascar, western Zambia, and eastern Angola.

The Mediterranean region has hot dry summers and cyclonic winter rains. Most of the vegetation in the region has been degraded over millennia. After being burned and over-grazed, particularly by goats, the forests disappear completely. Maquis scrub occurs both in dry and moist areas, and this is normally regarded as a degraded form of denser associations.

**Management and Use**

In terms of potential for forest management, only the moist forests, semi-deciduous forests, and the savannas are worthy of detailed consideration. Apart from about 2 million ha of natural softwood forests that occur in East Africa (mainly in the highlands of Kenya and Ethiopia), the natural forests of forestry importance can be grouped into closed hardwood and open hardwood (table 1). Each group can be subdivided on the basis of whether or not it can be intensively managed, that is, whether or not it is immediately operable.

Of the total productive forests of 466 million ha, 57 per cent, or 264 million ha, lie in Central Africa, whereas West Africa accounts for only 12 per cent (58 million ha). If the productive closed hardwood forests alone are considered, 115 million ha of a total 134 million ha are found in Central Africa. Central Africa, thus, has by far the most important forest resources in the continent, and West Africa now has relatively limited forest resources in relation to the present rate of exploitation.

Field studies undertaken in June 1980 have shown that timber production will rely increasingly on the reserved forest estate (Kio 1980). It is estimated that between 1990 and 2000 most of the timber outside the forest estate will have been extracted in Cameroon, Ghana, Kenya, and Nigeria.

The proportion of timber currently extracted from unreserved forest varies from less than 20 per cent in Nigeria to about 90 per cent in Cameroon. Of the six countries studied, only two (Cameroon and Ghana) exported more than half their total timber output. The others (Kenya, Nigeria, Tanzania, and Zambia) consumed virtually all their timber output internally.

The continent is faced with the possibility of timber and fuelwood scarcity toward the end of the century. What attempts are being made to alter the trends? By applying already available knowledge, by filling in crucial gaps in the understanding of the various ecosystems by well-directed research, and by recognizing the limitations imposed by the fragility of the African soils, this continent can arrest natural resource destruction and greatly increase production of natural raw materials.

Silvicultural treatment of the moist savannas of West Africa and Miombo woodland of East and Central Africa has consisted of protection from fire and thinning of mall-formed and over-mature trees. Harvesting is by clear-felling, and regeneration by coppice regrowth. This approach appears to be adequate, as the main products (pit props, particularly in Zambia, poles, fuelwood, and, in rare cases, sawn timber) can be more economically harvested through clear-cutting.

**TABLE 1. Estimated Areas of Natural Forests in Africa in 1975 (in million ha)**

<table>
<thead>
<tr>
<th>Subregion</th>
<th>Closed hardwood forests</th>
<th>Open hardwood forests</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Productive</td>
<td>Inoperable (operable)</td>
<td>Productive (operable)</td>
</tr>
<tr>
<td>Northern savanna</td>
<td>0.02</td>
<td>0.16</td>
<td>10.43</td>
</tr>
<tr>
<td>West Africa</td>
<td>12.13</td>
<td>1.95</td>
<td>45.94</td>
</tr>
<tr>
<td>Central Africa</td>
<td>115.36</td>
<td>55.29</td>
<td>148.43</td>
</tr>
<tr>
<td>East Africa</td>
<td>6.31</td>
<td>10.57</td>
<td>105.99</td>
</tr>
<tr>
<td>Tropical South Africa</td>
<td>0</td>
<td>0</td>
<td>21.72</td>
</tr>
<tr>
<td>Totals</td>
<td>133.82</td>
<td>67.97</td>
<td>332.51</td>
</tr>
</tbody>
</table>
Complex natural ecosystems, such as the moist tropical forest, with their many species and rich interaction structure, are in general dynamically fragile. Phenological changes tend to be distinctive for each species and occur over a very short time. Silvicultural and management treatments of the closed forests seem to alter the direction of the natural succession attributable to non-human phenomena. For these treatments to succeed, the largely unsolved problem of ensuring adequate regeneration following exploitation must be tackled. This requires detailed knowledge of flowering and fruiting sequences, of the processes and conditions of germination, establishment, and ensuing competition and growth of the desirable species.

The issue of natural regeneration of the moist closed forests is central to the problem of forest degradation and conservation in Africa. All silvicultural systems applied to tropical moist forests attempt to simplify the composition of the forest so that the stands are considerably richer in economic species after exploitation and treatment than before such operations. The methods include those of improving Aucoumea klaineana, Terminalia superb, Triplochiton scleroxylon, and similar forest stands in the Ivory Coast, the shelterwood system of Nigeria, and the selection system in Ghana. These techniques differ in their exploitation regimes. The Nigerian shelterwood system theoretically involves clearfelling with shelterwood regeneration to create a more or less uniform forest by a combination of intensive exploitation and clearance poisoning of shade-casting uneconomic trees in the middle and lower storeys. In reality, clear-felling as such has never taken place due to a highly restricted list of desirable species. Residual stands were so heavily wooded that higher volumes have been known to be removed in subsequent intensive exploitation than under the first exploitation.

As a result of the limited success and difficulties experienced with natural regeneration and the spectacular achievements of certain plantations such as Eucalyptus spp., Gmelina arborea, Tectona grandis, and Pinus caribaea, many foresters have proposed that natural forest should be replaced by predominantly monospecific plantations. This proposal gathered momentum after the World Forestry Congress at Buenos Aires in 1972 and is sustained by the readiness of international financial institutions to provide huge loans for plantation projects and their reluctance to finance natural regeneration programmes.

The consequences of the removal, modification, or transformation of substantial areas of moist forests in Africa are being publicized in national and international forestry conferences. An extensive bibliography is building up on the need to exercise caution and restraint in the exploitation and treatment of the tropical forests. It remains to be seen whether the traditional despoilers of the continent's natural resources will heed these warnings.

**Outlook**

Various studies have shown that, with the possible exception of Zaire, Cameroon, and Congo, the natural forests of most countries in Africa will be unable to meet the domestic demand for wood-based products by the beginning of the 21st century. The establishment of plantations in all suitable vegetation types (not necessarily only moist closed forest) is one way of meeting this huge demand. The species chosen should be fast-growing and high-yielding, and the wood product should be homogeneous in both size and quality in order to meet the specifications of particular industries. However, the main disadvantages are the dangers of monoculture and the loss of rich natural forests if the plantations are not carefully sited. Every large-scale plantation project that neglects the need to diversify species and to conserve some natural forests, both in the untouched state and under intensive management, may in the long run prove disastrous.

It is often argued that the growth of world population, including that in Africa, is leading to a demand for food, space, and raw materials so great that it can only be met by exploiting the area now covered by forest for living space for people, for growing food and raw materials, and also for industry (Poore 1976). Uncritical acceptance of this view implies that the disappearance of most of the closed moist forests is inevitable. However, a careful evaluation of the circumstances of natural-resource utilization shows that the disappearance of natural forests is only unavoidable if no effort is made to change the factors and policies that have in the past led to the abuse of these resources.

Problems associated with forest degradation cut across national boundaries, and only internationally co-ordinated programmes of control and amelioration can stand a chance of some measure of success. First, forest policies that emphasize rational utilization of resources should be harmonized throughout the continent. Second, every country should improve the management of the forest estate, including legal protection of reserves against encroachment, make an inventory of all the forest resources, improve the training of personnel, and establish an effective administration supported by adequate and timely financial allocations to forest services. Third, the strategy for development of tropical forests should be based on a careful balancing of ecological and economic considerations.

Source: Data by Lanlv end Clement (1979)
The major obstacles to good forest management are the lack of national and local institutions able to design and enforce proper strategies, and the disregard for the role of forestry in development.

Fourth, in spite of recent happenings in Chad, Niger, Senegal, and Gambia and in spite of the involvement of foreign elements in the recent Kano riots, regional economic groupings must be fostered for both economic and political reasons. Integration may become an important instrument for economic growth of subregions or the African continent as a whole. Removing barriers to the free movement of goods, labour, and capital within a region almost inevitably leads to the expansion of trade and, consequently, of incomes and employment.

Larger economic units, with their larger markets, permit economies of scale in production and justify the establishment of forest enterprises previously considered too costly. Resources and capital tend to move freely to the most productive areas with their larger markets and thereby stimulate further gains in production. Similarly, cheaper and more efficient transportation systems may result. The larger markets emanating from integration should attract more substantial foreign investment (Eken 1979). Especially in Africa, where forest resource endowments vary greatly from one country to another, the establishment of subregional economic groupings is the only way to strengthen collective self-reliance as an insurance against political subservience to metropolitan powers and against external subversion.

Finally, the practice of agro-forestry holds the key to the containment of shifting cultivation by replacing its destructive features with a system of land rotation that combines the simultaneous production of agricultural and tree crops. Much research into the various aspects of agro-forestry is in progress but is, at present, unfocused, and the role of the uneducated peasant farmer with little access to modern agricultural and forestry inputs is hardly defined in the schemes being suggested.

If socio-economic research is combined with the research strategy suggested by Lundgren (1979), greater progress is likely to be achieved: The suggested agro-forestry research strategy is:

- Identification of interrelations between soils and crops, including the monitoring of the soil over at least one rotation, quantitatively monitoring the effects of different tree crops in terms of inputs and outputs of nutrients and organic matter in the system during the rotation, assessing the importance of catenary gradients on research methods, and finding more or less self-maintaining land-use systems (that is, research must have a strong resource-conservation base);
- Identification of short- and long-term aims of soil management, including the importance of mulch cover and its duration; the maintenance of soil organic matter; the maintenance of dense and efficient top-soil feeder root systems; and the minimization of burning to prevent nitrogen and organic matter losses;
- Synthesis of the state of knowledge of soil-crop relations relevant to agro-forestry; and - Identification of problems and bottlenecks particularly related to the study of soils in agro-forestry.

For greater effectiveness these research programmes have to be co-ordinated at subregional and regional levels by the establishment of appropriate machineries for consultation, collaboration, and dissemination of research information. Coordinated research throughout the African region, at least in so far as research into conservation and agro-forestry problems is concerned, will minimize wasteful duplications and produce results that truly reflect conditions in the ecosystems studied.

Impact of agricultural systems and rural development on Nigerian forests

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Abstract

Agriculture is still the dominant means of livelihood in Nigeria, even though urban areas are growing rapidly in size and the rural-urban income and services gap is widening. The different types of traditional farms are discussed, with special emphasis on forest-farm interactions. The sequence of agricultural intensification from shifting cultivation to sedentary agriculture in south-western Nigeria is defined, with special reference to the woody and perennial species of compound farms. Possible alternatives, such as specialized horticulture and animal husbandry, are briefly reviewed with regard to their impact on the tropical rainforest. Recommendations are then made regarding the future course of agricultural development.

Introduction
As three-dimensional units of the biosphere, forests constitute biomass in which the climax vegetation is dominated by trees. The tropical rainforest is the climax vegetation in areas of constantly high temperatures, humidity, and rainfall, precipitation usually exceeding evapotranspiration for more than half the year (Bene et al. 1977). About 27 per cent of the world's tropical rainforest is located in Africa (Bene et al. 1977), and the tropical rainforest is estimated to amount to 31 per cent of the forested area of Nigeria (Redhead 1970). It usually consists of a plant formation of marked diversity of species-most of which are trees in association with shrubs and herbs arranged in a number of strata within which there are mechanically dependent climbers, stranglers, and epiphytes in addition to heterotrophs (saprophytes and parasites), all of which under normal circumstances are in equilibrium with their environment through competition, interdependence, and complementarily (Richards 1952; Walter 1971). As a unit of the forest eco-system, the zonal tropical forest, although closely related to the climate, soil, and rainfall of the region, may vary in species composition, extent of development, and physiographic features as a result of edaphic factors.

An agricultural farm or farming system consists of an enterprise or business in which sets of inputs and resources are uniquely orchestrated by the farmers in such a way as to achieve one or more desired objectives in a given environmental setting (Okigbo 1978). In the Nigerian context, the farm may be an enterprise or activity of one or more individuals-usually a family unit-with all or only some members participating for part or most of the time in farm work. In the complex traditional farming systems of tropical Africa, a specific farm system consists of one or more subsystems, each of which is differentiated from others in terms of the physicochemical (soils, water, climate, nutrients), biological (crops, plants, animals, pests), socioeconomic (labour, markets, preferences, religion), technological (tools, machines, practices) and managerial (knowledge, decisionmaking) elements involved. Consequently, a given agricultural system or subsystem is location specific in terms of sets of the elements that are involved in relation to the objectives to be satisfied.

Although the annual rate of urban population growth in West Africa is more than 5 per cent, the Nigerian population remains essentially rural, with only 12 per cent of the population estimated to be in towns of more than 20,000 (Unesco 1976). During the colonial era and, especially, since independence, pressures of modernization have resulted in high priority being given to industrialization and development of the non-agricultural sector of the economy. Agriculture, which is the dominant occupation and way of life of more than 80 per cent of Nigeria's population, has also undergone significant changes and development resulting from colonization, population pressure, introduction of new crops and techniques, and increasing commercialization. Changes in non-agricultural and agricultural activities involve interaction of environment, economy, and society that give rise to resource and environment issues (Knight and Newman 1976; Knight 1976). As a result of higher priorities being given to the industrial and non-agricultural sectors, higher incomes resulting therefrom, and probable greater complexity of the biological processes involved in agricultural production, much less progress has been made in agriculture. Consequently, the gap between rich and poor, and between rural and urban centres, is growing. Rural development is the process of redressing this imbalance by improving the quality of life and the rural environment through increased efficiency in management and utilization of resources. Development and modernization activities in agriculture and rural development vis-a-vis those in industrial and non-agricultural sectors may be competitive, complementary, or both. All the activities involved may have adverse effects on the forest ecosystem.

**Farming Systems and the Forest Ecosystem in the Rainforest Areas of Nigeria**

According to Okigbo and Greenland (1976), a simplistic model of traditional farming in the rainforest areas of Nigeria would regard each family farm as consisting of a more or less concentric pattern of fields on which are practised various methods of fertility maintenance or fallows, clearance systems, production of various species of crops, and cropping patterns and sequences (fig. 11. Each field differs in the length of fallow, number of arable crop species grown, and distance from the compound farm. The farther the field from the compound farm the longer the period of fallow, the fewer the arable and other crops cultivated, and the more protected or useful wild plants are selectively left dotted about the field during clearing.

Unlike farms of developed temperate countries, farms of the humid tropics of West Africa are extremely complex. A typical farm family may operate a compound farm, several field systems of arable food or export crops, patches of tree crops and vegetable crops under peculiar topographic situations, and non-food crops intercropped with the food crops. The same farm family may carry out floodland agriculture close to a river or stream in addition to always having animal production in the compound farm and adjacent areas in association with crop production.

**FIG. 1 Schematic Diagram of Compound Farms in Relation to Associated Fields in Traditional Farming Systems of the Humid Tropics of West Africa**

Hunting and gathering continue to be associated with agricultural production in present-day Nigeria. However, the extent of dependence on hunting, fishing, and the gathering of wild plant products varies considerably from one...
location to another in relation to population pressure and resultant adverse effects on forests and wildlife.

Richards (1952), Adejuwon (1971), and Whyte (1974) have observed that initial degradation and disruption of forest ecosystems result from clearing and cultivation, but usually the forest vegetation regenerates itself during a prolonged period of fallow. This, according to Nye and Greenland (1960), may take more than five years. The extent to which the cleared forest develops into a savanna woodland with a high proportion of graminaceous species depends on how frequently fires are applied to the vegetation. Sometimes mining activities or sheet erosion may also produce similar effects to frequent fires.

Okigbo (1977) listed bush clearing, burning of vegetation, fallowing, preplanting cultivation, manuring and fertilization, weeding, cropping patterns, grazing, restriction of livestock, and harvesting practices as the human activities that are associated with different farming systems. These practices determine the extent of erosion hazard associated with the farming systems, nature and magnitude of modification of vegetation cover, land use and eventual cultural landscape of a region.

In general, regular cultivation of arable crops is detrimental to forest regrowth unless long periods of fallow are involved in the land-use cycle. The different practices associated with different farming systems determine the magnitude and type of erosion that will occur and the adverse effects of soil-plant-water relations that may result in soil degradation. The effects may not be limited to the farmland where the practices are used but may extend to adjacent non-farmlands.

In the humid tropics, where population density is low, long periods of fallow result in secondary forest vegetation that usually never matures due to continuous sequences of clearing and cultivation. Classical shifting cultivation in which homesteads periodically move with the fields and forests become easily re-established after each cropping phase is no longer found in the rainforest region of Nigeria because of prevailing relatively high population densities. Even when fallows are long, the introduction of mechanical clearing results in poor forest fallow establishment.

**Shifting Cultivation and Compound Farms**

The bush-fallow system is a modern version of shifting cultivation; it results in isolated patches of secondary bush at various stages of regeneration. The climax vegetation attained never reaches the same level of maturity as in the earlier version in which fallows are longer. However, since this is associated with sedentary culture, compound farms become more developed and approximate secondary bush conditions. Usually selected numbers and species of trees grow on both compounds and outlying fields, but the proportion of trees may be much less than 50 per cent of the plant species growing per unit area. This farming system results in gradual replacement of forest ecosystems with compound farms and more open fields at various stages of secondary bush regrowth.

In rudimentary sedentary cultures compound farms are usually well-developed, and, although the compound farm has a much lower diversity index, it approximates rainforest ecosystem conditions where rainfall, soil conditions, and farm practices permit. Crop production on field systems associated with the compound farm is usually more intense than in shifting cultivation and bush fallow, and protected trees and shrubs on outlying fields may be less in number per unit area. This also results in isolated compound farms with a mosaic of selected tree crops and arable crops interspersed with more open fields of arable crops, with the fields becoming completely devoid of trees and shrubs where more modern farming techniques and machinery are used.

In intensive sedentary agriculture or compound farming, the compound farm system is most highly developed, and fertility is maintained by the use of household and compound refuse and concentration of plant residues from surrounding farm and fallow land. In south-eastern Nigeria, the animal population increases with population density, with the animals also involved in nutrient recycling. Several compound farms and adjacent fields may coalesce to form oil palm or secondary bush ecosystems that cover large areas of land. This accounts for much of the oil palm bush in south-eastern Nigeria.

**Terrace Farming and Flood Plain Agriculture**

Terrace farms are farms that are built on defensive hillsides on Bauchi Plateau, Adamawa Highlands, and in the Maku area of Awgu Division in Anambra State. Tree crops are abundant in the valleys, on some steep uncultivated slopes, and in compound gardens. The terraces are usually used for growing arable crops, high-value vegetable crops, and minimal tree crops. Usually, population density is very high and not much falling of more than two years is practiced.

Flood plain agriculture depends on alluvial deposits to maintain soil fertility. Farmers on banks of major rivers race
against floods in harvesting their crops. Usually forests are unable to develop on the flood plains because of the periodic inundation.

**Mixed Farming**

Mixed farming involves the keeping of livestock in association with crop production. Classical mixed farms with large animals used for work and transportation are limited to the savanna. Most traditional farming systems are mixed farms involving various numbers of small animals. There is always danger of over-grazing, forest clearing, and fires, since no efficient system of growing browse trees and shrubs for regular and intense small livestock production has been developed. Some of the most eroded and gullied areas of Anambra State are areas where both dwarf cattle and small animals are kept on land with physiographic features favourable for serious erosion when there is inadequate vegetation cover.

**Intensive Livestock Production**

Intensive keeping of poultry, pigs, and dairy cattle is also practiced. Poultry do not pose a serious hazard to vegetation cover except insofar as forests may be cleared for arable crops, such as maize, for poultry feed. Intensive production systems for pigs and cattle involve the growing of arable crops for feed and maintenance of pastures. Since these crops are generally under continuous cultivation, forest cover is usually totally removed. However, efficient pasture and crop management is necessary to maintain high levels of productivity without continuous clearing of more forest land.

**Large-Scale Plantations and Tree Crops**

Large-scale plantations and tree crops result in the replacement of the high species diversity of the tropical rainforest with monocultures of tree crops or mixtures of two or more tree crops, such as in the growing of coffee or cocoa with shade trees. Unless soil fertility is low and fertilization is not practiced, vegetation approximating forest formations usually develops. Poor mechanical forest clearing prior to plantation establishment may result in irreversible degradation of soil, failure of the plantation, and take-over of sites by weeds such as Eupatorium odoratum.

**Specialized Horticulture**

Specialized horticulture may involve production of tree crops or ornamentals that may be trees or shrubs and are similar in physiognomy to plantations. Intensive vegetable production usually involves permanent cultivation and initial removal of forest cover. Manuring and fertilization are usually practiced, but where adequate soil conservation measures are not taken, deterioration of farmland under permanent cultivation may threaten forests on land adjacent to the vegetable or ornamental plant gardens.

**General Observations on the Impact of Farming Systems and Rural Development on Rainforest Ecosystems**

The impact of human activities on vegetation, of which the tropical rainforest is but a part, is dependent on the extent of intensification of agricultural production and economic activities including clearing, grazing, burning, forest exploitation, hunting, gathering, mining, etc. In the humid tropics, agricultural systems, as they become intensified and commercialized, involve permanent cultivation and continuing extension of areas under cultivation except to the extent that tree crops are grown in plantations and compound farms. With the exception of savanna-like woodlands and grasslands that are found within the climatic climax areas of the tropical rainforest as a result of certain physiographic and other factors (Adejuwon 1968-1971), only isolated forest reserves amounting to about 2 per cent of the land area of Nigeria approach the primary undisturbed forest ecosystem. Even these remnants are threatened by rapid exploitation without an assurance of effective reforestation. Consequently, along latitudes 6 - 7.5°N, and even below this zone, high population densities and agricultural activities have culminated in the rainforest being replaced by secondary bush. In most of southeastern Nigeria this consists of oil palm bush and natural or planted bush fallows at different stages of regeneration, depending on the number of years after the last cultivation phase.

Fully developed bush fallows, five to ten years old, in southeastern Nigeria consist of shrubs, young trees, some grasses, and herbs. The canopy height ranges from 2.5 to 5 m, with Alchornea cordifolia, Acioa barteri, and Anthonotha macrophylla as the dominant species; abundant species include Harungana madagascariensis, Dialium guineense, and Crestis ferruginea, and some 60 other species (Obi and Tuley 1973). Occasionally fast-growing emergents and indicators of secondary forest regrowth such as Musanga cecroploides and Anthochleista spp. exceed the more or less uniform highs of around 3 - 5 m. Where over-cultivation and loss of soil fertility have occurred, a mixed grass and herbaceous dicot flora develop in which the dominant species may be Eupatorium odoratum, Panicum maximum, Andropogon tectorum, Mikania cordata, legumes such as Centrosema and Pueraria, Imperata...
cylindrica; and successions involving Melinis minutiflora, Pennisetum pedicellatum, Axonopus compressus, Schizachyrium brevifolium, and Brachiaria spp., culminating later in the appearance of Pteridium aquilinum (Obi and Tuley 1973) in certain locations. Bush fallows are most highly developed outside the compound farms with an agro-ecosystem consisting of useful trees such as the oil palm, coconut, Cola spp., etc.

Usually the compound farm contains plants that, under natural circumstances, do not occur together—such as Pandanus candelabrum and Raphia spp. Some of the trees on compound farms provide support for useful woody climbers such as Landolphia owariensis, Tetracarpidium conophorum, and even Strophanthus spp. for medicinal purposes. The compound farm system in Bendel State resembles those of south-eastern Nigeria, but generally the oil palm and planted or bush fallows are replaced by thicker forest or secondary forest fallows. There are still large areas of secondary bush with trees of over 20 - 30 m. In Bendel State there are tree crop plantations of oil palms, rubber, and, to some extent, cocoa. In Ondo, Ogun, and Oyo states there are cocoa and cola nut plantations but urbanization is more pronounced and complex compound farm systems are not as elaborate as in south-eastern Nigeria. Some of the cocoa plantations carry shade trees such as Albizia spp. and Terminalia spp.; newly established cocoa plantations may have plantains intercropped with the cocoa. In the outskirts of urban centres and in rural areas, the compound farms involve complex tree crop intercropping systems in which cocoa, citrus fruits, coffee, cola, mangoes, and bananas are grown.

Thus, traditional production systems are being replaced by rotational bush fallows and semi-permanent and permanent cultivation systems. Therefore, the cultural landscape in most of the tropical rainforest area of Nigeria is one in which the zonal vegetation of evergreen and deciduous forest is fast disappearing as increased agricultural production is attained by increasing land area under cultivation at the expense of the forest ecosystem. In addition, the management of forests in Nigeria and their exploitation leave much to be desired.

**Recommendations**

Increased food production is vital to Nigeria's economic progress and the feeding of its rapidly increasing population cannot be effectively achieved and sustained on the basis of technology that is limited to increasing land area under cultivation. A suitable strategy should involve packages of improved agricultural production technology that increase productivity per unit area on small farms and enhance multiple land use. There is need also to develop permanent food production systems that effectively reduce the periods of fallow, thus releasing more land for agricultural production and other uses, including forest plantations. Moreover, agricultural development, industrialization, and rural development should, as a matter of policy, be planned and executed as an integrated whole with the objective of achieving efficient resource management and utilization with minimum adverse effects on the environment. One way of achieving this desired goal is through integrated land development, whereby watersheds are used as units in agricultural development in such a way that various crops, including tree crops, are grown in the different toposquences to which they are best adapted.

All the above would require that in education, training, and research, efforts are made to ensure that cultural practices which have adverse effects on the environment, such as the scraping away of vegetation from compounds, markets, and army camps, are eliminated, while ecologically sound traditional practices, such as certain aspects of intercropping on small farms, are retained and scientifically improved. The present cultural landscapes in many parts of Nigeria are culminations of interactions between humans and environment. Continuous monitoring and evaluation of effects of human activities on the forest ecosystem are necessary if timely and effective interventions are to be undertaken for maintaining favourable environmental quality while achieving rapid general economic and rural development.
Crop mixtures in traditional systems

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Abstract

The traditional cropping system is stable because it is adapted to the farmers' level of technology and the soils' capability. It incorporates mixed cropping and bush fallow, and it gives a high total return per unit area of land. Furthermore, growing crops in mixtures is consistent with the farmers' goal of security. Their present systems have evolved naturally as an answer to the challenging environment in which they live.

Researchers have been hesitant to tackle multiple cropping experiments in general, and agro-forestry in particular, because of the infinite combinations possible, lack of knowledge about existing systems, and the traditional separation between agriculture and forestry. Also, multiple cropping is associated with unmechanized farming and low productivity; research in intercropping and multiple cropping should be geared to increasing the productivity and returns in both arable crops and forest products. The peasant farmers' system of agro-forestry should be improved upon, and researchers should evolve a combination of arable crops and fast-growing trees that can be easily adapted by smallholder farmers.

The traditional cropping systems will continue until an alternative is evolved that can fit into present technology, environmental constraints, and at the same time maintain high crop yield. My feeling is that agro-forestry research has the potential of offering an early and viable alternative.

Introduction

Farming systems can be defined as the distribution of plants and animals in space and time and the combination of inputs believed to give maximum production in socioeconomic, political, and cultural contexts.

In Africa, a farmer or farm family usually operates a small, diversified agricultural enterprise. According to Okigbo (1978), farmers with a homestead in an upland, well-drained soil may operate a compound farm or garden close to their homestead and maintain two or more plots in cropping systems involving natural or planted fallow and in the flood plain of a nearby river or steam. They may also keep pigs, goats, sheep, and poultry for manure, meat, sales, etc.; they may be palm wine tappers, basket-makers, musicians, or priests in the traditional religion. The cropping mixtures on the farms often involve major staples, vegetables, and condiments in multiple, double, relay, and patch intercropping patterns of annuals, perennials, or both. The compound farm or homestead garden usually carries more species of cultivated plants than bush fallow farms.

The most common tradition in African cropping systems is the spatial arrangement of crops on the field. The crops are established haphazardly in mixed culture (Okigbo and Greenland 1975), the objectives being to take advantage of local topographic features and micro-relief; disperse species at wide enough spacings so that they do not compete for nutrients and light; ensure that crop cover is adequate to control soil erosion and weeds; and ensure that each species's requirements for sunlight are met. Where annual staples are uniformly planted among tree crops, heavy pruning of the tree crops is usually carried out to ensure that adequate light reaches the ground level. Whether crops are grown on mounds, beds, ridges, or the flat, their spatial arrangement and frequency in mixtures usually indicate their importance in the diet and sometimes their uses.

Intercropping and Multiple Cropping
The simultaneous cultivation of different crops on the same piece of land has been described interchangeably as mixed cropping or intercropping by Webster and Wilson (1966) and Norman (1971). Ruthenberg (1976), however, distinguishes between mixed cropping and intercropping on the basis of the pattern of the intermixture.

The term intercropping has been used rather generally in the literature as referring to the practice of growing two or more crops simultaneously in different but proximate stands (Okitigbo 1978). Grimes (1963) defined a common practice in intercropping: the system of growing different crops in alternate rows, which he terms alternate row cropping. Row intercropping is common in filled areas, annuals often being planted under perennials. For instance, tall-growing crops such as cassava or bananas are planted in young coffee, cocoa, or rubber plantations (Sanchez 1979).

In multiple cropping, Herrera and Harwood (1973) indicated that each of the crop mixture patterns has different physiological characteristics and different advantages. For example, Norman (1974) showed that although there were at least 156 crop mixtures and many different spatial arrangements among Hausa farmers near Zaria (Nigeria), the most popular arrangement was a systematic spatial pattern on ridges. With intensification of cropping, interactions among plants become critical. The most widespread multiple cropping systems practiced in the humid tropics are mixed intercropping and relay intercropping.

Mixed intercropping is common when cereals, grain legumes, and root crops are grown together and when little or no tillage is practiced. For example, farmers in southern Nigeria plant simultaneously maize, cassava, vegetables, and cocoyam. In Abakaliki, Nigeria, mixed cropping is practiced in mounds or ridges of soil constructed with hoes. Several crops are planted on different parts of the mounds. For example, an Abakaliki farmer plants yams on the mound, rice in the furrow, and maize, okra, melon, and cassava on the lower parts of the mound. Mounding is beneficial because it increases the volume of soil available to root crops.

Relay intercropping is a practice where a second crop is planted after the first crop has entered the reproductive growth phase but prior to harvest. A common example is the maize-beans system used in most of Central America and much of tropical South America. Maize is planted in rows, usually at the beginning of the rainy season; when the ears are well formed, farmers break the stalks just below the ear and plant climbing bean varieties. Relay intercropping is also very common in rice-based systems in Taiwan. Up to five crops per year can be harvested by two relay successions, rice-melons followed by rice again relayed with cabbage and maize. At present, the maize-cassava relay is being developed at the University of Ibadan, with researchers studying the effects on soil nutrients.

Advantages and Disadvantages

Baker and Yusuf (1976) wrote that the almost universal practice of traditional cropping systems by subsistence farmers throughout the world is an indication that the system has evolved naturally as an answer to the challenging environment.

The rationales for crop mixtures are that they may be relatively more profitable than sole cropping (Chandra 1978), the difference between the marginal value product of resources and the opportunity cost of the resources being insignificant (Norman 1974); they are consistent with the goals of security and year-round subsistence needs (Andrew 1972); they may alleviate adverse conditions in the ecosystem; and they may maximize the space, water, and nutrients available. Some of these benefits can be further promoted by good tillage practices, based on the principle of minimizing disturbance of the ground and vegetative cover. The practice of minimum tillage, with ample crop residues left on the soil surface, has great potential.

Although monocropping tends to attract fewer diseases and insects, these are more likely to be highly prevalent and to cause considerable damage. Cropping mixtures may reduce the abilities of pests and diseases to spread. For instance, interplanting has been shown to reduce insect problems in groundnut-sorghum and cassava-maize mixtures and has reduced the incidence of bacterial blight.
The denser plant population usually found in crop mixtures may also help control weeds (FAO 1968). In addition, because crops mature at different times, mixtures may extend the period of the year during which the soil is protected by leaf cover and root systems (Igbozurike 1971).

The disadvantages of traditional systems are that there is reduced yield of the component crops (Chandra 1978; Webster and Wilson 1966; Agboola and Fayemi 1972); there may be competition for light, nutrients, and water (Dalal 1974; Willey 1979; Webster and Wilson 1966); there may be allelopathic effects due to excretion of toxic substances by one or more crops (Dalal 1974); the practice is not well suited to modern agriculture or mechanization and, thus, research on traditional systems has been inadequate (Ahmed and Gunasena 1979); and suitable methods for investigation are difficult to define (Haizel 1974).

Research

Unfortunately, research workers appear to have been hesitant to tackle multiple cropping experiments because of the many crop combinations in use, and because multiple cropping by the peasant farmer is associated with non-mechanical farming and low levels of productivity. Doubts have been expressed as to whether any of the positive benefits of multiple cropping can be exploited at more advanced levels of farming. Attempts to improve production by the application of technology developed in temperate cropping systems have failed in Nigeria and in most other tropical countries, not because of farmers' conservatism but because the approach is inappropriate.

Farmers in the tropics have been noted to grow complex crop mixtures on compound farms, especially in the rainforest zones, where staples, vegetables, and perennial fruit trees are interplanted. As early as 45 years ago, Leakey (1934) observed that the relay and mixed cropping practices had many obvious advantages, and he recommended that those involved in agricultural development should give serious attention to research on traditional food production systems, especially those involving intercropping. This recommendation has largely been ignored, despite the fact that peasant farmers have repeatedly refused to adopt monocropping practices recommended by extension agents.

The main objectives of research into the productivity of mixtures might be to screen mixtures for high-yielding combinations; to test alleged advantages of traditionally grown mixtures; and to gain an understanding of the processes that lead to advantages so that, in a specific environment, a rational choice of components may lead to higher yields than are possible in monocultures.

Sturdy (1939) noted in East Africa that intercropping Crotalaria with millet, and groundnuts with sorghum, helped in the maintenance of soil fertility. Lambers (1940) reported that coffee intercropped with bananas in Kuri provided a mulch that improved the fertility of the soil. Results of experiments carried out by Agboola and Fayemi (1972) showed that legumes intercropped with early maize gave a maize yield equal to that obtainable with 55 kg/ha of nitrogen supplied as mineral fertilizer.

Much work still has to be done to quantify the nutrient level of soils under traditional crop combinations. In a study conducted in 1981 composite soil samples were taken from eight farms and their adjoining fallows, and in only one case was the fallow land significantly higher in nutrient status than the adjacent cultivated land. P, K, Fe, Zn, and Ca levels in the top 0-15 cm layer were higher in the cultivated fields than in the adjoining fallows, and this was attributed to the effect of burning after clearing. These data support the view that the length of the fallow has been drastically reduced, thereby reducing also the nutrient build-up. They imply that most farmers are actually cropping infertile lands and that the nutrient status of the field does not influence the farmers' choice of crop combinations. The choice of crop combinations seems instead to be influenced by the food staples usually planted in the area, and the inclusion of vegetables is related to the economic value of the crops and food preferences. No definite effect of the crop mixtures on the soil nutrient status could be established.

Summary and Conclusions

The best cropping system in the tropics, once the soil is considered as the main factor sustaining crop
production, is one that will not expose the soil to erosion hazards. Therefore, more research is needed to identify better combinations, including agro-forestry schemes, so that the best type of rotation can be developed for each ecological zone. Although zero tillage has been advocated by IITA, this cannot be practiced all over the humid tropics because it is dependent on the soil, particularly the clay content, and the prevailing weather conditions. In some areas, the temperature is low during the harmattan, and the Fadama soils cake, necessitating extra soil preparation in the following rainy season. Thus at the University of Ife zero tillage has proved to be unsatisfactory.

Besides protecting against erosion, an appropriate cropping system must guard against the breakdown of the soil structure and nutrients. A good system needs to take advantage of the tonnes of human, plant, and animal refuse being produced. It should be emphasized, however, that traditional farmers will continue with their existing system until an alternative is found that will maintain higher yields, conserve the soil, control weeds, and generally fit into their present technology.

Acknowledgements

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Agricultural tree crops as a no-tillage system

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Abstract

The crisis in tropical agriculture is demonstrated by falling food production and migration to the towns. It is argued that this is an inevitable process resulting from the inability of tropical agriculture to compete with the industrialized agriculture of the temperate zones. Industrial agriculture is a high-input agriculture, and success or failure depends on the input:output ratio. In the humid tropics, the input:output ratio is unfavourable, and industrial agriculture therefore impossible; hence the only viable form of production is subsistence farming. The obvious alternative to subsistence farming is mixed tree cropping, in which the characteristics of the natural forest cover are copied as closely as possible. Only in this way can the productive potential of the environment be realized and the fertility of the soil maintained. Crop mixtures may be selected from oil palm, coconut palm, breadfruit, plantains, coffee, cocoa, cola, citrus, and other trees. A plea is made for a research programme to be devoted to mixed tree cropping as one of the possible ways to improve the agriculture of the region lying between 10°N and 10°S.

Introduction

The growth of temperate agriculture over many centuries has involved the destruction of forests and the planting of annual crops in their place. Land clearing and progress are seen to be linked. When developers come to tropical Africa, they assume that clearing the forest is progress; likewise, African people, anxious of emulating progress seen in other countries, follow the same course.

As an agricultural engineer, I suppose that I should be in the camp of forest destroyers, and I certainly would be if I thought that this policy could be successful in economic terms and acceptable ecologically. But all the evidence indicates that the widespread clearing of tropical forest and the large-scale planting of annual crops leads to financial and ecological disaster. The worst possible combination of circumstances for Nigeria would be for the fertility of the soil to run out at the same time as the oil runs out—a possibility which could well arise unless great care is exercised. A new type of agriculture, such as that based on mixed tree cropping, must be developed with all urgency, as it offers, perhaps, the only hope for the future.
Proposition

I propose that there is a crisis in the agriculture of the region lying between 10°N and 10°S and that there must be a reason for it.

The evidence for this crisis is falling food production and an increase in food imports. Further evidence is the mass migration from the rural areas to the towns. For those who stay in the country, the standard of living remains low, and there is little hope of improvement. The great majority of the people in the countryside are still subsistence farmers, just as they were before and during the period of colonialism, depending for the most part on the unaided strength of their bodies to wrest a living from the soil. They would seem to live in a world with which Western technology is unable to communicate.

Over the past 30 years, there has been no lack of attempts to improve agriculture in the humid tropics. That none of these efforts has significantly changed the methods of production, even in a limited area, cannot reasonably be held to be a result of bad luck or bad management. There must be fundamental economic reasons to explain why these attempts have failed so catastrophically. The competitiveness of tropical agriculture has seriously declined in relation to temperate agriculture; the reasons for this decline include:

- The development of bigger and more effective machines. Just as it is no longer possible for a person with a headpan to shift earth competitively against one with a Caterpillar D9, so it is no longer possible for a person with a sickle to compete against one with a combine harvester; 30 years ago, however, when machines were smaller and less efficient, it was still possible for hand labour to compete;
- All major crops have now been mechanized; 30 years ago, machines had not been perfected for the harvesting of cotton, groundnuts, or sugar cane. Production of these crops can now only be competitive (and provide the producer with a reasonable standard of living) if they are mechanized; and
- Temperate region substitutes have been found for tropical crops. Soybean, sunflower, and oilseed rape have greatly reduced the demand for groundnut oil. Cotton has been displaced to a considerable extent by artificial fibres. Cane sugar has been threatened by sugar beet and, more recently, by high-fructose corn syrup.

Agriculture has gone through three phases: subsistence farming, commercial farming, and industrial farming. This last phase is still in full evolution and is rapidly displacing all forms of small-scale production because it is economically more efficient. Never in the history of human beings have the main food items been produced so cheaply in real terms as they are now in the temperate countries.

Industrial agriculture is, of necessity, a high-input agriculture because it depends on inputs of machinery, fertilizers, herbicides, insecticides, etc. Because labour forms a small part of production costs, the system cannot be made to work by a substitution of labour and land for capital.

Success or failure of industrial agriculture depends on the input:output ratio expressed as the cost of the various inputs that are needed to produce a given value of produce. By using this ratio, one can compare the efficiency of production at different places (table 1).

A profit of $0.05 is made on every dollar of produce in the USA, whereas a loss of $1.20 per dollar of produce occurs in the tropics. The loss has to be covered, for example by subsidizing inputs to subsidize the price, or by introducing import restrictions that keep the price artificially high. Support for the reliability of such input:output ratios is provided by the comparative farm gate prices of maize—approximately $1 50/t in the USA vs. $450/t in Nigeria.

Generally, profitability increases as expenditures on machinery and chemical inputs increase, up to a limit of about $0.55 per dollar. If the inputs cost more than about $0.65, commercial production is no longer possible. Production becomes economically absurd if the foreign exchange cost of the inputs exceeds the foreign exchange cost of the product.
TABLE 1. Indicative Input:Output Ratio of Maize Production in the USA and Nigeria (cents input to produce $1 output)

<table>
<thead>
<tr>
<th></th>
<th>USA</th>
<th>Nigeria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land</td>
<td>20 cents</td>
<td>30 cents</td>
</tr>
<tr>
<td>Infrastructure and machinery</td>
<td>15 cents</td>
<td>50 cents</td>
</tr>
<tr>
<td>Seed and agric. chemicals</td>
<td>35 cents</td>
<td>110 cents</td>
</tr>
<tr>
<td>Management and labour</td>
<td>10 cents</td>
<td>30 cents</td>
</tr>
<tr>
<td>Finance and taxes</td>
<td>15 cents</td>
<td>-</td>
</tr>
<tr>
<td>Total cost of production</td>
<td>95 cents</td>
<td>220 cents</td>
</tr>
</tbody>
</table>

Input:output ratios are generally unfavourable in the humid tropics. Low yields are a result of leached soils, heavy runoff, loss of nutrients, and weed competition. Drying and storage in a hot, humid environment present further problems. Generally, unfavourable input:output ratios are found where yields are low. Approximately the same inputs per hectare will produce about 2.5 tonnes of maize in the humid tropics as against 7 tonnes in the USA. In other words, only 0.15 ha of land in the US, as compared with 0.4 ha in the humid tropics, is required to produce 1 tonne of maize. All land, machinery, herbicide and insecticide costs are directly related to area. Thus, they are all three times more expensive in the humid tropics per tonne of maize produced.

Increasing energy costs make the possibility of high-input agriculture recede even further. When inputs are expensive they can only be used where the return per unit used is high; only when inputs are cheap can they be used extensively. Since the oil price rise of 1973, hopes of using expensive inputs in marginal areas have declined.

Subsistence farming is the inevitable consequence of the unfavourable input:output ratios associated with the production of annual crops in the humid tropics. All other forms of annual crop production are economically impossible until such time as the agricultural scientists develop varieties that give input:output ratios comparable with those of similar crops grown in more favourable climates. This conclusion accords with the observable fact that subsistence agriculture is the universal form of annual crop production in West Africa.

But subsistence farming has been shown to have already failed: it cannot produce sufficient surplus to feed the large towns; it cannot supply cheap basic foodstuffs; and it cannot retain the young people on the land. The impasse appears total—the only system that is economically viable is incapable of supporting the modern economy for which developing countries are striving.

The Tree Crop Alternative

The tree crop alternative offers some hope. It is logical in both economic and ecological terms. The climax vegetation of the humid tropics is high forest, which produces the greatest sustainable rate of biomass formation. It captures all solar radiation year-round by virtue of the different layers of foliage. The layers of leaves, twigs, and branches absorb the incoming energy of tropical rainstorms, thus protecting the soil. Organic matter on the forest floor is protected from the direct sun. Runoff is reduced so that more water is available for plant growth, and extensive root systems explore the whole soil profile for nutrients. If society demands that the high forest be removed, it must be replaced by economic crops that copy as closely as possible the characteristics of the natural forest, and that afford equal protection to the environment. If mixed tree cropping is to be freely chosen in preference to annual crops it must show economic advantages.

There are reasons to think mixed tree cropping will significantly outperform annual crops as the cost of highenergy inputs rises because of its low labour requirements; low fertilizer, herbicide, and insecticide requirements; the prospects for an ideal no-tillage system; and reduced weed competition.
Conclusion

Tree crops appear to be so well-suited to the environment and have so many economic advantages that a research programme of tree crop development is urgently required. The potential for tree crops exists and in many cases is already being realized. The oil palm, for example, is by far the most efficient and cheapest source of vegetable oil. Under good conditions it will produce up to 6 tonnes oil/ha. It will, therefore, always hold a competitive advantage over the annual oilseed crops. It may be expected to constitute an important part in any mixed tree crop system. The coconut palm produces a good yield of both oil and protein. Further, the open canopy makes it very suitable for mixed cropping with plantains or bananas. The breadfruit tree (Artocarpus altilis) appears to produce up to 8 tons carbohydrates/ha. Accurate yields are not available because the tree has not been seriously studied. The best cultivars should be assembled to determine its productive capacity under a range of environmental conditions. The shea butter tree (Butyrospermum parkii) should be studied and improved so that it may replace groundnuts in the drier areas.

For the wet tropics, it is suggested that mixed tree cropping is likely to be most effective, as it copies as closely as possible the natural forest. Oil palm or coconut palm would be interplanted with breadfruit to form the top gallery. Beneath this would be planted plantains, cocoa, and coffee, and, in places, as a bottom layer of vegetation, small plots of maize, sweet potato, and cocoyams. The aim would be not to get the maximum yield of one particular crop per unit area but, rather, to maximize total production.

The objective must be to give the people of the wet tropics crops that will outyield and undersell the main food crops grown in the temperate zones. Oil from palm oil already does this; it is to be hoped that carbohydrate from breadfruit would become cheaper than maize as the cost of high energy inputs increases. If the people of the wet tropics attempt to grow temperate crops competitively, they will always be losers, and, if they cannot produce cheap food, industrialization may well be impeded.

Long-term tree research is a most urgent requirement. It is a field that has been totally neglected except in the plantation context. Trees have all the right characteristics for smallholder farmer production in an energy-hungry world, although in some cases breeding programmes must be undertaken to combine desired properties.

It is essential that one get away from the idea that trees only grow in forests or in plantations. This concept has meant that the people of the wet tropics have been (and still are) denied the help of modern research. Economic trees grow just as well on smallholdings as on plantations, and there is little loss of economic efficiency. On has only to think of the struggle of the Chagga people in Tanzania before they were allowed to grow coffee to realize how obstructive the plantation mentality can be.

One cannot know what the future holds but surely one must plan for several different possibilities. One of these is a world of increasing energy shortage, where energy-related products become more and more expensive. In such a situation low energy-input tree crops have a potential that is unmatched. Prudent people do not put all their money on one horse, and scientific researchers and government policymakers should likewise spread their bets. Mixed tree cropping may be a favourite for some, or an outsider to others, but it looks to be so well-suited for the next 20 years that it would be unwise not to put some money on it.

Traditional agro-forestry systems in the central African republic

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Abstract

The Central African Republic is a land of forests, and yet its agrosilvicultural balance is being
jeopardized by the lack of an afforestation policy. This paper contains a detailed description of the seven types of trees cultivated on many types of plantations and combined with food and other crops. The report also describes the traditional systems in use and proposes a series of measures aimed at improving their productivity. Finally, it is recommended that multidisciplinary research on soil protection and restoration be conducted, with the understanding that human and social factors are of paramount importance in the restoration of tropical forests.

Introduction

The Central African Republic is located between latitude 2° 16' and 11° 20' N and longitude 14° 20' and 27° 45' E. In the extreme north, between Sudan and Chad, is the Birao region, with which this report is mostly concerned. Here the climate is Sudano-Sahelian to the north and Sudano-Guinean to the south, and nowhere does the yearly rainfall exceed 1,000 mm.

Despite various botanical explorations, the vegetation of the area is still not very well known. The following divisions for the Sudanian forest were proposed by Sillons in 1950.

- **District XI**, between the Chari and Logone rivers, north of a line running north of Batangafo and south of Ndélé and Ouadda. This is characterized by the alternation of wooded savanna with Uapaca sp., Isoberlinia sp., and Monotes sp. (Oxytenanthera abyssinica may also be present) and shrub savanna with Terminalia laxiflora, Grewia mollis, and Combretum hypopilinum.
- **District XII**, along the Upper Aouk River, between 9° and 10° N. This is characterized by the alternation of parkland savanna populated with rachitic trees (with Piliostigma [Baubinia] reticulate, Combretum glutinosum, and various acacias) and easily flooded grass savanna with Andropogon grasses etc.
- **District XIII**, north of Birao, between 10° and 11° N. Thornbush tropical steppe covers this entire region, with acacia shrubs, jujubes, and various mimosas dominating.

All of these formations may be grouped together in three regions: the first being that of the Bahr Aouk River (west of 21° E); the second that of the plains of Chad between the Kumbala River and Birao; and the third that of the areas of rocky relief south of Birao, around Ouanda Djallé and the Ouandjia Mines and along the Sudanese border. In the Bahr Aouk Zone, on quartzitic crests of the Old Precambrian period (sometimes with surface induration) grows woody vegetation composed of Daniellis oliveri, Anogeissus sp., Butyrospermum parkii, Parkia filicoides, and Pterocarpus lucens.

In the Aluk-Aoukale zone one finds tree savannas where the most widespread woody plants are Terminalia laxiflora, Hymenocardia acida, Prosopis africana, and Anogeissus. Actually, this is not a homogeneous zone, as there are also the main types of graminaceous pastures and dry termite forests with a tree layer of Khaya sp., Tamarindus indica, and Anogeissus and a shrub layer of Combretum spp., Cacia sp., and Bascia sp. Around the grassy plain of Lake Manoun, one may observe Borassus aethiopium, and Hyphaene thebaica, with Anogeissus, Butyrospermum, Tamarindus, Balanites, and Isoberlinia dominating. In the villages, alongside planted Ceiba pentandra, Moringa oleifera is found, which indicates a former Chadian occupation of the area. Between Dahal Hadjer and Tissi, Combretum savanna grows on the gaz (ancient aeolian sand fields).

Traditional Associations between Crops, Fodder Species, and Trees

Forest Zone

The Central African Republic is a land of forests, and thus its inhabitants have no difficulty in obtaining wood. The Republic's forest belt covers the prefectures of Sangha, Sangha Economique, Lobaye, and the southern part of Ombella-Mpoko. Bananas, cassava, coffee, taro, some groundnuts, and some sesame are grown in these regions. The cultivation of all these crops entails the destruction of forests. All trees are cut down, with the largest trees being killed either by burning or girdling. After the forest has been cleared and all the plant material burned, the plot is ready for sowing. For all except two or three of the above-mentioned crops, the soil must be turned before seeds are planted. Since the crops must have full sunlight,
not a single tree is left standing and the forest is irreversibly destroyed.

Moreover, since the tropical forest is rich in wood products, the people do not spare any trees when cultivating their fields. Coffee is one of the country's main cash crops, and a modern system of cultivation is followed. If, in this type of cultivation, one finds trees still standing here and there, especially on plantations belonging to the village people, it is because they feel that allowing the trees to remain will protect the coffee plants from over-exposure to the sun, thus increasing production. Generally speaking, no trees are left standing on large-scale coffee plantations. In cocoa cultivation, trees are preserved for their shade. This type of cultivation is not widespread in the Central African Republic because of the relatively unfavourable growing conditions for cocoa. Other crops are raised on land that has been cleared and burned, although sesame is often cultivated in pockets of savanna in the midst of the forest. Production per hectare is superior to that found in typical savanna regions.

Intermediate Zone

The intermediate zone is located between the forest zone and the Vakaga zone. Its climate permits the cultivation of different types of crops. In this zone, where the majority of the population lives, cotton, sesame, groundnuts, and many other subsistence crops are cultivated. In Basse-Kotto and Mbomou, even coffee is grown. The crops are raised on Sudanian savanna where tree density per hectare is considerable. This means that the forest must be completely destroyed except where trees are of some use because they provide edible fruit, shade, or some other byproduct for which the farmer feels there is a need.

Vakaga Zone

The trees are carefully preserved in Birao (which is roughly in the middle of Vakaga prefecture) as wood is the primary fuel for cooking and lighting. As the rainy season approaches, inhabitants lay in a supply of firewood to tide them over until the next dry season. Inhabitants of this region traditionally protect "useful" trees that grow in their fields - useful because they provide fruit, oil, medications, and fodder for livestock.

There is a noticeable lack of industrial-scale cultivation in the Vakaga region. The population depends primarily on subsistence agriculture, sheep-herding, hunting, and gathering. There are approximately 15,000 inhabitants of the Vakaga prefecture, with a population density of 2 people/km². The Vakaga prefecture is divided into two subprefectures, Birao and Ouanda Djalle. The region's chief town is Birao. All Ministry of Rural Development services are represented there: agriculture, animal husbandry, and forestry. The latter is further divided into three sections (Birao Centre, Gordil, and Ouanda Djallé) with ranger stations and patrol areas.

The Vakaga region differs from other regions of the Central African Republic in that cassava has been introduced there fairly recently. Millet is grown in light, sandy soils and its abundant foliage is favoured by horses and cattle. Two varieties of Sorghum condatum are found, as well as Sorghum vulgatum, an intermediate variety, and red and white berbere (the term is used to describe heavy, compact, clayey soil and also for several varieties of Suorghum durra). Groundnuts are cultivated, but maize is not very widespread since it is simply planted around huts as a back-up cereal.

The population of the Vakaga region consumes vast quantities of roselle (Hibiscus sabdariffa), whose calyx and early fruit are used as ingredients in couscous and whose flower is used in herbal teas. This malvaceous plant is almost always planted in millet fields and around huts. Hibiscus esculentus (okra or gumbo) is one of the most common field and garden vegetables. Sesamum indicum (sesame) is planted in sandy soil, especially in fine sand, where its yield is excellent. Cucumis sativus (cucumber, or fagouss) is one of the most widely cultivated vegetables, and this is often cultivated together with squash.

Trees Recognized as Useful

Vegetation in the Vakaga region, as in most Central African regions, has been greatly affected by human intervention. Over-grazing has sometimes caused the almost total disappearance of woody vegetation in
some areas. Vast stretches of desert can be seen around Birao, even though climatic conditions warrant the growth of abundant thorny vegetation. Nevertheless, six trees are recognized as being particularly useful: Balanites aegyptiaca, Butyrospermum parkii, Parkia biglobosa, Borassus aethiopium, Adansonia digitata, and Tamarindus indica. This is proof that, even when the inhabitants do not try to protect trees in their fields and incorporate them into their farming system, a certain equilibrium between agriculture and silviculture is sometimes established.

Throughout the Birao region, Balanites aegyptiaca is carefully cultivated because of its many uses. Its fruit provides an oil that is often used in cooking and some old people will eat only sauces made with Balanites oil. The sulphur-yellow flesh around the pit is eaten in much the same way as chocolate. The tree is often stripped by livestock, which favour its foliage, and also by herders, who cut off branches to build shelters for their calves. Treated in this way, the tree acquires a straight trunk. Village people use it as the main member in the frames for their huts, because the hard wood resists attacks by termites. The wood is also used to make handles for spears, axes, and other tools. Villagers are fond of eating fried beef liver on Balanites aegyptiaca leaves, which are reputed to cure liver ailments. Sometimes there are clashes between stock breeders and village people, not because livestock have destroyed millet fields but because a herder has cut branches from a tree to make a bed. This species more or less covers the northern part of the area, and three or four of these trees can be found in even the smallest fields. Its many uses cause it to be cultivated also in Bangui, the capital of the Central African Republic.

Butyrospermum parkii .(karite, or shea tree) is characteristic of the region. It provides a fleshy fruit and a stone whose oil extract is valued as a preservative. Farmers gather the bark to make beehives; this usually kills the tree. In some villages, this practice is forbidden by tradition, except for trees that have been declared unproductive.

Parkia biglobosa (nitta) is a leguminous mimosa producing pedunculate fruit and a yellow powder eaten by the local inhabitants. The seeds are boiled, fermented, and used to make a tasty sauce for eating with Hibiscus esculentus (okra). Village people often set their beehives in this tree.

Borassus aethiopium (palmyral is widely used in this region. All huts constructed by the government are made from planks from this tree, rough-hewn locally. Since the palmyra resists termites, it is also used locally in the frames of huts. The flesh of its fruit is eaten by village people; elephants are also fond of it and can sometimes even be seen in an inebriated state near large stands of palmyra. Young shoots are gathered and marketed as in other regions.

Adansonia digitata (baobab) figures in African mythology and is greatly revered. The local inhabitants make sacrifices under this tree. Shoots are eaten in a smoked fish sauce. The tree is found throughout the area but is practically non-existent in places where elephants have come to rest, for they strip the tree of its bark. The white powder around the seeds is eaten in the same way as chocolate.

There are several varieties of Tamarindus indica in Birao. Some do not sprout leaves until the start of the dry season; their fruit is picked toward the end of this season to feed livestock (sheep and kids). Others, however, have year-round foliage. It is this second kind that is usually found in fields and villages. It produces a very sour fruit thought to be a good cure for colds because it is rich in vitamin C. The branches are gathered, boiled, and used as a medicine for fevers, rheumatism, and fatigue.

Oxytenanthera abyssinica (bamboo) must be added to the six described above because of the role it plays in local construction. It is used for roofing and especially for fences, for the region is Moslem and each hut must have a fence around it.

**Agrisilvicultural Equilibrium**

The theory that some sort of balance must be established between agriculture and silviculture presupposes the maintenance of an ecosystem. The ecosystem is greatly influenced by climatic, biotic, human, and soil-related factors, but must be continuously maintained by agronomists, veterinarians, and foresters. Such multidisciplinary activity is difficult. When farmers in the Vakaga region allow trees to remain
standing, the reason is that they derive some products or service from the trees. This explains why, although there is indeed a certain traditional agro-forestry system, its aim is not just to preserve trees or to ensure a certain equilibrium between agriculture and silviculture. Thus an information programme should be set up to teach agro-forestry methods in the areas concerned.

An information campaign presupposes an established plan ready for execution. Consideration should perhaps be given to the application, in this region, of all silvicultural methods used to date in wet forest zones and savanna: the taungya method, the Malayan uniform system, the tropical shelterwood system, the semi-selective management system, the cross-ride method, full-capacity planting, and restricted grazing. Some of these methods can be applied only in forest zones, but taungya, full-capacity planting, and restricted grazing (which is the most economic and most important method), could be widespread. Initially, farmers in central Birao should be organized into three groups, according to the kinds of crops that suit each system. The first group would adopt the taungya method; the second and third groups would practice full-capacity planting and restricted grazing, respectively. Later, all three systems could be applied in every village of the Vakaga region, depending on the crops grown and the environment, the main factor being the dominant species of tree. A five- or six-year rotation would suffice to allow the rural population to grow crops on land enriched by fallowing to improve its yield.

The taungya method may be practiced in conjunction with full-capacity planting and restricted grazing. In heavily treed areas where the dominant species of trees are those that farmers are in the habit of preserving and growing in their fields, the taungya method will be applied. In Birao Centre, Ouanda Djalle, and the rural areas in these two subprefectures, the same method will be used but the kinds of crops will vary depending on the farmers' means of livelihood. This will give rise to a wide diversity of crops being raised in conjunction with Balanites aegyptiaca, Parkia biglobosa, Butyrospermum parkii, and Tamarindus indica, which are the only local trees suitable for the taungya method and restricted grazing. Even if the taungya method and full-capacity planting fail, restricted grazing (which is the least costly method) will undoubtedly be successful if brush fires and human factors can be contained.

From the example of other African countries, it can be seen that farmers automatically preserve useful trees in their fields. However, it should be noted that this still does not provide the level of forestation necessary to maintain a favourable climate and soil fertility.

Other solutions may be considered, such as:

- Prolonging fallow periods;
- Planting a large number of useful trees in the fields;
- Planting useful trees (fast-growing exotic species) alongside paths leading to fields and around the boundaries of these fields; and
- Planting fast-growing species and fruit trees along cattle and goat paths through farm areas and around water holes.

**Conclusion**

The immediate result of this activity will be to check deforestation around the city of Birao and the villages in that region, and to create an environment favourable to reforestation. Over the medium term, the main objectives will be to combat soil erosion and to make local inhabitants aware of the forest's usefulness and of the adverse effects of systematic deforestation on agriculture. Over the long term, the forest cover will be re-established and city-dwellers will be supplied with firewood through cuttings on a rotational basis.

This work will involve considerable multidisciplinary research on soil protection and restoration in each ecological zone, keeping in mind agriculture, animal husbandry, and forestry - without neglecting the human and social aspect. Customs are so important that nothing can be accomplished without a great information, popularization, and organizational campaign. The future of our tropical forests depends on it.
Prospects for agro-forestry in Benin

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Abstract

Benin's forest resources have been impoverished by 25 years of sawmill operations, bush fires, clearing by state farms and corporations, insufficient fallowing periods, and the encroachment of the Sahel in the north of the country and the savanna in the south. The country must depend on imports to make up a growing deficit in firewood, timber, and lumber. This report describes the objectives for an agro-forestry research programme aimed at improving Benin's forest economy.

Introduction

Situated on the Bight of Benin between Togo, Nigeria, Niger, and Upper Volta, the People's Republic of Benin - with a surface area of 112,000 km² - is a country with limited forest resources.

A brief outline of the ecological factors affecting Benin helps explain the country's forest situation. The southern and coastal regions correspond to the terminal continental shelf and have soil of variable quality derived from long-shore drift materials, alluvial deposits of silicon clay, and cretaceous formations that have developed into Vertisols. Further north, in central Benin, there is crystallized rock, granite jutting out of the Precambrian substratum, with ferruginous types of tropical soils, occasionally with lateritic concretions.

According to surveys by the Food and Agriculture Organization (FAO) and the United Nations Development Programme (UNDP), 60 per cent of the country's surface is covered by natural, uncultivated vegetation, which is threatened every year by bush fires. Most of Benin's classified forests are located in the country's northern and central regions. For a full appreciation of Benin's forest situation and the problems that have arisen, other factors must be added to these ecological data; these include the extent to which state farms and corporations have been clearing the land, the inadequate natural fallow periods on most traditional farms, the encroachment of the Sahel in the northern areas and the savanna in the southern areas, and the development of urban areas.

Benin's national forests cover a total of 2 million ha, or 19 per cent of the country's territory. However, commercially valuable forests represent a mere 2 per cent of the land area. Classified forests account for 1,580,028 ha and plantations (mostly teak) cover 10,000 ha. These plantations, between 14 and 30 years old, are mainly located in the country's southern region and are intended for timber production. In teak farming, both short-term (45-55 years) and long-term rotations are used. To these teak plantations must be added the existence of a natural reserve in the Djougou-Bante-Beterou triangle; in the immediate future, however, this reserve's annual timber production will not exceed about 35,000 m³ of Khaya grandifoliola and K. senegalensis, and 40,000 m³ of Antiaris sp. and Triplochiton sp. Current production is low as a result of 25 years of overexploitation by local sawmills.

In addition to the 10,000 ha of plantations already mentioned, there must be added 6,000 ha of cashew trees, which supply a small shelling plant in Parakou (annual capacity: 1,500 tons). Furthermore, although lumbering in Benin is not sufficient to keep a foreign trade going, other forest products such as Karite (Vitellaria paradoxa) and cashew nuts have made possible a considerable influx of foreign exchange-about 542 million CFA francs. in 1977-1978. Production rose sharply in 1979-1980. National parks and wildlife preserves cover a total of 578,000 ha.

Shortage of Wood

The problems that arise from a scarcity of forest products can be expressed in terms of needs. Wood is the leading domestic fuel and is used for cooking in Benin. It comes to people's homes in the form of firewood or charcoal. Wood is currently in chronically short supply in all urban centres and even in rural areas. The rural district of Ouake in Atacora Province, where millet stalks and cow dung are used for cooking fuel, is a good example of the problem.
In the south, this shortage is aggravated by the progressive shortening of natural fallow periods. According to Huart (1976) of the FAO/UNDP forest industries advisory group for Africa, an increase of 15 per cent in the total area sown to crops would cause a deficit for cities such as Cotonou and Porto-Novo of 57 per cent (table 1).

**TABLE 1. Fuel Requirements, Present and Predicted**

<table>
<thead>
<tr>
<th></th>
<th>Firewood equivalent (in m³)</th>
<th>Present requirements</th>
<th>Estimated requirements in 1990</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cotonou-Porto-Novo</td>
<td></td>
<td>360,000</td>
<td>1,015,000</td>
</tr>
<tr>
<td>Parakou and Djougou</td>
<td></td>
<td>180,000</td>
<td>315,000</td>
</tr>
<tr>
<td>Rural areas and other localities</td>
<td></td>
<td>2,640,000</td>
<td>3,470,000</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td></td>
<td>3,180,000</td>
<td>4,800,000</td>
</tr>
</tbody>
</table>

However, the country's wood shortage affects more than the supply of fuel; there is also a widespread shortage of timber that is felt at every level of society. To the figures for annual timber consumption must be added 1,500 m³ of plywood and fibreboard, most of which is at present imported. This analysis indicates an annual deficit of 6,000 m³ of saw timber and plywood and 1,000 m³ of roundwood.

**Prospects for Agro-forestry Solutions**

Attempts have been made to combine and integrate farming, forestry, and animal husbandry methods for improved farm management with a view to continually increasing production without causing major deforestation and yet obtaining a substantial yield from marginal land.

In concrete terms:

- Structures have been established to provide guidance and support for rural production;
- Experience has been acquired in agro-forestry; and
- An agro-forestry research programme has been developed.

Agriculture, forestry, and animal husbandry are not rigidly compartmentalized in Benin. Maize is sown, trees are planted, and animals are raised by the same labourer on the same farm. Rural development structures devised and implemented by the government of Benin take into account the concern for integrating these systems. Specifically, regional rural development action centres (CARDERs) bring together all government aid services in rural areas.

The involvement of rural populations in forest development is a proven technique in Benin. The taungya planting method is one agro-forestry production system in which farmers take part in setting up state plantations. This practice has made it possible to plant 6,000 ha of teak in southern Benin.

There have been many variations in the practice of taungya. In the south, maize is cultivated in combination with the establishment of teak plantations. In North Zou, maize or groundnuts are grown on cashew plantations. Mixed cultivation of cotton and cashew has not proved as successful because of the high risk of attacks by parasites, notably Heliotis, a cotton parasite that causes a great deal of damage. In the north, millet and cashew have been successfully combined; cashews and yams can also be cultivated together if the yam's twining stalks are kept from winding themselves around the young trees.

Generally speaking, agro-forestry experience to date in Benin has been based on the taungya method.

**Agro-forestry Research Objectives**

The shortened fallow periods currently noted in southern Benin, and the resulting problems-decreased soil fertility, decreased firewood production, and reduced natural fallow areas-motivated the Department of Agronomic Research to start a research programme in 1980 with a view to including timber trees in traditional crop rotations.
The objective of this programme is to upgrade soil fertility and obtain substantial forest production over a relatively short fallow (three to four years). Acacia auriculiformis and Leucaena leucocephala are being grown as fallow species and being observed for their positive contribution to soil fertility and firewood production. If successful, this programme will enable agro-forestry to play an important role in improving Benin's forest economy.

Summary of discussion: Traditional agro-forestry systems

In the discussions on traditional agro-forestry systems and their prospects for development, the first major point which emerged was that insufficient attention had been paid to the improvement of traditional cropping systems, in short, to make them economically viable as well as to meet subsistence needs. To continue to divorce agriculture from forestry was to be moving in the wrong direction, and this was especially true in the humid tropics. One participant observed that the value of mixed cropping systems was being demonstrated all around us, but that we have been blinded by the success of monocultures in the temperate zone. A "farming systems" approach was strongly advocated, although it was recognized that such an approach was relatively rare and demanded large inputs of scarce, trained personnel to be effective.

It was pointed out that the rapidly increasing population density was leading to smaller farms, yet these had to meet the basic food needs as well as provide cash income. Stable systems must be developed, and research must be carried out to determine whether agro-forestry will indeed provide greater benefits to the small farmer. The claim that higher diversity will increase stability (i.e., lessen risk) was questioned, as the data were still ambiguous. Certainly from a management viewpoint a higher diversity of crops makes it difficult to maximize the yield of the individual components. The problem of crop compatibility was also raised, and it was noted that there was great variability in the demands of annual crops for light, nutrients, water, etc. Similarly, crops vary greatly in their response to different management practices such as weeding. This means that each component within a given system will have to be tested independently and in situ in order to fully evaluate the potential of the system in question. Because of this inherent complexity we must use existing systems as guideposts, and only test systems which could fit in the existing socioeconomic milieu.

The question of tree root architecture was brought up, and the trade-off in the humid tropics between trapping nutrients with a dense, shallow root system vs. increased root competition was recognized. In this case further complications arise because the tree root system is also affected by the herbaceous component, and one would expect the balance to vary in accordance with rainfall, soil type, management practices, etc.

Several speakers felt that insufficient attention had been paid in the past to the development and management of the tree crop component. In this context the point was again made that one has to work within the context of the existing system by looking at the farmers' needs and then providing new plant material or other inputs which are demonstrably better. Improved coconut varieties and the Crop Diversification Project in Sri Lanka were cited as examples from outside Africa. It was also suggested that a type of planted fallow might be developed which would hasten the fertility recovery rate and provide a crop which could be harvested at the end of the fallow.
Taungya systems from biological and production viewpoints

Taungya systems: Socio-economic prospects and limitations
Establishment of forest villages in Gabon
Taungya in Sierra Leone
Taungya practices in Togo
Development trends in taungya systems in the moist lowland forest of Nigeria between 1975 and 1980
Food crop yield under gmelina plantations in southern Nigeria
Summary of discussion: Taungya systems from biological and production viewpoints

Taungya systems: Socio-economic prospects and limitations

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Abstract

Taungya systems embrace multiple land-use practices involving joint production of forestry and agricultural crops. In the tropics, land is a most important factor of production and there is overwhelming dependence of the population on land for livelihood. The introduction of taungya has alleviated the problems created by the wasteful use of land under the traditional agricultural production systems, increased food supplies, and significantly contributed to the socio-economic well-being of the rural population. It is indicated in this paper that socio-economic factors favour continued development of taungya in the tropics, particularly if the limitations of labour and capital can be removed through adequate government support of the programmes.

Introduction

Land is a basic, if not the most important, factor of production in the tropics. The primary occupation of the people is agriculture, which employs more than 60 per cent of the active labour force. Agriculture constitutes the dominant sector of tropical economies, not only as the principal source of food for the majority of the population but also in terms of the sector's share of total national production, which frequently exceeds 50 per cent. For many tropical countries, development prospects depend on the prices of agricultural and forestry products in international markets.

The past concentration on, and bias towards, export cash crop production in the tropics was a major factor in the incidence of food shortages and malnutrition, the true dimensions of which are only now being appreciated (Okurume 1970). Data available from FAO (1976) indicate that the annual growth rate of food production per person in developing countries fell from 0.6 per cent in 1961-1970 to 0.2 per cent in 1971-1975. In Africa, the annual growth rate in 1971-1975 was -2.1 per cent compared with 0.4 per cent in 1961-1970.

Unless these trends are reversed, the developing countries of the tropics will be confronted by the spectre of chronic food shortages, widespread malnutrition, and mass starvation by the end of the twentieth century.

Tropical agriculture is particularly extensive, relying on a system of shifting cultivation or rotational agriculture whereby the farmers cultivate a piece of land for a few years, abandon it to fallow to regain fertility, and move on to cultivate another piece of land. They may cultivate several pieces of land successively before returning to recultivate the first piece of land at the end of the cultivation cycle.
Ordinarily, shifting cultivation requires a large amount of land per farming family, and its successful practice depends on virtually unlimited land availability or a relatively small farming population (Kio 1972).

The population of the tropics has grown very rapidly in the last two decades, averaging 2.5 per cent a year compared with 1 per cent in the developed countries of the temperate region (UN 1979). Given their small industrial sectors and their limited capacity to absorb excess labour in agriculture, developing countries have faced continuing fragmentation of farm units to accommodate requirements of new families. The institutional framework of land use in most tropical countries directly promotes such fragmentation of holdings.

The fragmentation of holdings and the prevailing institutional framework that does not fully view land as a factor of production have contributed to declining agricultural productivity and food shortages in the tropics. Equally important are the failure to introduce appropriate technologies (superior farming implements, seed varieties, and production techniques) and the inefficient organization of agricultural production. The causes of declining agricultural productivity with particular reference to Nigeria have been well documented by Olayide (1973). To overcome the constraints would require a revolution in agricultural production in the tropics, an event likely to occur only in the distant future.

Solutions to the defects of shifting cultivation as a form of extensive agriculture have been provided by the system known as taungya-combined production of forestry and agricultural crops on forest lands. King (1968) found that the system has been practiced for a long time and existed at some time in all the five continents. He also indicated that, despite the differences in terms or labels used, the taungya system always exhibited certain basic attributes and required some preconditions for its adoption. The preconditions, such as land hunger and low standard of living of the population, are clearly socio-economic in nature. The fact that the system is virtually extinct in the economically advanced countries supports this assertion.

The socio-economic environment is central to the prospects and limitations of taungya systems. Indeed, King (1968) concluded that the system was self-terminating once a country achieved a certain level of economic development.

**Socio-economics in the Development of Taungya**

The introduction of the taungya system into the humid tropics was a response to various socio-economic factors. For example, in Nigeria a major objective was to solve the problem of high cost of forest regeneration (Enabor 1979). In Ghana, the objective was to solve the existing land hunger problem in the rural areas (Amissah 1978). Whatever the reasons for introducing taungya, King (1968) insisted that the successful establishment and development of taungya depended on the pre-existence of land hunger, underemployment, and low standards of living among the rural communities. Apart from these three prerequisites, other socio-economic factors contributing to the development of taungya include population growth, land availability, farm labour supply, food supply, income-generating potential, availability of infrastructural facilities and organizational institutions.

In Burma, where taungya originated, it was used mainly as a means of regenerating both the soil and the forest by employing and improving upon shifting cultivation. It was essentially a method of shifting cultivation because forest land was cleared, farmed for a few years, and allowed to revert to forest so that fertility was restored naturally. It was an improved system because selected tree species such as Casuarina equisetifolia and Leucaena glauca were sometimes planted to assist in re-establishing the forest fallow (Nao 1978). The indication is that a low population density and a long fallow period were required for the system to be successfully practiced. Under the present high population densities it is doubtful that the system in its original form would succeed in many tropical countries.

The modern taungya system seems to differ significantly from the original concept. The practice has been reserved to forest estates, and rapidly growing rural populations have often put pressure on foresters and forced them to adopt taungya within the estates. Kio (1972) concluded that until the industrialization of
tropical countries becomes large enough to absorb the increasing rural population, pressure on forest estates by farmers would continue. The greater the pressure on forest lands, the more taungya would be sustained.

At the time when the present forest estates of many tropical countries were constituted, land was abundant, forests dominated the landscape, and shifting cultivation was successfully practiced. Agricultural expansion, introduction of permanent cash crops, and over-cultivation of available arable land have resulted in rapid soil deterioration and lower crop productivity in the unreserved land areas. The reserved forest lands have remained fertile, thus constituting highly productive farmland potential. Such imbalance in soil fertility between reserved and unreserved areas may facilitate successful development of taungya. King (1968) reported that, despite the existence of unoccupied and uncultivated land outside reserves in Uganda, farmers still participated in taungya because of higher fertility of the reserved land. Similarly, Lowe (1974) stressed that one of the major reasons that farmers participated in taungya in Nigeria was the opportunity to use the residual fertility of newly cleared land.

With population growth, an increasing number of farmers have found it difficult to acquire more land for farming. Immigrant labour required for the various forest operations may not get land outside the reserve to grow food to meet their own consumption requirements and that of their families. The introduction of taungya would be a big relief to such farmers. Thus, in some parts of south-west Nigeria, Ijalana (1979) found immigrant fishermen (llajes) constituting about 90 per cent of taungya farmers because they could not get land outside the reserves. Nigerians working their way to or from Mecca have similarly been mentioned by King (1968).

In general, where arable land is too scarce to permit agriculture or forestry as single land uses, taungya will develop. Over the past 54 years in Nigeria, the adoption of taungya has constituted an effective means of providing more farmland to the farmer and, at the same time, transforming the natural forest into more productive forest plantations at relatively low direct cost to government.

**Labour and Other Inputs**

The growing of both agricultural and forestry crops is involved in the taungya system. The activity is labour-intensive, especially as modern farming techniques are at present nonexistent in taungya operations. For a successful implementation of taungya, the supply of labour must be ensured. In this way the absence of alternative non-farm occupations also favours taungya. Some farmers in southwest Nigeria were apparently unwilling to practice taungya because they were not unemployed (King 1968).

Several authors, including Mergen (1978) and Nao (1978), have contended that the taungya farmer is exploited by participating in the establishment of plantations without being adequately rewarded. King (1968) went further, to suggest a sharing of the savings in the cost of establishing the forest plantation between the farmer and the forester. The thinking is that if there are other job opportunities in the rural areas, the farmer may prefer them. However, 99 per cent of farmers in south-west Nigeria reported that they gained from participating in taungya (Kio and Bada 1981). The indication is that even if farmers are being exploited they are not aware of it and they are quite willing to participate.

Taungya, whether traditional or departmental, is an arduous task. The labour has to be drawn from the existing pool of farm workers because out-migration to the urban areas has depleted other sources. As long as out-migration continues taungya will suffer a drain in the most productive labour force, the young men and women. In order to sustain the system rural life must be made attractive and comparable to urban conditions so that rural labour is retained. The introduction and success of the departmental taungya system in southeast Nigeria seems to be a manifestation of the importance of this factor in the development of taungya (Enabor and Adeyoju 1975). What still remains largely unsolved is the introduction of improved farming techniques so that the work becomes less arduous and the system more productive.

**Food Supply and Income Generation**
Nao (1978) estimated that taungya systems in Nigeria have directly provided enough food for about 700,000 people, constituting about 1 per cent of the country's food needs. In Thailand the indication is that taungya farmers produce enough food to feed themselves and sell the surplus to the market, and in China, taungya farmers contribute about 56 per cent of the country's food requirements.

It is not clear from these figures whether the taungya farmers enjoy a higher standard of living than their nonparticipating counterparts. It is sometimes argued that farmers would be more willing to participate in taungya only if their standard of living, measured by level of income, were improved. However, King (1968) maintained that the taungya farmers' income is improved only if they are provided with wageearning employment in the forest plantation. In this respect departmental taungya would satisfy the income requirement for the successful development of taungya, because it ensures regular income comparable with that obtainable in other sectors of the economy.

Under the traditional taungya system, income generation is left entirely in the hands of the farmer, who may find it difficult to get a ready market for the produce. However, Kio and Bada (1981) found that although most of the taungya farmers sold less than half of the total crop volume harvested, they obtained between N500 and N2,000 per year. Also, Lowe (1974) maintained that most of the food produced by taungya farmers is consumed locally, yet farmers may earn between N600 and N800 a year if they concentrate on yam production. If maize and cassava are produced, the estimated income would be N100-N200. Another estimate by Enabor (1979) was that per capita income of taungya farmers in Nigeria is about N72, which is below the N90 estimated for urban centres but well above the N30 estimated for rural areas.

Despite such improved income estimates for the taungya farmer, Olawoye (1975) contended that the living conditions of the traditional taungya farmers have not improved as compared with those of other rural villagers. In contrast, the departmental taungya farmer has enjoyed substantial benefits in terms of provision of infrastructure and other amenities. The indication is that, although a low standard of living is required as a prerequisite for the introduction of taungya, its continued successful development depends on the extent to which it improves the standard of living of the farmer. As long as improvement does not occur, the capable farmer will look to the urban centres in search of a better living standard, the practice of taungya being left to less efficient hands.

**Infrastructural Facilities and Social Amenities**

Some of the major infrastructural facilities that may affect the development of taungya systems include transport, marketing, and storage facilities. To the farmers who do not have means of transportation and have to walk to the farm, the distance from home to the farm is a major determinant of their level of participation in taungya. In well-organized taungya systems accommodation at very convenient locations may be provided for the farmers.

Where transport facilities are readily available or where land shortage is acute, farm distance is less important in determining the farmer's participation. For example, King (1968) showed that farmers in Trinidad travelled up to 16 km to participate in taungya because transportation was relatively cheap and easy. In Kerala (India), there was no distance limit because of the acute land shortage problem and low standard of living of the farmers. In Nigeria, Ijalana (1979) found that taungya farmers travelled between 3 and 6 km by motor vehicle or bicycle to the farms.

Distance may not constitute a limitation to participation but it surely has an effect on productivity. Farmers who travel long distances may reach the farm already exhausted. They may arrive late and have little time to participate before closing time. Thus Mergen (1978) estimated that 3-5 km should be the maximum walking distance.

The improved crop yield obtained from taungya farms is not meaningful if there is no means of storing the excess food produced or transporting it to the market for sale. Farmers can only be encouraged to produce more if they get reasonable returns.
The availability of schools, sanitary and health facilities may encourage farmers, particularly young ones, to stay in the rural areas and participate in taungya rather than migrate to the cities. Moreover, such facilities would improve the farmers' capabilities and make them more contented and productive workers.

Easy access to credit facilities for taungya farmers would enable them to improve their methods of cultivation and to store, process, and sell their produce at the right time to obtain maximum profit. Credit facilities are also necessary to enable farmers to acquire improved farm inputs, such as fertilizers, herbicides, and farm machinery.

**Prospects and Limitations**

Numerous studies confirm the positive role of the taungya system in augmenting food supplies and fostering the socioeconomic improvement of rural communities in tropical countries. The system has also been instrumental in preserving forests. The prospects for the taungya system hinge on the continued interest of the farmers and the foresters in its maintenance, aided by the government.

The socio-economic prospects of taungya systems in the tropics depend on such factors as development trends of the economy in general (and of agriculture in particular), population growth, unemployment, income-generating potential, effectiveness of forest management, and the role of government in providing necessary incentives.

The disappointing development performance (UN 1978) of tropical countries has prompted a rethinking of growth strategies to solve the mounting problems of poverty, ignorance, disease, and malnutrition. In the 1980s emphasis has shifted to self-reliance and self-sustaining economic growth in which high priority is given to food and agriculture, raw materials, and natural resource development (ECA 1980).

The economic growth strategy demands action by government to improve agricultural productivity and rural income, provide infrastructure and social amenities, and promote diversification of employment opportunities that will stabilize rural communities. In the short term, measures to stimulate rural development must focus on the smallholder farmers rather than on large-scale capital-intensive agricultural projects. The taungya system should constitute an ideal development tool. Its adoption on a large scale should greatly expand food and wood supplies, increase rural employment opportunities, and raise living standards. Many of the inputs to a successful rural development programme, such as improved seed varieties, fertilizer, infrastructure, and social amenities, are complementary to the operation of the taungya system.

At the level of the smallholder, income considerations are the dominant concern. The income prospects depend in turn on such factors as soil fertility, crop combinations, production costs, and prices, as well as on the efficiency of harvesting, transporting, and marketing. While the taungya farmer initially has access to highly fertile soil in newly cleared areas (Lowe 1974), the soil fertility may be depleted after two or three years, depending on the particular crop combinations used and cultural practices. Fertilizers or other inputs must be used to maintain soil fertility and high yields. The effects of combining crops on each other as well as on soil fertility in forest lands need to be investigated. There are signs, however, that more flexibility is being introduced into the system, as farmers in some countries are given permission to grow fodder crops and cash crops such as cocoa and coffee, and raise livestock.

Production costs also affect income prospects. Under the traditional taungya system, the bulk of the production costs to the farmer is implicit and consists of the labour provided by himself and members of his family.

The farmer's needs for cash will probably increase under a well-developed taungya system for the purchase of superior seed varieties, farm equipment and tools, and services of hired labour during intensive operations such as land preparation and harvesting.

With population growth and improved living standards, the prices of food and livestock feeds are bound to rise. Taungya farmers are thus assured of good prices for their output, especially where they are able to
transport and market their own products. In Nigeria, where good road systems have been extended to many rural communities, farmers can now convey their surplus produce to markets about 100 km away, obtain good prices, and return home the same day. They can now dispense with the services of intermediaries, who, in the past, absorbed the bulk of the profits from production efforts.

Several estimates of income earned by the farmer under taungya have been made. In Nigeria, the estimates of annual income range from N50 (Ball 1977) to N600 (Okojie 1975). In Zambia, the profit (net present value) from maize intercropped with pines in an industrial plantation increased 7 per cent in one year compared with the pure pine plantation (Kufakwandi 1980). Although the figures vary widely, they provide evidence that the farmers inside taungya earn higher incomes than those outside. A majority (55 per cent) of farmers interviewed in Oyo State, Nigeria, reported definite improvements in income (Kio and Bada 1981). Taungya is especially profitable for farmers who obtain supplementary employment in forestry or have privileged access to forests to hunt, collect wood for sale, gather fruits and nuts, or harvest other forest produce freely. If income-generating potential alone were considered, the taungya system's prospects would be bright.

For taungya systems to be successful, however, it is necessary to have a regular supply of labour. The estimated agricultural labour force of developing countries rose from 648.1 million in 1965 to 709.2 million in 1975 (FAO 1980), representing 31 per cent and 34 per cent, respectively, of the total rural population. At present a high proportion of the labour force in tropical agriculture is unemployed or under-employed. The taungya system provides a unique and attractive opportunity for absorption of unemployed rural labour. In particular, it represents the only alternative available to landless rural farmers.

Ironically, however, many unemployed farmers are reluctant to participate in taungya. First, the majority of young potential farmers in rural areas find rural life dull and uninteresting. They are migrating to urban centres, where life is less arduous and monotonous, in search of jobs. Rural-urban migration on a large scale has been encouraged by the worsening rural-urban terms of trade (FAO 1980). Thus, the majority of farmers participating in taungya in the tropics are people aged 40 years and over (Kio and Bada 1981). A high proportion of such farmers tend to be under-nourished and in a poor state of health, so their productivity is low (Enabor 1978). Some unemployed farmers are willing but unable to participate in taungya because they lack the necessary inputs to cultivate the land allocated to them in forest reserves. The youth must be retained in the rural areas by the creation of more attractive living conditions. To some extent, the establishment of departmental taungya schemes based on integrated forest villages provided with all the basic social amenities has enhanced participation of younger farmers in taungya systems (Enabor and Adeyoju 1975).

The effectiveness of forest management also affects the prospects for taungya in the tropics. The objective of forestland management under taungya is to obtain the maximum rent from the soil under use. This requires viewing the system as an integrated joint enterprise. Profit is to be maximized for the whole enterprise rather than for the component parts (Enabor 1978). Currently, forest management in the tropics is still very weak or ineffective and lacks necessary information, trained personnel, and adequate financial inputs. It is, therefore, not surprising that most foresters distrust farmers who, in turn, are discouraged by the host of restrictive regulations in taungya schemes. A possible solution to the problem is to strengthen forest management with adequate legislation and supply of productive inputs. Alternatives are: (1) departmental taungya, in which the forestry department owns both the agricultural and forest crops, or (2) agro-forestry, where total ownership rests with the farmer.

King (1968) postulated that the taungya system would die a natural death once farmers' incomes reached a sufficiently high level. However, a survey in Ando State indicated that high income farmers were more interested in agro-forestry than were low-income farmers (Ijalana 1979). Taungya in the modern sense is a multi-product enterprise rather than a system that provides supplementary income through a forestland tenancy. There is evidence that the concept of agro-forestry as a rational and profitable multiple land use is gaining increased attention in some economically advanced countries (anon. 1978).
The most important limitation of the taungya system is the lack of adequate inputs of land, labour, and capital. An adequate supply of land is particularly critical to traditional taungya confined to forest reserves, because in most tropical countries the chances of further expansion of the land area under reserves are slim indeed. In practice, only parts of the forest estate will be effectively available for taungya. With time the problem of land hunger is bound to surface as the population of taungya-dependent communities expands. Where the physical availability of land for taungya is not limiting, the difficulty of transportation would still proscribe the area that farmers can effectively cultivate.

The problem of shortage of labour for taungya systems in the tropics was mentioned above. The available evidence indicates that more and more farmers are relying on hired wage labour to perform essential farm tasks. On the other hand, many more farmers are unable to afford high cash wages, and therefore spend longer hours in cultivating their food crops. Less time is thus available for planting and tending forest tree crops from which they receive no direct income. Increased capital resources of farmers would enable them to recruit the hired wage labour needed to effectively cultivate an optimum farm size under the taungya system. Loans for this purpose should be granted to the farmers by the forestry departments, which are in a position to ensure repayment at the time of harvesting and sale of the farmers' crop.

Another limitation of the taungya system is management. There is an acute shortage of the funds and trained personnel needed to institute effective management. Necessary information on performance of alternative crop combinations and their impact on the soil is lacking. So foresters may prefer reversion to monoculture, with which they are more familiar, or to natural regeneration. Some recent studies (Kio 1978) have concluded that natural regeneration systems are at least as productive as artificial plantations, and they do not incur the loss of vital ecological benefits.

The limitations of taungya systems in the tropics are more those of operational constraints than those of concept and meaning. With real economic progress, the constraints should gradually disappear so that the practice can be rationalized into a permanent and profitable system of land use.

The socio-economic factors favour the survival and expansion of taungya systems in the tropics, at least up to the end of the present century, provided the practice is backed by adequate government support. As Adeyoju (1980) has stressed: The future of agro-forestry depends not merely on the quantity and value of joint products arising from the enterprise, but largely on the package of sociopolitical strategies built into the programmes.

Establishment of forest villages in Gabon

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Abstract

*Gabon is a country whose dense forests constitute the main natural resource. The forests are stocked mainly with okoume (Aucoumea klainiana) and, because they have been exploited by industry, the government has established a reforestation programme of natural stands. This paper describes the means used to attain this objective and the results of initial endeavours. The conclusions include recommendations for improving the programme.*

Gabon-A Country of Forests

Seventy-five per cent of the area of Gabon is covered by dense, humid, evergreen forest of low and medium altitude, while 15 per cent of the country is savanna. Gabon produces a great deal of wood (particularly okoume, Aucoumea klainiana) and its forests have been subjected to intense exploitation for more than half a century. For many years the government has been working on a reforestation programme in over-exploited forests and an improvement programme for dense natural okoume stands.
The vacant, unclaimed forests of Gabon and the reforestation areas belong to the government and constitute part of its private domain. This is the basic legal status governing the forests but rural communities, which account for 86 per cent of the population, exercise their customary right to use the government-owned forest, a right strictly limited to meeting the personal and community needs of users (collecting firewood and building materials, picking medicinal and edible plants, and so on).

In this way, the forest is a reservoir from which rural people can obtain basic essentials. Various food-producing crops are also raised in these forests. This situation dates back to precolonial times and, unfortunately, has not developed since then. This explains why rural communities have failed to evolve. For obvious financial reasons, the forests are systematically exposed to a well-established exploitation operation, with solid financial backing. The forestry activities of big businesses do not meet the fundamental rural development criteria, namely that the basic structure for any development effort must be the village.

Forestry regulations in effect in Gabon have provided for a forestry permit which allows rural people to acquire a certain amount of forest land, if they meet fairly simple requirements. These provisions have actually favoured the development of some geographically superior areas. The permits apply to what are known as family-cutting areas, which are most sought after in zones rich in okoume located close to transportation routes. This made exploitation inexpensive and required only rural manpower. Over the years, however, these activities, along with demographic pressure and intensified exploitation, have led to forest shrinkage. Favourable zones are now in distant locations and are becoming rare. Nowadays, this type of permit has lost its original character. It has been diverted from the traditional practice and has been used to benefit tenant-farming contracts which, as they become more common, make the lot-owner a "shareholder" in the forest. This runs counter to efforts in Gabon to develop a class of native contractors in rural areas.

**Reforestation Centres**

The most important activity of reforestation centres is the creation of artificial stocks of okoume. Studies and research on forest ecology and on the biology of this species have made it possible to develop a sophisticated silviculture technique. The artificial regeneration of the stocks of this species no longer poses major problems. Twenty-six thousand hectares of okoume have been planted so far.

The establishment of a reforestation centre always begins with plans for a road network and home construction. Under normal circumstances, each of these centres consists of a staff of between 100 and 400 people. Including families, approximately 1,000 people live in a centre. The staff should be broken down as follows: 70 per cent unskilled workers; 25 per cent technicians (experts); and 5 per cent training personnel.

In an effort to alleviate insufficient food crop yields among elderly villagers and the families of staff (who are mainly seeking self-sufficiency), the reforestation authorities decided to introduce intercropping in the reforestation plots. they had both social and economic objectives in establishing an agro-forestry system. The social objective was to encourage the population to participate in the artificial regeneration of the forest, and thereby to solve the conflicts of interest that often divide forestry specialists and farmers when the latter feel they are being deprived of arable land and are not benefiting from reforestation activities. The economic objective was to increase the quality and value of the plantations.

An agro-forestry solution was thus chosen, aimed at increasing the value of plantations by the incorporation of food crops. There was a choice between two types of crops: the traditional food crops such as cassava, cocoyam, and corn; and the profitable cash crops such as coffee, cocoa, oil palm, and bananas.

For the traditional food crops, experiments were conducted on the Nkoulounga reserve located north-east of Libreville; cocoyam and cassava were planted between rows of okoume, either the same year as the okoume was planted or the following year. The okoumes were planted $3 \times 3$ m, $5 \times 5$ m, and $6 \times 6$ m apart. An attempt was also made to introduce okoume in a one-year-old cassava plantation where the
okoumes were planted 12 x 12 m apart. It soon became apparent that the requirements of the okoumes and the food crops were incompatible. To grow well, okoume needs a lateral screen of young forest undergrowth to protect its bole. Food crops, on the other hand, need rich soil, must be well maintained, and should be kept free of competing vegetation. The work required to maintain the food crops in densely planted areas favoured the development of crowns on the okoume, which finally overshadowed the food crops. In low-density plantations (where trees were at a distance of 5 x 5 m or 6 x 6 m apart), the boles of planted trees became exposed over the years—a situation that leads to the growth of suckers and poor form due to the lack of natural pruning.

A good silviculture method for okoume, then, does not permit intercropping. Instead, spaces were set aside in the reforestation zones for food crop production, and cash crops were sought for long-term cultivation. In future, however, an agro-forestry method for okoume may be designed, using traditional food crops, so that people living in reforestation centres and neighbouring villages can grow their own food. Land left fallow will be used by the villagers after the growing cycle. This land will be interplanted with okoume, or prepared for natural regeneration if the presence of seed-bearing trees permits this.

Agro-forestry experiments aimed at cash crops have identified four crops whose essential requirements are known: cocoa, coffee, oil palm, and banana.

The search for practices that would reconcile the silvicultural management of okoume (which is characterized by difficulties in terms of pruning and the shape of the bole, sensitivity to changes in light, and requiring forest undergrowth between the rows of plants) with those of selected cash crops (which require as much light as possible and demand the suppression of forest undergrowth during the first growth stage and the elimination of all competing growth during the second stage) is stymied by two technical problems: the distance between the okoume plants and the other crops; and the mode of transplantation for the okoume, given the differences in the natures of the species in question. Experiments were therefore conducted using different planting techniques: arrangement of seed spots, open planting, strip planting, and so on.

The most interesting results were obtained with the GrosMichel variety of banana. The production experiments yielded an average harvest of 10 t/ha during the first cycle, 25 to 30 months after planting. This is not high for a cash crop, but it is enough, given the extensive interplanting with okoume, since the object is to involve the population in agro-forestry activities.

**Conclusion**

In future, consideration must be given to transforming reforestation centres into rural development centres. Combining agro-forestry activities and wood-processing cottage industries, such centres would make more productive and rational use of the forest, as well as involving the local population economically. They would then be ready to be integrated into the life of the centres. It is also imperative that more thorough professional training be provided on the site for specialists (machine operators, assistant diesel mechanics, drivers, nursery personnel, and so on), for junior staff (supervisors, foremen), and for intermediate-level staff from technical schools who would spend periods on the site to augment their theoretical training.

This is the beginning of a process that will lead to the creation of private forests using plantations created by the villagers through agro-forestry methods. Experience to date shows that the forest cannot play an effective role unless the management objectives envisage real profits for the rural inhabitants. For this reason, development plans should be simple and well adapted to the environment. They should be designed in such a way as to allow the rural people to participate in their implementation and to derive maximum benefit from them.

Small processing industries in the villages will afford villagers access to semi-finished construction materials to improve their homes. A source of employment and income, they could become real centres of activity around which a multitude of related activities could arise.
Taungya in Sierra Leone

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Abstract

The paper briefly describes the agriculture and livestock industry, the method of afforestation by the taungya system, and the evolution of silviculture and agro-forestry in Sierra Leone.

Two factors necessitated the introduction of agro-forestry- namely, the rapid rate of deforestation of unreserved forest lands due to increased agricultural activity, and the reluctance of landowners to set aside any more lands for forest conservation, which did not yield immediate financial returns.

The acute and increasing demand on forest lands is being alleviated by modified forest management and silvicultural techniques, which include various agricultural crops as understoreys in forest plantations. The idea is to conserve the vegetation, minimize soil erosion, and encourage active participation of farmers in the production of both food and wood on the same piece of land.

Introduction

Sierra Leone has a tropical climate with high temperatures, high humidity, and heavy rainfall. The rainy season extends from May to October, with the heaviest rains falling in July and August. The rainfall decreases from the coast inland, e.g., 3,800 mm in the coastal city of Freetown to 2,100 mm in Kabala in the far north-east.

Topographically, the country can be divided into three main zones: (1) the low-lying, swampy coastal area; (2) the interior plateau (about 450 m in elevation); and (3) the mountain ranges of the north-east with peaks of over 1,800 m.

The total area of Sierra Leone is 72,326 km², and this can be classified into agricultural land (60 per cent), pastures (18 per cent), mangroves and inland swamps (8 per cent), forest (4.25 per cent), and other (9.75 per cent).

Agriculture is the largest sector of the economy, but, in spite of the economic and social measures applied, this sector has the lowest income level. Annual productivity per worker is estimated to be Le 100,* or less than half the average (Le220) for all sectors. This figure compares with Le880 for mining and between Le330 and Le900 for the other sectors. The poor productivity of the agricultural sector indicates the need for more effective approaches and practices. The current farming systems need to be reevaluated and upgraded.

Farming Systems

In the northern half of the country, the long dry season limits production to cattle and annual crops, whereas the south has rainfall and climate suitable for the production of cocoa, coffee, and oil palm, which together form the backbone of agricultural exports. The important food crops grown in Sierra Leone are rice, sorghum, millet, maize, cassava, sweet potatoes, groundnuts, and sesame, with rice being by far the most important. It accounts for more than 75 per cent of the area under food crops and provides employment for more than 80 per cent of the farming population. Yearly production is currently estimated at 800,000 tons.

The total area under upland rice in 1970 was about four times that in swamp rice (236,400 ha compared with 60,800 ha), even though the average yields of the former are generally much lower and are showing a
downward trend owing to shorter fallow periods.

Traditionally, upland farming has consisted mainly of the bush fallow or grass fallow system in which a few years of cropping is followed by an interval of fallow—8-12 years in the Eastern Province, 4-6 years in the Northern Province. After the fallow, the natural groundcover is cut and burned. Rice seed is mixed with other upland crops such as maize, guinea corn, millet, sesame, pigeon pea, okra, beans, etc. and is broadcast by the farmers over a series of separate strips. The rice is harvested first. Cassava, the major root crop in the country, is planted as the last crop before the land is fallowed.

Although swamp rice farming has been found to be more profitable than upland crop farming, many farmers are reluctant to adopt it, either because they do not know about swamp rice farming or because they prefer upland farming for the variety of crops it produces.

Coffee, cocoa, and oil palm are the primary agricultural exports; therefore, tree crops constitute an important source of foreign exchange. The total area under oil palm is estimated at about 4.5 million ha in natural stands, varying in density from 15 to 150 trees/ha. Under cocoa, there are about 2,240 ha, confined mostly to the Eastern Province. Other tree crops are cola nuts, cashews, coconuts, and citrus fruits.

The growing of tobacco started not so long ago. In 1961 there were 24 tobacco farmers and by 1971, more than 15,000. Cultivation, which was originally confined to the Northern Province, has recently been introduced into the Southern Province.

The livestock industry is centred on cattle. The cattle population is concentrated mainly in the northern part of the country, which comprises vast tracts of natural savanna pastures interwoven with gentle slopes. The mild climate and sparse population increase the potential production. The cattle are N'dama, their estimated numbers being between 250,000 and 300,000. Nomadism is a basic social and economic problem, and settlement schemes by the Livestock Division have been unsuccessful.

The estimated population of smaller livestock in the country for the year 1975 was 62,000 sheep and 175,000 goats. They are spread throughout the country, but the largest flocks are kept by cattle owners of the Northern Province.

**Agro-forestry: From Modest Beginnings**

During the mid-1940s the native administrations became interested in forestry and began to plant timber-producing trees, often on roadside strips not more than 170 m wide. This effort led to the examination of the afforestation techniques and the search for ways to reduce the costs of clearing the bush fallow for the trees and reduce the long waiting period from the time the plantation was established to the time it began to yield revenue.

Taungya was considered as a means of reducing time and costs involved in establishing the forest. The first real attempt to establish forest plantations by the taungya system was made in the late 1930s, using 50 per cent indigenous species and 50 per cent of the exotics, Gmelina arborea, Tectona grandis, and Cassia siamea. It was observed that the 50 per cent indigenous and 50 per cent exotic species mixture was not a useful proposition, as the exotics grew faster and the indigenous species lagged behind.

Subsequently, underplanting the established Gmelina stands with local species was tried. The aim was that if any of the more valuable indigenous species showed signs of succeeding, thinning in their favour would be resorted to later. In general this was a reaffirmation of the policy of preferring indigenous species to exotics. But Gmelina, being a fast-growing species, eventually swamped all the indigenous species.

In the early years of the system, there was one notable effort to reduce the time between plantation establishment and plantation exploitation through the introduction of an understorey of cocoa. Demonstration and observation plots were established under various light conditions. The plots were successful, and afforestation along these lines was gradually extended as the local administration nurseries
produced more planting stock. The cocoa, which replaced part of the natural understorey, yielded quick monetary returns as minor forest produce. Unfortunately, as a result of staff changes and the difficulty of growing cocoa in unsuitable soils, these experiments were neglected and eventually discontinued.

The taungya system, however, is still in operation and is based on co-operative efforts between the government and farmers. Each year planting areas are demarcated in December or January and invitations issued through the Paramount Chiefs to the farmers who formerly owned the land. It is the original landowners who have the first rights to farm the land in exchange for clearing the bush fallow and following the planting guidelines set out by the government. Only the original landowner can reject the offer to farm, and pass on the rights to someone else.

After the bush is felled, the cut vegetation is allowed to dry and is then burned about March-April. The forestry department lists crops that are allowed to be cultivated and lays down other requirements. In June-July, the young forest trees are planted by the forestry staff, and this is done after the farmer has planted his own crops.

Spacing for the forest trees varies according to site and species to be employed. The general trend is toward wide spacing, e.g., 2.5 x 2.5 m, 3 x 3 m, and 4.5 x 4.5 m for Gmelina arborea, Terminalia ivorensis, T. superba, Cordia a/liodora, and Nauclea diderrichli.

The principal agricultural crop used in taungya is rice, but farmers are allowed to sow maize, guinea corn, peas, sorghum, cassava, and okra. During this time, the farmers tend the young trees in addition to their agricultural crops.

After the second, and sometimes the third, year the farmer is allotted another plot. In most cases where there is no land hunger and in remote areas where the forestry department is obliged to carry out rapid afforestation, the farmers are the forestry employees. Forest villages are built for them, and all the agricultural crops they cultivate belong to them.

The idea of simultaneous production of timber and agricultural crops on the same piece of land was revived as a result of certain developments in the country during the implementation of the first five-year national development plan. These developments included the rapidly diminishing unreserved high forest as a result of the rising population, the return to the land of people previously engaged in mining, and the government emphasis on increasing food and cash crop production to conserve and obtain much-needed foreign exchange.

Most land in the country is held communally with individual right of usufruct; there is no formal tenure except on the Freetown Peninsula, i.e., the old colony area. Also, there was a growing feeling in the country that landowners who had given up land for forest reserves and protected forests generally did not receive adequate or immediate compensation. Thus, it became extremely difficult for the government to obtain additional land for forest plantations or even to retain the existing forest estate.

The forestry department, therefore, began in 1976 to introduce cocoa, coffee, and cola, as understoreys in Terminalia ivorensis and T. superba plantations. Initial experiments at Kasewe Forest Reserve in the late 1950s had proved satisfactory, and the indications are that coffee will soon become the main understorey in extensive areas of wide espacement plantations in forest reserves and the lineplanted areas in native administration forests.

These perennial crops are being introduced as understoreys at spacings of 7.5 x 7.5 m, 9 x 9 m, and 10.8 x 10.8 m such that the final crop will be 178,121, and 85 stems/ha respectively when the plantations are between 12 and 15 years old. It is hoped that when the agricultural crops have outlived their usefulness (about age 30), the whole area will be clear felled and replanted by the taungya system. Maintenance from the time the agricultural crops are planted will be carried out by the farmer (the original landowner or holder), to whom the plantation would be leased on payment of an annual rent to be mutually agreed upon. Cassava and sweet potatoes have also been recently introduced in nearly mature T. ivorensis, T. superba, C. alliodora, and G. arborea plantations. No measurements of yield have so far been made.
Taungya practices in Togo

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Abstract

This report briefly describes the development, brought about by demographic pressure, of agro-forestry practices in Togo. The first part describes the balance that existed between traditional land-use methods and the land's capacity for natural regeneration at a time when population density was still low. With population growth and the need for increased agricultural production, this balance was upset, the forest ecosystems were destroyed, and the traditional farming methods were made obsolete. The second part describes the taungya system, as it was introduced for the first time in Togo in 1954, and its development up to the present.

Togo has approximately 4,794 km² of dense, semi-deciduous forests, generally divided into clumps of fewer than 5,000 hectares, for the most part heavily planted with coffee and cocoa. Present agro-forestry practices are closely linked to the traditional land-use system.

Introduction

Traditional land use derived from the tribal organization of the population, and is characterized by the occupation of independent pieces of land by communities made up of descendants of a common ancestor. The basic principle underlying traditional land tenure was collective ownership, whereby land did not belong to anyone in particular; all land within the territorial boundaries of a tribe was regarded as a unit, at the disposal of all members of the tribe. The traditional land-tenure system was perfectly suited to the extensive shifting cultivation that was, and still is, practiced by the populations concerned.

Shifting cultivation has gradually claimed vast areas from forests through indiscriminate clearing practices. Forests have been progressively and unavoidably destroyed in direct proportion to the increase in population density.

As the tribal forest reserves diminished, the natural capacity for regeneration of the "grassed" lands was also endangered by bush fires. Only a few species of grass vital to the life of the rural people were preserved and cultivated. Human activities had a remarkable effect on the landscape, with Butyrospermum parkii (or Vitellaria paradoxx&l, Parkia big/obosa, and Adansonia digitata stands being maintained because of their importance to the life of the local communities while many other species of trees practically disappeared.

Agro-forestry, defined here as the combination of trees and agriculture to obtain ligneous products, does not exist as a farming system in Togo. Nevertheless, in the south-west of the country, coffee and cocoa are cultivated among tall shade trees to the extent that at present all the woodlands of this region have been replaced by coffee and cocoa plantations.

Taungya System

Aware that the forests in the vicinity of rural settlements were in serious danger of extinction, the forestry department decided to introduce taungya. As early as 1954, farming in forests was authorized in some areas of the country on condition that the farmers would not only plant food crops but would also cultivate teak, a forest species that was introduced during German colonization and is well adapted to conditions in Togo.

At first, the farmers were allowed to select their own site and desired acreage in a forest reserve, according to their own criteria and abilities. Using traditional methods, they prepared the ground and...
planted and nurtured the seedlings supplied by the forestry department, which, in principle, supervised all operations. The food crop harvests belonged entirely to the farmers, who were authorized to open up new plots according to their needs. When the cover of the teak plants began to hamper the development of food crops, the forestry department resumed responsibility for the care of trees. The farmers were also allowed to choose the food crops they wanted to grow, according to practical experience. Only perennial crops, such as oil palms, citrus fruits, coffee, and cocoa, were forbidden. Later, following an evaluation of the results by the forestry department, some changes were made to the formula.

As early as 1958, farmers were compelled to cultivate plots in a continuous block rather than interspersing them throughout the forest. This regulation derived from the difficulties associated with managing small heterogeneous plots that were spread throughout the forest and that included seedlings of many different ages.

With regard to the kind of crops to be grown, it was recommended that only corn, yams, and beans be cultivated together with teak. This recommendation was based not on scientific evidence but rather on observations of poor teak growth in combination with other crops such as cassava, cotton, and sorghum.

In spite of the generous concessions by the forestry department in allowing food crops to be grown in reserved forests, the hostility of traditional farmers towards the principle of reserving forests intensified and resulted in a massive and uncontrollable invasion of the forests by the traditional custodians, who went as far as planting forbidden crops- oil palm, coffee, cocoa, etc. This situation led the forest service, in the early days of the country's independence, to suspend the taungya system in order to protect the reserved forests. The hostility shown by the population towards the taungya programme stemmed from discontent with the principle of systematically setting aside forest reserves. The farmers felt the reserves were unjustified because no development was carried out in them.

With FAO (Food and Agriculture Organization) assistance, the Office de Developpement et d'Exploitation des Forêts (Forest Development and Exploitation Authority: ODEF)

- a government organization set up in 1971 to stimulate reforestation activities-reintroduced the taungya on its sites in 1972, adding new elements such as incentives in the form of bonuses in cash and in kind. The cash bonus was fixed at 6,000 fr CFA (in 1981, 400 fr CFA = US$1 ) and there were supplies worth 23,000 fr CFA for the first year of the contract. These incentives made it possible to plant more than 1,200 ha of Terminalia superba before the system encountered two difficulties that led once more to its abandonment:
  - The Terminalia superba plantations were established in dense, semi-deciduous woodlands that are much sought after by farmers, who clear them for food crop production. The new taungya system allowed the planting of corn, which in Togo is generally grown on forest clearings and is not the leading rotation crop. Because the ODEF was unwilling to allow rotation of crops under the taungya system, farmers felt it was pointless to continue with the system, as grasslands were readily available all around the forest reserves; and
  - T. superba and teak plantations were usually handed over to the forestry department after two years of cultivation by farmers. Since these plantations were far from human settlements, there was inadequate labour for maintenance and reforestation activities. A great many of the plantations were thus left in a deplorable state.

Given that the taungya system faced virtually insurmountable difficulties at the sociological and technical levels, a new formula had to be found. Thus, under state supervision, a semi-mechanized eucalyptus reforestation site was established near a major urban centre capable of supplying needed labour. Both food and tree crops were to be cultivated as before but the state would reap the benefits of all harvests and would pay labourers a wage (often described as "departmental taungya"). This formula was expected to solve some of the problems of the taungya system for T. superba plantations.

For the first time in Togo, the theory of maximum gross yield from land under agro-forestry was advanced. Although this theory is inherent in the taungya system, the basic difference is that in
conventional taungya the aim is to get maximum food and timber production, regardless of cost (with the main cost being the farmer's labour), whereas in the new state-supervised version, the production cost must be taken into consideration. Experiments have been conducted and will continue, stressing both improvement of yields and appropriate technology (e.g., food-crop density in forest plantations).

At present, the cost of food crop production under state supervision and within the framework of agro-forestry exceeds acceptable limits. This situation is not peculiar to agro-forestry but applies also to the traditional system of agriculture, which is based on obtaining staple foods through the investment of minimum human effort.

Besides efforts to alleviate both timber and food shortages through the taungya system, the state is also supporting an experimental programme in north Togo to shorten fallow periods. In this part of the country, where the population density (40 people/km²) makes it impossible to observe the traditional fallow period of 25 years, techniques that accelerate the natural regeneration of soils are essential because farmers are financially unable to maintain fertility through the use of chemical fertilizers.
Development trends in taungya systems in the moist lowland forest of Nigeria between 1975 and 1980

J.B. Ball and L.I. Umeh
Federal Department of Forestry, Ibadan, Nigeria

Abstract

This paper investigates trends in the development of two taungya systems in southern Nigeria between 1975 and 1979-1980. The two systems are traditional taungya, where the farmer retains the proceeds of the food crops raised during the establishment phase of the forest plantation, and departmental taungya, where employees raise the food crops and the forest authority retains the proceeds. The area of land devoted to traditional taungya has declined very slightly, but there has been a large decline in the number of farmers participating. The reasons for this are not clear. The area of departmental taungya has declined considerably for administrative and financial reasons. The system is likely, however, to expand in at least two states from 1981. The economics of the two systems became much more favourable between 1975 and 1980 because of increases in forest fees and volume yields as well as agricultural prices. There are also large potential reductions in costs, despite increases in wages. It is recommended that monitoring of the taungya systems continue but that socio economic studies be included in the future.

Introduction

One of the most challenging problems of modern times is the production of sufficient food and forest resources to sustain the ever-increasing world population. The problem would be greatly simplified if one type of land use would expand without impinging upon the land needed for other purposes. Unfortunately, the fixed nature of the world's land resource base makes the realization of this ideal impossible. Accordingly, each new upward spiral in the demand for land may be expected to contribute further to competition and possible conflicts between existing land uses. In Nigeria, this competition for land is increasing because of population upsurge, industrialization, urbanization, and farming. According to Allen (1981), farmland covers nearly 35.9 million ha or 39.5 per cent of the total area of the country. Only 0.3 per cent of the farmland area consists of plantations and agricultural projects. Most of the land has been impoverished by shifting cultivation and has a low productivity. A system of management that would accommodate the production of different natural commodities on the same piece of land becomes most desirable.

It is in this light that taungya, a healthy marriage between agriculture and forestry, is considered a dynamic tool of resource management. It was first introduced to Nigeria in Sapoba, Bendel State, some 54 years ago, but quantitative data were not generally available until recently. The information that had been produced was brought together in 1975-1976 by Ball (1977), and the present paper is an attempt to update that review and to detect trends in the development of taungya in Nigeria.

Taungya Systems

There are basically two types of taungya systems, called, in this paper, the traditional and departmental systems. The traditional taungya system is the earlier and more widely practiced of the two in the tropics. It is widely practiced in Nigeria. Under it, local farmers are recruited by the forestry department to undertake arable farming in allocated areas within a forest reserve. The size of the farm ranges from 0.4 to 2.87 ha, depending on the total land the department plants in the season as well as the size of the farmer's family.

Each Year the farms are demarcated and allocated between November and December. The farmer clears the bush, burns the slash, and generally prepares the site between January and March the following Year. There is little or no cost to the forestry department. Under certain conditions, the forestry department cuts down the big trees in the reserve before the farmers move in. Onyeagocha (1966) stated that farmers in the Emo River Forest Reserve were reluctant to accept farming of areas stocked with large trees. Even when they accepted it, they took a long time to prepare the sites, and the forestry programme consequently ran late. To avert this situation, all remaining trees are usually poisoned after exploitation for timber but before agrisilvicultural operations start. After site preparation the farmers plant crops according to specifications laid down by the forest department. Soon after, the forestry department interplants forest tree seedlings with the farm crops using paid labour. In the first year the farmers tend
the food crops as well as the forest trees. Between July and October in the first year the farmers harvest most of their crops. They store enough for their families and for planting the next season and any surplus is sold. In October they may plant a second crop such as maize, which they harvest in December or early January of the second year; however, the forestry department may by then have taken over the tending of the tree crops. The farmers sometimes continue raising crops for two to three years, after which they are allocated another plot in a new area. Farmers who have not tended the tree crops well are not given new allocations.

Departmental taungya was introduced in the Cross River State of Nigeria in 1971. The scheme is operated by forest labourers who may have no previous experience in farming. It differs from traditional taungya in that:

- The farmers are paid wages and do not own the farm crops harvested;
- There is no allocation of fixed plots to individual farmers. Instead, the farmers are allocated to different phases of the programme such as nurseries, site preparation, planting, harvesting, processing, and sale of crops; and
- Employment of farmers is not based on family units but on individuals. Thus, it is possible for each member of a household to work as a paid employee in the same taungya establishment.

The State of Taungya in Nigeria

The total area of traditional taungya farms in Nigeria in 1979 was 9,226 ha; this is a decrease of about 3.6 per cent since 1975 (table 1). Only two states, Oyo and Ondo, increased their area, whereas taungya in Cross River, Imo, Kwara, and Ogun states declined. Most states could not increase their acreage because of lack of funds and a reduced number of farmers participating in the practice Anambra State does not practice taungya officially, but forest workers still intercrop food crops with trees. There are no data from Anambra state on this.

Only Cross River and Ogun States still carry on departmental taungya, and there was a sharp decline in the area cultivated in 1979 compared to 1975. Ondo State stopped the practice because revenue realized on food crops usually went to the agricultural division of the ministry. The state's Pulpwood Afforestation Project has reactivated the practice and about 250 ha of early maize, cowpeas, and late maize will be planted in 1981. Anambra State is also planning to reactivate departmental taungya in the 1981 planting season.

In 1975, more than 70 per cent of the plantations in the moist lowland forest zone were established under one of the taungya systems. No reliable data are available for 1979, but the proportion is believed to be approximately the same. Some states have been allowing farmers to cultivate their taungya farms but have not been able to plant the trees because of lack of funds. This development can lead to overrecording of the plantation area, and it could result in the forest authority's losing control of all or part of the forest reserves.

In 1975, there were 24,427 traditional taungya farmers in the southern states of Nigeria. It was estimated that 19,500 people had casual employment for six to ten weeks of the year in traditional taungya farms, but no reliable figure could be obtained of the numbers in one family who worked on the taungya farms.

| TABLE 1. Area of Taungya Farming in Southern Nigeria in 1975 and 1979 |
|-----------------|-----------------|-----------------|-----------------|-----------------|
| State           | Traditional     | Departmental    | Remarks         |
|                 | 1975 | 1979 | 1975 | 1979 |                          |
| Anambra         | 858  | -    | 153  | -    | No licensees after 1975. Unrecorded intercropping by forest labourers. |
| Bendel          | 4,606 | 4,596 | -    | -    |
| Benue           | -    | 220  | -    | -    |
| Cross River     | 818  | 770  | 992  | 385  |
| Imo             | 494  | 25   | 121  | -    |
| Kwara           | 621  | 98   | -    | -    | No taungya since 1978 because of lack of forests. |
| Ogun            | 704  | 460  | 61   | 20   |
In 1979, however, the number of taungya farmers had fallen to 17,744 (table 2), despite the facts that the area of traditional taungya remained nearly the same and that in some states taungya farms were not planted with trees. This decline may reflect the continuing lack of recruits to traditional taungya farming (Olawoye 1975; Ball 1977). Another factor affecting employment in taungya farming has been the recent introduction of universal primary education; there may be fewer young family members available, resulting in an increase in casual employment during land preparation, mounding, and harvesting.

In 1975-1976 1,221 jobs were created in departmental taungya, either in growing or in processing the food crops. No reliable estimate is now available, but the figure has been considerably reduced because the area has fallen considerably (from 1,448 ha to 405 ha) and because none of the cassava crop is processed into gari. It is anticipated that departmental taungya will increase in Ondo and Ogun states from 1981 onwards.

In Nigeria the agricultural crops cultivated in traditional taungya farms are many and varied (table 3); they are chosen because of the dietary habits of the farmers' families or the available markets rather than because of their interaction with the tree crop.

Yams, maize, and vegetables, which make the greatest demands on soil fertility, are grown first, followed by cassava. A second crop of maize may be grown, but it is low-yielding and is generally used for seed the following year.

In departmental taungya the only two crops grown are maize and cassava. In Cross River State, in rare cases, two crops of maize are grown, the second being for seed. A new development is that the Ondo Afforestation Project will introduce cowpeas in 1981.

In the past, it was forbidden to grow certain crops, such as cocoa, rubber, plantains, etc., because they were permanent or semi-permanent crops that competed with the forest crop and could lead to alienation of the forest reserve if they grew long enough. Crops such as rice or guinea corn were banned because they are aggressive root competitors, and tobacco was banned probably because of root eel worm. Spreading cassava was also banned, and in Bendel State, where taungya started some 40 years ago, all cassava was forbidden. These rules have now been considerably relaxed. Plantains may be grown in Ogun, Ondo, and Oyo states as boundary markers and in Bendel State throughout the plot. Rice and guinea corn are raised in Bendel, Kwara, and eastern states.

---

**TABLE 2. Number of Farmers and Area of Traditional Taungya in Southern Nigeria in 1975 and 1979**

<table>
<thead>
<tr>
<th>State</th>
<th>No. of farmers</th>
<th>Average area allotted (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1975</td>
<td>1979</td>
</tr>
<tr>
<td>Anambra</td>
<td>2,120</td>
<td>-</td>
</tr>
<tr>
<td>Bendel</td>
<td>11,376</td>
<td>12,000</td>
</tr>
<tr>
<td>Benue</td>
<td>180</td>
<td>220</td>
</tr>
<tr>
<td>Cross River</td>
<td>3,580</td>
<td>1,021</td>
</tr>
<tr>
<td>Imo</td>
<td>1,220</td>
<td>121</td>
</tr>
<tr>
<td>Kwara</td>
<td>1,202</td>
<td>177</td>
</tr>
<tr>
<td>Ogun</td>
<td>807</td>
<td>1,150</td>
</tr>
<tr>
<td>Ondo</td>
<td>3,122</td>
<td>3,000</td>
</tr>
<tr>
<td>Oyo</td>
<td>1,000</td>
<td>55</td>
</tr>
<tr>
<td>Total</td>
<td>24,607</td>
<td>17,744</td>
</tr>
<tr>
<td>Weighted average</td>
<td>0.39</td>
<td>0.50</td>
</tr>
</tbody>
</table>

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The tree crops planted in Nigeria are Gmelina arborea, teak (Tectona grandis), opepe (Nauclea diderrichii), and white afara (Terminalia ivorensis) (table 4).

Generally the licensees are responsible for tending the tree crop from after planting until they harvest the final food crop, which is usually cassava. In Bendel State, however, the forestry department staff do the lining out and pegging while the licensees plant the trees. This practice can lead to problems, as poor planting and lack of weeding have been noted at several centres in other states and in some places there has been deliberate damage to trees.


<table>
<thead>
<tr>
<th>State</th>
<th>Crops (in decreasing order by area)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anambra</td>
<td>Yams, cassava, maize, rice</td>
</tr>
<tr>
<td>Bendal</td>
<td>Yams, maize, cassava, rice, plantains, vegetables, cocoyams, beans</td>
</tr>
<tr>
<td>Cross River</td>
<td>Cassava, maize, yams, cocoyams, plantains, vegetables, guinea corn, groundnuts</td>
</tr>
<tr>
<td>Imo</td>
<td>Yams, cassava, maize, rice</td>
</tr>
<tr>
<td>Kwara</td>
<td>Yams, maize, cassava, rice, vegetables, guinea corn</td>
</tr>
<tr>
<td>Ogun</td>
<td>Cassava, yams, maize, vegetables, rice</td>
</tr>
<tr>
<td>Ondo</td>
<td>Yams, cassava, maize, plantains, vegetables</td>
</tr>
<tr>
<td>Oyo</td>
<td>Maize, yams, vegetables, cassava</td>
</tr>
</tbody>
</table>

TABLE 4. Tree Species Planted in Taungya Farms in Some States of Southern Nigeria in 1975

<table>
<thead>
<tr>
<th>State</th>
<th>Tree species (in decreasing order of importance)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anambra</td>
<td>Gmelina arborea, teak (Tectona grandis)</td>
</tr>
<tr>
<td>Bendal</td>
<td>G. arborea, teak, opepe, white afara (Terminalia superba)</td>
</tr>
<tr>
<td>Cross River</td>
<td>G. arborea</td>
</tr>
<tr>
<td>Imo</td>
<td>G. arborea, teak, white afara, opepe</td>
</tr>
<tr>
<td>Kwara</td>
<td>G. arborea, white afara, teak</td>
</tr>
<tr>
<td>Ogun</td>
<td>G. arborea, teak, opepe</td>
</tr>
<tr>
<td>Ondo</td>
<td>Teak, G. arborea, white afara, opepe</td>
</tr>
<tr>
<td>Oyo</td>
<td>G. arborea</td>
</tr>
</tbody>
</table>

Economic Trends

There have been several changes in the factors affecting the economic and financial returns of taungya since the last review. Those considered here are:

- The recent general increase in the minimum wage: the rate now used is 5 naira,* or double the previous daily pay;
- The collection of more reliable data by the Inventory Unit of the Federal Department of Forestry; this has resulted in an increase in the average annual yield figure for G. arborea plantations in the moist lowland high forest zone of 25 per cent, to 25 m³/ha; the Federal Department of Forestry; this has resulted in an increase in the average annual yield figure for G. arborea plantations in the moist lowland high forest zone of 25 per cent, to 25 m³ /ha;
- The general increase in forest fees, either enacted already (for saw logs) or proposed (for pulpwood), as well as a general increase in producer prices for agricultural produce; and
- The demonstration of the benefits of both incentives and better nutrition in terms of increasing output.

These changes have been used to recalculate net discounted revenue (NDR) in the basic models for G. arborea and teak that were used before (Ball 1977). The reason that NDR is used as a basis for comparison and not economic rate of return (ERR) is that ERR in some cases gives such a high figure as to be misleading. The interest rate used for the NDR calculation was 8 per cent. The systems considered are traditional taungya, departmental taungya, and direct planting (i.e., no taungya). With the current higher benefits and lower costs an increase has
occurred in NDR (table 5).

ERR, calculated for direct planting for the two species, increased for G. arborea from 5.8 per cent in 1975 to 18.0 per cent in 1980; corresponding figures for teak were 4.0 per cent and 6.6 per cent. The comparison of ERR shows that the rate of return has increased considerably with G. arborea, due to both the lower costs and the higher returns used. With teak the returns have increased slightly, due mainly to the lower costs.

Departmental taungya has continued to show for both species the best returns, followed as before by traditional taungya and direct planting. It must be stressed that these increases are true only for the figures used in this calculation, and organizations considering taungya options should collect data relevant to their locale.

For G. arborea in traditional taungya and direct planting systems, the NDR appears to be more sensitive to increases in revenue than to reductions in costs, whereas in departmental taungya reduction in costs and increases in forest fees had an equal effect. Because of high costs early in the rotation for both departmental taungya and direct planting, the NDR for teak in them appears to be more sensitive to reductions in costs than in traditional taungya. With traditional taungya, it appears equally sensitive to decreases in costs and increases in revenue (table 6).

**TABLE 5. Comparison of NDR (Net Discounted Revenue) for Gmelina arborea and Teak with Different Systems of Establishment (in naira/ha)**

<table>
<thead>
<tr>
<th>Year</th>
<th>G. arborea</th>
<th>Teak (Tectona grandis)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Traditional taungya</td>
<td>Departmental taungya</td>
</tr>
<tr>
<td>1975</td>
<td>195</td>
<td>387</td>
</tr>
<tr>
<td>1980</td>
<td>1,942</td>
<td>2,489</td>
</tr>
</tbody>
</table>

**TABLE 6. NDR for Teak and Gmelina arborea in Traditional Taungya, Departmental Taungya, and Direct Planting**

<table>
<thead>
<tr>
<th>System</th>
<th>Species</th>
<th>Direct Planting Change in basis NDR (in naira/ha) due to</th>
<th>Sensitive to:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>25% cost reduction</td>
<td>25% forest fee increase</td>
</tr>
<tr>
<td>Traditional</td>
<td>G. arborea</td>
<td>178</td>
<td>506</td>
</tr>
<tr>
<td></td>
<td>Teak</td>
<td>90</td>
<td>95</td>
</tr>
<tr>
<td>Departmental</td>
<td>G. arborea</td>
<td>423</td>
<td>506</td>
</tr>
<tr>
<td></td>
<td>Teak</td>
<td>292</td>
<td>96</td>
</tr>
<tr>
<td>Direct</td>
<td>G. arborea</td>
<td>221</td>
<td>506</td>
</tr>
<tr>
<td></td>
<td>Teak</td>
<td>138</td>
<td>17</td>
</tr>
</tbody>
</table>

Although in the 1980 calculations lower cost figures were used for the inputs, there may still be opportunities for further reducing unit costs, possibly by incentive schemes or by some degree of mechanization. Two types of incentive are considered: one is to provide forest workers with subsidized food from departmental taungya and the other is to provide them with some assistance in land clearing, crop processing, and crop storage. In the first case, a 25 per cent reduction in costs is assumed, as well as a 25 per cent reduction in agricultural produce revenue. In the second case, an increase of N290/ha is divided between the costs in years 0-2 inclusive (table 7).

These incentives are believed to be very generous, so that the NDR for G. arborea is reduced to just below that for direct planting. With departmental taungya, the 25 per cent reduction in agricultural revenues, representing subsidized food for the workers, would have virtually no effect on the NDR for both species, provided there was also a reduction in costs of 25 per cent.

However, it is not reasonable to expect these reduced costs to be achieved immediately. With the introduction of new techniques and incentive schemes, a period of worker and supervisor training will be needed. While this is happening costs will be higher than the basic model, and alternatives were therefore considered with a cost increase of 50 per cent. Another calculation assumed that most of the costs of the basic model were incurred
quickly but that the land preparation costs were N500/ha rather N162/ha. This increase may arise because of the need to have the job done on contract or with high mechanization (table 8).

Departmental taungya remains a useful method of increasing the returns from teak, but because it is done twice with the G. arborea model the returns are below traditional taungya. If the cost of clearing in the basic model is too optimistic then the effect on returns from G. arborea will not be too great. Introducing wages for direct supervision also does not reduce the returns greatly.

There are also proposals for increases in forest fees; alternatively, the yields used may be conservative in some cases. If a 25 per cent increase in returns from the forest crop is assumed, the direct planting system with teak shows little increase in NDR because of the long rotation. The other alternatives however, all show significant gains.

TABLE 7. The Effects on NDR of Incentive Schemes for Traditional and Departmental Taungya (in naira/ha)

<table>
<thead>
<tr>
<th></th>
<th>G. arborea</th>
<th></th>
<th>Teak</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Trad.</td>
<td>Dept.</td>
<td>Trad.</td>
<td>Dept.</td>
</tr>
<tr>
<td>Basic model</td>
<td>1,942</td>
<td>2,489</td>
<td>8</td>
<td>464</td>
</tr>
<tr>
<td>Reduction of agricultural revenues and all costs by 25 per cent</td>
<td>-</td>
<td>2,445</td>
<td>-</td>
<td>441</td>
</tr>
<tr>
<td>Incentives to farmers of N290/ha spread over years 0-2</td>
<td>1,590</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

TABLE 8. Effect on NDR of Cost Increases (naira/ha)

<table>
<thead>
<tr>
<th></th>
<th>G. arborea</th>
<th></th>
<th>Teak</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Trad.</td>
<td>Dept.</td>
<td>Direct</td>
<td>Trad.</td>
</tr>
<tr>
<td>Basic model</td>
<td>1,942</td>
<td>2,489</td>
<td>1,639</td>
<td>8</td>
</tr>
<tr>
<td>50 per cent increase in costs</td>
<td>1,643</td>
<td>1,528</td>
<td>1,188</td>
<td>-281</td>
</tr>
<tr>
<td>*500 land preparation</td>
<td>-</td>
<td>2,151</td>
<td>1,301</td>
<td></td>
</tr>
</tbody>
</table>

The net establishment costs (years 0-2 for G. arborea and 05 for teak) indicated that departmental taungya shows a net benefit because of the assumed high revenue from gari; the maize crop is grown at a loss (table 9).

A comparison of the figures for traditional and departmental taungya with the cost of direct planting indicates net financial benefits to the forest authority. Traditional taungya with G. arborea nets N287/ha and with teak, N212/ha; whereas departmental taungya with G. arborea nets N750/ha and with teak, N750/ha.

Conclusions

There continues to be a demand for land for traditional taungya. The desire to farm on forest land is not necessarily caused by a shortage of agricultural land but rather the inherent fertility of the forest land. Agrisilviculture has not succeeded where there is fertile agricultural land.

The area of traditional taungya farms in Nigeria declined very slightly between 1975 and 1979. The area of departmental taungya fell considerably, due to administrative problems and difficulties of funding. It is expected that departmental taungya will expand from 1981, in Ondo and Ogun states in particular.

The number of traditional taungya farmers has fallen, whereas the average area they cultivate has increased. The reasons for this change are not clear. It might be expected that traditional taungya farmers cannot farm a larger area because they are predominantly older than 45 years (Olawoye 1975), and they may not be able to draw on many family members because of the spread of full-time education. They may, however, be employing more casual labour, or the standards of maintenance may have fallen. No information is yet available on this.

Problems with transport from villages to farm areas continue and may increase since the sites for new plantations are becoming further away.
Farmers are still reluctant to fell large trees or to pay for it to be done. Some forest services are poisoning these trees, but others are reluctant to do so because of possible harmful side-effects.

Problems of discipline and control continue. Few states issue licences or charge a fee (which could be refundable).

Incentives could be introduced for traditional taungya farmers. One possibility is to assist them to add value through processing and storage of their crops. To do so would be to reduce the benefits of traditional taungya, but these are sufficiently high to bear such a reduction.

**TABLE 9. Establishment Costs and Benefits of Plantations**

<table>
<thead>
<tr>
<th>Species</th>
<th>System</th>
<th>Cost (naira/ha)</th>
<th>Benefit (naira/ha)</th>
<th>Net Cost (Benefit) (naira/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gmelina arborea</td>
<td>Traditional</td>
<td>369</td>
<td>0</td>
<td>369</td>
</tr>
<tr>
<td>(years 0-2)</td>
<td>Departmental</td>
<td>1,361</td>
<td>1,455</td>
<td>(94)</td>
</tr>
<tr>
<td></td>
<td>Direct</td>
<td>656</td>
<td>0</td>
<td>656</td>
</tr>
<tr>
<td>Teak</td>
<td>Traditional</td>
<td>315</td>
<td>0</td>
<td>315</td>
</tr>
<tr>
<td>(years 0-5)</td>
<td>Departmental</td>
<td>1,232</td>
<td>1,455</td>
<td>(223)</td>
</tr>
<tr>
<td></td>
<td>Direct</td>
<td>527</td>
<td>0</td>
<td>527</td>
</tr>
</tbody>
</table>

A cash bonus might even be introduced for tree crops that have been successfully established. Subsidized food could be provided from departmental taungya at little loss of return provided there is an increase in productivity.

Agricultural yields from departmental taungya continue to be low, but the appointment of agricultural officers to schemes in two states should improve the situation and demonstrate to other forest services the value of such personnel. These projects may also be a source of data on the agricultural component.

An analysis of economic trends shows that large changes occurred in economic and financial returns between 1975 and 1980. The reasons for these are increased prices for agricultural crops, increased timber fees, increased forest yields, and (potentially) reduced costs, despite large increases in wages. The calculation of net discounted revenue for various alternatives shows that:

- There has been a large increase in returns since 1975;
- Departmental taungya is still more profitable than traditional taungya or direct planting;
- The return from long rotation crops such as teak is especially sensitive to cost increases or reductions. If such species are to be profitable then a taungya system is necessary, whereas species such as G. arborea are still profitable even if the taungya system is not used.
- Increases in the revenue from the forest crop improve the returns of both taungya systems with short- and longrotation species but do not greatly benefit long-rotation species grown without taungya; and
- The net financial benefits to the forest authority of using taungya systems are considerable, particularly with long-rotation species.

The need to continue monitoring trends in taungya systems has been demonstrated by the large changes that are reported in this paper, even over so short a period as four to five years. The economic figures presented here are, however, indicative only, and calculations should be done with reliable local figures for individual projects.

Socio-economic studies are needed on benefits accruing to the farmers, the forestry employees, and the nation.
Food crop yield under gmelina plantations in southern Nigeria

O. O. Agbede and G. O. A. Ojo
Forestry Research Institute of Nigeria, Ibadan, Nigeria

Abstract

Experimental taungya plots were established at six different locations in southern Nigeria to investigate the productivity and competitive relations of intercropping agricultural crops (yams, maize, and cassava) with trees (Gmelina arborea). Experiments were set up in 1978 and 1979 at Gambari, Ore, Sapoba, Ukpom-Bende, Ikom, and Awi-Calabar. With the exception of Gambari, the locations are in the tropical rainforest zone of Nigeria. Results of the experiments showed that cassava depresses Gmelina arborea, especially when planted at close intervals. This effect tends to diminish at age 12 months, when the trees usually attain canopy closure. Trees under yams and maize tend to perform better than those planted alone or with cassava.

Varying the space between Gmelina arborea plants markedly influenced the trees, while the different spacings of agricultural crops had no effect. Likewise for crops, the space between trees was not important but the spacing between crops was significant. Yams planted at 1.5 x 1.5 m were found to be the most profitable.

Introduction

A recent trend in Nigeria is towards the production of sufficient pulpwood, fuel, poles, and timber. Hence, state forestry services have set up annual planting targets of 20,000 and 6,000 ha for Gmelina arborea and teak, respectively. Similarly, the recent food crisis in Nigeria has become a major concern in official circles. In 1977, the value of Nigerian food imports was approximately N270 million (Enabor 1978). Adequate food supply for the increasing Nigerian population demands the harnessing of both the productivity of Nigerian agriculture and the contribution of forestry through the management of forest lands for the simultaneous production of wood and food.

Taungya is a form of agrisilviculture, or farm forestry, whereby food crops are interplanted with tree crops at the time of establishment (or regeneration) of the tree crop, and in which the forestry agency collaborates with peasant farmers (King 1968). The farmers are responsible for clearing, burning, and packing operations within their allocated plots. The Forestry Department may assist with the felling of large trees. In return for their labour, farmers are permitted to grow food crops until the tree crop canopy closes, which is generally for one to three years, depending on the species planted and the spacing. Gmelina arborea, for example, which produces pulpwood in 10 years and timber in 20 years, closes its canopy within 12 to 15 months when planted at 2.5 x 2.5 m. Taungya is a land management system used extensively by state forestry services to reduce the cost of plantation establishment and maintenance.

Usually, peasant farmers involved in taungya are allowed to cultivate the food crops of their choice, with some control as to how and when to plant the crops, especially in the case of plantains and cassava. The crops commonly raised are yams, maize, cassava, and rice, usually intermixed with melon, okra, pepper, tomatoes, beans, and other vegetables. In Cross River State, where the forestry staff are directly involved in food crop production, greater attention is paid to maize and cassava than to labour-intensive crops such as yams. The Forestry Research Institute of Nigeria is currently growing yams, maize, and cassava in its taungya farms at six research locations in southern Nigeria.

The taungya farms established by the Forestry Research Institute of Nigeria are located at Gambari (Oyo State), Ore (Ondo State), Sapoba (Bender State), Enugu-Ngwo (Anambra State), Ukpong-Bende (Imo State), and Ikom and Awi (Cross River State). Since the participation of local farmers has resulted in
variations in and damage to the tree crop during the agricultural cropping, the work is now undertaken by
the Institute staff. In this way they can ensure that the crops are spaced, treated, and harvested according
to plan, and thereby validate the results. Both land preparation (clearing, felling, burning, and packing)
and cultivation for arable cropping, especially yams, are carried out by the staff of the Institute. The
harvesting and marketing of the food crops are also undertaken by the Institute.

The purpose of this study was to determine quantitatively the yields of food and tree crops and their
competitive relations under taungya in selected locations in Nigeria.

Materials and Methods

Experimental taungya farms were established at six different locations in southern Nigeria where taungya
is widely practiced. With the exception of Gambari, the locations are in the tropical rainforest zone of
Nigeria.

In 1978, 0.80 ha of Gmelina arborea was established in combination with three agricultural crops-yams,
maize, and cassava. These crops were selected because they are the most widely grown crops in all the
states where the experiments were located. Other important arable crops such as rice, cocoyams,
plantains, and vegetables, and tree crops such as Tectona grandis, Nauclea spp., and Terminalia spp., are
proposed for future experimental work. For 1978, each experimental farm was divided into five blocks, of
four plots each. Each plot was 20 x 20 m and contained 64 trees at 2.5 x 2.5 m. A randomized complete
block design was used. The treatments and the control were Gmelina arborea (control), Gmelina arborea +
yam, Gmelina arborea + maize, and Gmelina arborea + cassava. Yam (Dioscorea rotundata), Nigerian
selection no. 1 maize, and a local cassava variety were grown on all the sites. All the arable crops were
planted at 1.2 x 1.2 m. Maize and yams were planted during March-April, whereas cassava and stumps of
Gmelina arborea were planted in June-July of the same year.

In 1979, separate areas were used for each arable crop (yam, maize, cassava), and G. arborea was used as
the tree crop. The experiment was to study the interaction of both agricultural and tree crops when
interplanted at different densities. The design was a 4 x 4 x 3 factorial, i.e., three planting distances plus a
control for Gmelina arborea and each agricultural crop. G. arborea was planted at spacings of 2.0 x 2.0 m,
2.4 x 2.4 m, and 3.0 x 3.0 m, while yam, maize, and cassava were planted at spacings of 1.0 x 1.0 m, 1.5 x
1.5 m, and 2.0 x 2.0 m. There were 16 treatment combinations replicated three times for each arable crop.
The experimental area for each arable crop was 50 x 160 m divided into three blocks of 48 x 48 m; each
block was further divided into 16 small plots (12.0 x 12.0 m). Crop varieties and time of planting were the
same as in the 1978 experiments.

All farm operations, including land preparation, planting, tending of arable crops, weeding, harvesting, and
marketing, were carried out by departmental labour so as to minimize mishandling of the tree crop and to
have firm control over the farms and the crop yields.

At maturity (i.e., 3 months, 8 months, and 12 months for maize, yams, and cassava respectively!), the
agricultural crops were harvested, weighed, and marketed fresh. The tree crop was assessed for height,
girth, and percentage of survival 6 and 12 months after planting.

Results and Discussion

Growth assessment of G. arborea interplanted with yam, maize, and cassava in 1978 indicated that the
growth of the trees under agricultural crops was superior to trees grown alone. Nevertheless, the
performance of trees under cassava was slightly less acceptable than trees intercropped with yam and
maize (table 1). Observations indicated some competition for space between the trees and cassava as
shown from the whiplike, weak, and deformed stems of the G. arborea trees.

The trees that were planted at 2.4 x 2.4 m had attained canopy closure at 12 months in all the sites. Thus
the growth of any crop under the Gmelina had become impracticable. The depressing effect of cassava on
the survival and girth of Gmelina trees observed during the assessment 6 months after planting was still
evident at 12 months though in a diminishing magnitude. This finding shows that, though Gmelina is a fast-growing species, it takes some time before the tree can overcome the effects of being intercropped early with cassava. The good performance of trees with agricultural crops (table 2) was possibly due to the initial cultivation and regular cleaning of the yam and maize plots in the taungya farm.

**TABLE 1. Survival and Height of Gmelina arborea Six Months after Planting in Taungya Farm, 1978**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Survival %</th>
<th>Mean height (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Gambari</td>
<td>Sapoba</td>
</tr>
<tr>
<td>G. arborea (control)</td>
<td>58a</td>
<td>99a</td>
</tr>
<tr>
<td>G. arborea and yam</td>
<td>68 b</td>
<td>95 b</td>
</tr>
<tr>
<td>G. arborea and maize</td>
<td>75 c</td>
<td>94 b</td>
</tr>
<tr>
<td>G. arborea and cassava</td>
<td>67 b</td>
<td>98 a</td>
</tr>
<tr>
<td>Standard error</td>
<td>±3.12</td>
<td>±1.06</td>
</tr>
</tbody>
</table>

The figures represent the means of five replicates. The means in any given column with the same letters in common are not significantly different at $P = 0.05$.

At each of the three yam spacings, the height growth of Gmelina tended to decrease as planting distance between the trees increased (table 2). This supports observations that the denser the tree population the more they compete for space and light. The performance of Gmelina under maize and cassava followed the same trend (table 3).

Data have been collected on the yield and revenue accruing from each of the agricultural crops, and these have been converted to a per hectare basis (table 4). Actual measurements of yam, maize, and cassava crops were made, and their values obtained from organized sales made at the various sites where the experiments were carried out. The higher yield of yams in 1979 than in 1978 is a reflection of better weather conditions and improved management practices (e.g., earlier land preparation and planting time). The yields compare favourably with those of peasant taungya farmers in the state forestry services (Ball 1977).

The influence of different densities of agricultural and forest crops on the yields of agricultural crops is exemplified by the values obtained for yams: the yields per hectare increased with increasing agricultural crop density at each level of the tree crop spacings. However, there was a slight decrease in the yields of yams, as the planting density of G. arborea was increased. In plots where no G. arborea was planted, the yield of yams was 17.8 tonnes ha; this yield dropped to 13.08, 12.68, and 12.86 tonnes ha at Gmelina spacings of 3.0 × 3.0 m, 2.4x2.4 m, and 2.0 x2.0 m respectively. The implication of the above observations is that, though agricultural crops have positive effects on the establishment of trees, the latter tend to have a slight negative effect on the yields of agricultural crops.

**TABLE 2. Survival and Mean Height of Gmelina arborea at Three Different Sites after Six Months of Interplanting with Yam**

<table>
<thead>
<tr>
<th>Treatment levels</th>
<th>Survival %</th>
<th>Mean height (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y-levels</td>
<td>G-levels</td>
<td>Sapoba</td>
</tr>
<tr>
<td>Y0</td>
<td>G0</td>
<td>-</td>
</tr>
<tr>
<td>G1</td>
<td>82</td>
<td>90</td>
</tr>
<tr>
<td>G2</td>
<td>85</td>
<td>63</td>
</tr>
</tbody>
</table>
### TABLE 3. Effect of Different Spacings of Yams, Maize, and Cassava on the Survival and Height of Gmelina arborea Six Months after Planting

<table>
<thead>
<tr>
<th>Factor Levels</th>
<th>Survival %</th>
<th>Height (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Y-levels</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Y0</td>
<td>83</td>
<td>118</td>
</tr>
<tr>
<td>Y1</td>
<td>87</td>
<td>104</td>
</tr>
<tr>
<td>Y2</td>
<td>84</td>
<td>111</td>
</tr>
<tr>
<td>Y3</td>
<td>84</td>
<td>97</td>
</tr>
<tr>
<td>Standard error</td>
<td>+1.2</td>
<td>+6.4</td>
</tr>
<tr>
<td><strong>M-levels</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M0</td>
<td>79</td>
<td>58</td>
</tr>
<tr>
<td>M1</td>
<td>89</td>
<td>73</td>
</tr>
<tr>
<td>M2</td>
<td>86</td>
<td>64</td>
</tr>
<tr>
<td>M3</td>
<td>84</td>
<td>64</td>
</tr>
<tr>
<td>Standard error</td>
<td>+3.0</td>
<td>+4.4</td>
</tr>
<tr>
<td><strong>C-levels</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Key to tables 2 and 3
G0 = No Gmelina arborea planted;
G1 = G. arborea planted at 2.0 x 2.0 m;
G2 = G. arborea planted at 2.4 x 2.4 m;
G3 = G. arborea planted at 3.0 x 3.0 m;
Y0 = No yams planted;
Y1 = Yams planted at 1.0 x 1.0 m;
Y2 = Yams planted at 1.5 x 1.5 m;
Y3 = Yams planted at 2.0 x 2.0 m. The same spacings used for yams were used for maize (M0, M1, M2, and M3) and cassava (C0, C1, C2, and C3).
The most profitable yam spacing in the experiments was 1.5 x 1.5 m. At this spacing, the yield of yams was almost equal to those at 1.0 x 1.0 m, whereas the inputs were about half.

### Practical Implications

Agricultural cultivation during the establishment of G. arborea was found to be desirable. In all cases of taungya farming, the growth of G. arborea usually improves with the additional advantage of achieving reasonable agricultural yields. The results presented in this paper tend to support earlier observations made by Jaiyesimi (1966), King (1968), and Agbede and Ojo (1978) that the combination of agricultural crops with tree crops during the establishment phase of the latter is not detrimental.

On plots of Gmelina grown alone or interplanted with food crops, the trees reached a mean height of 5.80 m and 6.50 m respectively in 12 months; the equivalent girths were 29 cm and 33 cm. G. arborea interplanted with yam and maize performed better than those planted alone or with cassava. The provision of shade for the newly-planted tree crop by the sprouting maize and the improved soil conditions in both the maize and yam plots positively affected the growth of G. arborea.

### TABLE 4. Yields and Revenue Obtained From Agricultural Crops in Taungya Research Plot. 1978

<table>
<thead>
<tr>
<th></th>
<th>Yield (fresh weight in tonnes/ha)</th>
<th>Revenue (naira*/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Gambari</td>
<td>Ore</td>
</tr>
<tr>
<td>Yam</td>
<td>7.7</td>
<td>3.3</td>
</tr>
<tr>
<td>Maize</td>
<td>4.5</td>
<td>2.0</td>
</tr>
<tr>
<td>Cassava</td>
<td>6.6</td>
<td>4.5</td>
</tr>
</tbody>
</table>

* In 19781 naira = US$1.60

### Summary of discussion: Taungya systems from biological and production viewpoints

From the papers presented, and subsequent discussion, it was clear that taungya systems have met with widely varying success in different countries and—at least in the case of Nigeria—in different sections of the same country. In large part this has not been due to technical or even economic problems, but more to basic political decisions and social acceptance. In particular, lack of continuity was cited as a problem. In Togo taungya has generally failed because the government has claimed forests as its property. This has led to widespread discontent and the destruction of timber trees in favour of fruit trees, which provide regular income after a relatively short period of establishment. In Kenya the taungya system is being phased out because labour costs are relatively high, there is a problem with the labourers or their relatives trying to settle in the forest, and very large areas need to be planted as industrial plantations.

With regard to the experiments on taungya in Sierra Leone, it was clarified that the plantations are used for food crops for the first one or two years, and then the farmers must stay out of the area until the final thinning is carried out. The farmers are then allowed to return and plant tree crops such as cola, citrus, coffee, and cocoa. It is expected that the timber crop will mature and the tree crops will decline in yield at
about the same time (about 30-35 years after planting the timber crop), and the area will be clearfelled in order to begin a new cycle. It was noted that in Nigeria a similar system had been tried but had failed because the farmers began to think the forest reserve belonged to them and acted accordingly. The importance of crown shape and density on the yields of the tree crops was raised, but long-term data were not available.

The long-term effect of tree plantations was also discussed, although there was, again, a lack of decisive evidence. It was noted that fertilization may well be necessary when establishing second or third generation tree crops, depending on the inherent soil fertility, and that an initial dose of fertilizer at an early stage of growth could be far more effective than fertilization at establishment. The type and frequency of the products removed are also important. The export of timber, for example, might remove large quantities of calcium, while palm oil is almost pure carbohydrate. In most cases the harvesting and removal of forest products would remove far fewer nutrients than represented by the harvesting of food crops on an annual basis.
Current agro-forestry activities

The integration of livestock production in agro-forestry

Intercropping of terminalia superba with cocoa and banana in mayombe, people's republic of the Congo

An example of agro-forestry for tropical mountain areas

Intercropping tree and field crops

Promising trees for agro-forestry in southern Nigeria

Food crop yield under teak and cassia siamea in south-western Nigeria

Agro-forestry possibilities in oil palm plantations in the Ivory coast

Effect of food crops on tree growth in Tanzania

Selection of leguminous trees for agro-forestry in Cameroon

Forestry aspects of agro-forestry practice in Nigeria

Summary of discussion: Current agro-forestry activities

The integration of livestock production in agro-forestry

J. Lazier, A. Getahun, and M. Velez

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Abstract

West African Dwarf sheep and goats appear to have the potential to satisfy the increasing demand for animal protein in the humid zones of West Africa. Their current management is described, and their integration - together with that of cattle-into agro-forestry systems is discussed. The planting of browse species such as Gliricidia septum and Leucaena leucocephala may overcome the constraint to animal production caused by the lack of fodder in the dry season. Grazing in forests, plantations, and alley cropping systems is also discussed.

Introduction

The population of the countries of the humid zone of the west coast of Africa is about 160 million and is growing by more than 2.5 per cent annually (Unesco 1980). The increasing population has resulted in smaller farms and larger cities, as well as a rising demand for animal protein. What meat cannot be produced within each country must be imported. In Nigeria, for example, if per capita production and consumption rates of animal protein remain unchanged, in 1985 an estimated 200,000 tons of animal protein will have to be imported.

At present, many African villagers derive their animal protein from forests and secondary growth, which are havens for wildlife. As much as 50 per cent of the population south of the Sahara utilizes animal protein derived from nondomesticated species such as fish, insects, snails, and rodents. In the southern states of Nigeria, where trypanosomiasis has inhibited cattle production, wild or bush meat is particularly important. It constitutes an estimated 20 per cent of the animal protein consumed and has been valued at N30 million (Afoloyan 1980).

The replacement of natural forests with tree plantations will limit the availability of bush meat unless carefully planned so that there are young trees at all times to encourage its presence. One method is to extend tree planting over a period of years.

Cattle, West African Dwarf sheep and goats, and poultry are the main locally produced sources of animal protein in the humid zone of West Africa. As trypanosomiasis is endemic in the area, the breeds of ruminants present are mainly trypano-tolerant, i.e., they are generally resistant to the disease (table 1).
TABLE 1. Numbers of Trypano-Tolerant Livestock in Humid Tropical Africa (in millions)

<table>
<thead>
<tr>
<th>Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cattle</strong></td>
</tr>
<tr>
<td>N'Dama</td>
</tr>
<tr>
<td>West African Shorthorn, Savanna</td>
</tr>
<tr>
<td>West African Shorthorn, *</td>
</tr>
<tr>
<td>Dwarf</td>
</tr>
<tr>
<td>Zebu x N'Dama</td>
</tr>
<tr>
<td>Zebu x Shorthorn</td>
</tr>
<tr>
<td>West African Dwarf Sheep</td>
</tr>
<tr>
<td>West African Dwarf Goats</td>
</tr>
<tr>
<td><strong>Total</strong></td>
</tr>
</tbody>
</table>

Source: ILCA (1979)

In the expansion of livestock production, ruminants will be important, as they are able to use low-quality feeds, such as grass, that can be produced on marginal soils. As a result, these animals need not compete with humans for food or land on which crops are grown.

Limitations to a rapid increase in the ruminant population include disease, rate of reproduction, feed supply, and management. As there appears to be no imminent, simple, and broadly effective solution for trypanosomiasis, trypanotolerant livestock will continue to provide the bulk of the meat produced in the humid zones of West Africa. West African Dwarf sheep and goats have the potential to become a more important source of animal protein than cattle because they reproduce much more rapidly (1.5 offspring/year after the first year).

**Current Management Practices**

Up to 90 per cent of village families have three to five sheep and goats. Mortality is high because of disease and accidents, and offtake (sale or home consumption) averages about 15 per cent (Okali, personal communication).

Though animals are allowed to range freely, they graze and browse close to the village. Studies have shown (Carew 1981) that in the forest zone of southern Nigeria, West African Dwarf sheep and goats, respectively, spend 98 per cent and 95 per cent of their browsing/grazing time browsing. In the derived savanna, where there is a higher proportion of graminaceous species, the proportions of browsing/grazing time spent browsing are 47 per cent and 62 per cent. Household scraps-cassava, yam, banana and plantain peelings, and maize chaff-are considered critical in the diet of these animals and may determine the number of animals maintained by a household.

The figures on time spent browsing and grazing indicate that grass can form a substantial portion of the diets of sheep and goats, though the goats prefer browse. Browse feeding by cattle, sheep, and goats is standard in villages throughout the region, particularly in the dry season when the graminaceous and herbaceous fodder has been consumed or is of such low nutritive value as to be unpalatable. Browse species that are not deciduous provide green foliage throughout the dry season.

Leguminous browse is particularly nutritious. When six Species of browse were tested for nutritive value (Ficus exasperate, F. sp., Newbouldia laevis, Aspilia africana, Spondias mombin, and Cylicodiscus gabunensis) all had crude protein levels as high as Panicum maximum (13 per cent), with the maximum being A. africana at 17 per cent. All six species were at least as digestible in vitro as P. maximum (Carew 1981). The high nutritive values of the browse species and their potentially good dry season productivity
suggest that they can reduce the current dependence on household scraps and make larger herds feasible.

**Improvement of Ruminant Production**

The provision of permanent pastures could eliminate the need for household scraps in the diets of the Dwarf sheep and goats of the region. Permanent pastures would be mainly considered for marginal lands where farm holdings are larger and where low rainfall, low soil fertility, or high susceptibility to erosion make cropping uneconomic.

Native species of grasses may provide adequate pasturage in the early rainy season, but as the pastures normally are composed of both palatable and unpalatable species, the palatable ones are heavily grazed and disappear from the paddock. The remaining grasses are usually early maturing and fibrous, and are thus of lower feeding value. If it were economic, it would be preferable to replace the native grasses with productive perennial species such as Panicum maximum, Brachiaria decumbens cv. Basilisk, or Cynodon nlemfuensis cv. IB 8. Short cultivars should be planted for Dwarf goats as they will not graze in wet grass.

The addition of a selected forage legume of such genera as Stylosanthes, Centrosema, Desmodium, or Macrophtilium to pastures can improve the productivity of the pasture. The forage legumes provide foliage of higher nutritional value than grass, and this value is maintained throughout the dry season. Nitrogen transfer from the legumes to the grass improves the growth of the grass, and because many legumes are deep-rooted they continue to grow longer into the dry season. Although the legume must be palatable, it should be of sufficiently low palatability to receive only minimal grazing until the dry season so that it accumulates as much dry matter as possible.

Although grasses provide adequate fodder in the wet season, and careful selection of herbaceous forage legumes may extend the value of the pastures into the dry season, the severity and length of the dry season in much of the humid tropics requires that other sources of feed be available. The preservation of feed as hay or the utilization of silage or fodder crops such as sorghum or maize is neither practical nor economic for a small farmer. Thus, the production of browse, as occurs in the villages, is probably the most viable solution.

Browse plantings in permanent pastures may be valuable for uses other than fodder. Leguminous trees enhance the growth of pasture grasses and improve soil fertility. The plants are sources of construction material and firewood for the farmer, and may be sold for timber. Other uses for browse plants include shade, living fences, and shelterbelts. Samanea (Pithecolobium) saman and Ceiba pentandra are two locally available species of trees that are browsed and that provide excellent shade and timber. Species such as Gliricidia septum, which readily sprout from cuttings, are useful for living fence posts. Though fairly weak for the first year or so until they are well rooted, they are fire" and rotresistant and can be pruned as a source of fodder. However, where there are extensive areas to be fenced and labour costs are high, it may prove expensive to prune the trees as often as necessary. Belts of trees providing timber, browse, and shade can be placed between the paddocks. These are less useful for temperature and wind control than in a temperate environment but may prove useful during periods of water stress by increasing the relative humidity in the adjacent paddocks (Marshall 1967). They may also extend the grazing time of goats by reducing the chill factor in rainy periods.

Browse may be planted in the pasture scattered throughout or in hedge rows several metres apart. It can be maintained at low heights so that it is available for browsing through the year, or it can be allowed to grow so that it can be cut for feed in the dry season.

Browse species are usually leguminous and may be shrubs, small trees, or large trees. Their agronomic characteristics should include leafy, vigorous growth, good seed production, a non deciduous habit in the dry season, deep rooting, ready coppicing, and palatability. They should be high in nitrogen and digestability, and have no toxic effects on the animals.

The species that has received most attention to date is the leguminous tree Leucaena leucocephala.
Vigorous, palatable, and a heavy seed producer, it unfortunately can produce toxic effects because of its mimosine content (Jones 1979). Desmanthus virgatus (Skerman 1977) and Codariocalyx gyroides (Lazier 1981) have received some attention for possible use as browse. Gliricidia septum, a small tree used for living fence posts and as a shade plant in plantations, is of interest in West Africa because of its ability to establish from cuttings and its leafy and vigorous growth through the dry season. It can be planted in paddocks in such a manner that the tops of the cuttings are above the browsing level of the animals, thereby conserving the growth on the upper part of the cuttings for the dry season. Recent trials have demonstrated that sheep can be successfully fed diets of up to 80 per cent G. septum (Chadhokar and Kantharija 1980).

In Nigeria, initial trials with G. septum have indicated that 18 month-old cuttings will produce leaf dry-matter yields of 350-450 kg in the dry season. If 600 kg of dry matter are required daily by each animal, two cuttings would supply the needs of one animal, and in a five-month dry season about 300 cuttings would be required per animal. With 15 animals/ha, 4,500 cuttings would be required.

Planting at spacings of 0.5-1 m would require that one-tenth to one-half of a one-hectare paddock be planted to browse. As the cuttings became better established, fewer plants would be required to maintain the same number of animals and stocking rates could be increased.

West Africa, with its long history of domesticated grazing animals, has identified a wide variety of browse species. A literature survey that was not exhaustive has listed 95 tree and shrub species in West Africa. Little is known about methods of managing these species or of their effects on animals. Noteworthy among those on the list are the leguminous species Albizia adianthifolia, A. lebeck, A. zygia, Dalbergia sissoo, and Daniellia oliveri. Much work needs to be done in selecting vigorous species and cultivars from among those used in the villages.

**Integration of Livestock with Forestry**

Large areas of forests in Africa are managed for the production of timber, pulp, or firewood. Bush growth in the forests seriously concerns forest managers because it presents a fire hazard and competes with young trees. Although livestock can be used to control this growth, there are no reports indicating this practice in the tropics (Adams 1975). In favour of livestock grazing in forests is the fact that it reduces the costs of clearing the bush, and the savings can offset some of the costs of planting and managing the trees.

Studies have determined that the damage caused by cattle trampling and rubbing the trees, and sheep grazing them, can be minimized by good management (Adams 1975). Damage increases with the stocking rate and depends on such factors as the stage of growth of the trees and the season of the year. The pine forests of the southern United States are a good example (Halls et al. 1964) of how animals can be successfully raised in the forests. Goats, however, are not regarded as suitable for inclusion in forest grazing as they depend largely on young trees for browse. They also eat the bark of certain tree species. It has been observed in the International Livestock Centre for Africa (ILCA) Small Ruminant Programme in Nigeria that the West African Dwarf goat eats tree bark mainly during the dry season when there is a shortage of alternative feed. Thus, appropriate management, including adequate provision of feed, preventing grazing while the tree leaves are within reach of the animals, and the use of trees with unpalatable bark, is the key to successful grazing of goats in forests, particularly in forest plantations.

There are often problems, however, in the implementation of a grazing policy, for the time when bush clearing expenses are highest is when trees are youngest and most vulnerable to grazing and trampling. The provisions of fencing, water points, skilled personnel to manage the operation, and the infrastructure to support these is a major financial undertaking. As forests are commonly in remote and thinly populated areas, housing must be provided, and it is difficult to recruit good managers and staff. Also, livestock handling is difficult among trees, particularly over large areas. The remoteness of the operation encourages petty larceny in the removal of fences and rustling.

The large variation in feed supply throughout the year results either in a serious lack of feed in the dry
season or in undergrazed bush in the wet season, with the accumulation of coarse, unpalatable material in
the dry season. If livestock are to thrive, some provisions must be made to reduce the stocking rate in the
dry season or to provide extra fodder. Forests are usually established in marginal areas either naturally low
in fertility or degraded due to cultivation or overgrazing with consequent erosion. Such areas produce
poor-quality forage and thus slow weight gains among the animals. Macro- and micro-nutrient deficiencies
must be corrected before there can be successful livestock raising in forested areas.

The alternative to forestry-managed livestock raising is the rental of forest areas to livestock owners at
specific times of the year, normally in the early rains when the vegetation is fastest-growing and most
nutritious. A considerable degree of management would still be required by the forest manager to limit
damage, but there would not be the high investments required of forestry-run operations.

Uncontrolled grazing of forests can result in an increase in fires, poaching of trees and firewood, damage
to young trees, and deterioration of the soil due to over-grazing. Although the decisions on individuals'
rights to forest grazing are often not in the hands of foresters, the existence of a well-reasoned grazing
management system that balances the needs of the livestock owners with those of the forester may well
return control of such grazing to the foresters.

One of the main impediments to integrating livestock with forestry is probably the hesitation of foresters
to introduce new complications into a carefully controlled monocrop system. The inclusion of livestock
management courses into forestry training may largely overcome this reluctance.

Integration of Livestock with Plantation Crops

The use of livestock, particularly cattle, under plantation crops to control grass and bush regrowth has
been frequently recommended (Thomas 1978); maintenance costs are lowered while a further source of
income is provided. The animals rapidly recycle nutrients through the production of faeces, and there may
be an increase in soil fertility. Where leguminous crops are planted between the trees, these provide a
nutritious source of feed for livestock, as do byproducts of tree crops such as rubber seed, palm kernel,
and coconut meals. Grazing under plantation crops is particularly evident in the coastal coconut
plantations of the humid zone of West Africa.

In a review of raising livestock on plantations, Thomas (1978) noted that plantations do not have a
constant supply of fodder. Feed must be provided during the drier times of the year, and, as plantations
are usually planted relatively rapidly, the large amount of fodder available when the trees are young is
much reduced as they grow, only increasing again when they are tall and mature. Monoculture operations
often do not have the trained personnel, facilities, or sufficient interest to develop such operations
successfully. Cattle may knock off collection cups in rubber plantations, depress yields by soil
compaction, puddle heavy textured soils, increase soil erosion, and remove nutrients.

Although oil palm production in large commercial operations on heavy soils may not be adapted for
livestock raising, there is interest in such a system (Aseidu 1978; Boye 1968; Renault 1968), and
commercial operations are possible. SODEPALM in the Ivory Coast has been raising cattle under oil palm
since 1973, and in 1977 was grazing 4,000 head (Koua Brou 1977; see also the paper by Tchoume in this
volume, pp. 111-114). Research on sheep has indicated that those grazing in oil palm plantations have
their grazing pattern less affected by high temperatures and driving rain than do those in paddocks without
such shelter (Aseidu 1978).

The scattered semi-domesticated stands of oil palm around the villages of West Africa also offer excellent
opportunities for development as grazing areas. The lighter soils in many of these areas reduce the chance
of compaction and puddling, and the sparse canopies allow greater light penetration. Some degree of
management is, of course, necessary to prevent over-grazing, and there needs to be some provision of
fodder, perhaps in the form of browse, for the dry season.

Sheep and cattle have been reported from many countries as having been successfully integrated with
coconut plantations, for example in Tanzania (Childs and Groom 1963), Sri Lanka (Appadurai 1968), and
Livestock production has been reported as being low in combination with all of these tree crops, but the use of fertilizers and improved forage species has increased both coconut and livestock yields (Barker and Nyberg 1968). Providing leguminous browse species under the tree crop and cutting it as feed for the dry season may improve livestock yields without reducing tree crop yields. Extra paddocks for dry season feeding are another possible solution.

The addition of grazing animals to fruit orchards in an effort to control the understory of bushes and grasses results in some reduction of fruit yields, particularly in the case of cattle, for the lower branches of the trees will be pruned and the fruit within reach will be consumed. Much less foliar damage would occur if sheep or goats were used, though the goats may damage the bark of some species. In peasant systems in which the farmer is more interested in flexibility of income rather than intensification of monoculture system, losses in fruit yields may be more than offset by the time, money, and energy saved in clearing and the greater financial flexibility offered by the system.

**Alley Cropping**

The establishment of pastures on exhausted cropping land with leguminous browse species in hedgerows leads naturally into an alley cropping system (i.e., planting crops in the alleys between rows of trees). Once the soil fertility and structure have been improved under the grass/tree combination, the alleys between the trees could be cultivated and cropped for a year or more. The land would then be returned to pasture. During the cropping cycle, uses of the browse would include either green manure year-round, green manure in the early wet season and cut-and-carry feed for livestock for the rest of the year, or cut-and-carry for the whole year with the animal manure returned to fertilize the crops. One possible constraint to such a system is the feeder roots of the browse, which may make cultivation difficult and compete with the crop for available water and nutrients.

**Current Research**

Current research in the ILCA Small Ruminant Programme in Ibadan involves village surveys to determine the constraints to livestock production in the villages, the effect of veterinary care on animal mortality, and the establishment of unit farms to develop the management systems required to raise small ruminants on pasture and browse. Preliminary screening of 23 native types of browse used in the villages is planned. The comparative value of a number of farming systems, both to the farmer and in terms of soil fertility maintenance, will be tested. Treatments will include permanent pasture with browse in hedges, alley crop-pasture rotations, cropping with the leaves of the alley tree species as mulch, and continuous cropping without alleys. Leucaena leucocephala and Gliricidia sepium will be the browse species utilized.

**Intercropping of terminalia superba with cocoa and banana in mayombe, people's republic of the Congo**

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**Abstract**

The Mayombe forest is situated 70 kilometres north-east of Pointe-Noire, the economic capita/ and sole seaport of the Congo. Initially very rich in Terminalia superba, this forest was very heavily exploited.
In 1950 an extensive limba (Terminalia superba) planting programme was implemented to ensure sustained production of this species. In addition, experimental limbacocoa and limba-banana intercropping was undertaken in sample plots. Although limba-banana intercropping yields are encouraging for both plants, the same is not true of the limba-cocoa intercrop. After 15 years problems arise with regard to the silvicultural management of the limba—especially thinning and root competition between the two species.

Farmers often intercrop food plants with T. superba. This should be encouraged, provided that farmers take sufficient care during clearing and burning.

Research should be carried out to determine factors likely to affect the success of new techniques. Finally, an effort should be made to educate and inform the people of these new planting methods.

**Introduction**

Mayombe is a very rugged forest zone starting some 70 km north-east of Pointe-Noire and stretching to Zaire and Cabinda. The Mayombe forestry station was set up around 1927 on the first buttresses, about 80 kilometres from the coast. The area has a subtropical, semi-humid climate. The rainy season begins in November and ends in April, with a break of variable duration between December and February. Rainfall varies between 1,300 and 2,300 mm, but it is usually around 2,000 mm. The heaviest rainfall is generally in November or March-April. The dry season is characterized by four to five ecologically dry months during June to October. It is marked by a low saturation deficit and an abundance of morning fog. Normally temperatures fluctuate around 25°C, but during the dry season they are about 18-22°C.

The natural vegetation is semi-deciduous forest that is rich in limba (Terminalia superba). The overstorey species frequently found growing with T. superba are: Desbordesia pierreana, Dacryodes pubescens, Irvingia gabonensis, Combretodendron africanum, Gambeya africana, Staudtia stipitata, Pentaclethra macrophylla, Baillonella toxisperma, and Dialium spp. Until 1950 the work carried out at this station consisted mainly of setting up a tree nursery of about 20 ha and studying the silviculture of a few native species. As a result of the heavy exploitation of limba, especially in the wake of the Second World War, an extensive planting programme was begun. Between 1950 and 1961, 6,435 ha of limba were established in order to ensure a steady production of timber. The limba were planted from two centres fairly close to each other—Nboku-Nsitu, situated at latitude 4°26' S and longitude 12°16' E, and Bilala, situated at latitude 4°30' S and longitude 12°13'E.

The Mayombe forest plantations have been established on extremely variable soils. For instance, stands are to be found on soils depleted by food crops, on relatively fresh and fertile alluvial soils, and on very fertile schistocalcareous and schisto-sandy soils. Limba does well on clayey soils with an adequate water content.

Demographic pressure is particularly high in the area covered by the limba plantations. Because of the dense population and the intensive agricultural activity, on the one hand, and the large area occupied by the limba stands, on the other, farmers sometimes intercrop banana, cassava, and cocoyam with the limba.

Every four years, the Centre Technique Forestier Tropicale du Congo (Tropical Forestry Research Centre of the Congo) evaluates the condition of these stands in a survey of one-hectare sample plots, which include experimental limbacocoa and limba-banana combinations.

Forest management techniques likely to stimulate natural regeneration were not approved in the plantations. The same was true of artificial regeneration techniques that do not permit limba to receive the maximum amount of light, which is particularly important since limba is a very heliophilic species. For this reason, the corridor method was discarded. Taungya was also ruled out, although later attempts at intercropping were made on a very small scale. The formula finally adopted consisted of planting pure, even-aged stands of limba, generally at a final spacing of 10 x 10 or 12 x 12 m. In general the following operations are carried out:
A quick survey of the ground and vegetation one to two years in advance;
Detailed survey: The area to be planted is mapped out in January-February so that the amount of labour needed can be determined and supervision planned;
Clearing of the existing forest: An effort is made to destroy the forest as completely as possible before planting. The underbrush is cleared with cutlasses; the intermediate storey and overstorey are destroyed, with trees less than 30 cm in diameter being felled and the remainder girdled;
Burning in the dry season, defining of plots, and the preparation of planting lines;
Planting at the beginning of the rainy season in November, using plants cultivated in nurseries for 16 months (stumps).

**Limba-Cocoa Intercropping**

An intercropping experiment with limba and cocoa was undertaken on a plot of 450 ha. The edaphic conditions of this plot are among the best in the area. The opening up and preparation of the land were carried out according to the method described above. Limba was planted in November 1954, 12 x 12 m apart. Cocoa was planted from 1963 to 1965 between the limba at a distance of 3 x 3 m.

Limba requires a very good soil, and, in the natural forest it generally grows in clusters on fine-grained, well-structured soils with good air- and water-permeability. It is an indicator of fertile soils and farmers rely heavily on its presence in choosing their farmlands.

Cocoa is a perennial crop with stringent edaphic requirements. It prefers soils with a deep profile and good structure, providing adequate air- and water-permeability. In the Congo, it does particularly well in red clayey soils with a favourable water content. In addition to an adequate reserve of mineral matter, the organic matter content is vital to the success of the plantation.

From the start, the combination proved very beneficial to the limba, as its growth surpassed all other plots. Competition from weeds was suppressed and the soil remained perfectly clean under the cocoa plants. About 1969, the growth (in girth and average volume) of the limba above cocoa slowed, in comparison with similarly fertile sample plots. This relative decrease was more noticeable on the 39 finest trees in the plot. It seems, then, that after about 15 years, the cocoa had entered into keen root-level competition with the limba.

Since the cocoa plantation was not properly followed up, reliable data are not available on the behaviour of the cocoa under limba. For an area of about 10 ha, production over the first four years (1970-1973) was 49 kg/ha, 67 kg/ha, 31 kg/ha, and 16 kg/ha, respectively. These relatively low production figures probably reflect, on the one hand, Mayombe's utterly marginal ecological conditions for the growth of cocoa and, on the other, the depressing effects of the limba.

**Limba-Banana Intercropping**

The limba-banana combination is very widely practiced both by the Office Congolais des Forets (Congolese Forestry Authority) - a national organization responsible for reforestation - and by the populations of Bilala, Bilinga, and the surrounding areas. The preparation of the land for bananas consists of totally destroying the existing vegetation under old limba. Holes are dug and sprouts planted at the beginning of the rainy season at spacings of 4 x 4 m. The most frequently planted species is Musa sapientum, usually the Gros-Michel variety. This type of farming had already been successful in the Mayombe region of Zaire (at Luki) in the 1950s (INEAC: National Institute for Economic Study of the Congo).

Annual yields of bananas have been approximately 3 t/ha. The limba benefits greatly from the maintenance work done on bananas. Competition at root level is minimal, because of the creeping nature of the banana's roots and the banana's life span, estimated at about ten years.

**Intercropping of Limba with Other Crops**
As a result of increasing demographic pressure in the area, farmers quite often combine several food crops—such as cassava, plantain, cocoyam, corn, yam, and vegetables—with limba. Because these crops are neither perennial nor deep-rooted, there is very little risk of competition. However, it should be noted that cassava is likely to make the soil acidic.

The great danger in intercropping limba with other food crops lies in the fact that traditionally these crops are grown on burned areas. Farmers therefore tend to burn their land before planting without taking the necessary precautions to protect the limba. The trees wither very rapidly because the species is sensitive to heat.

**Conclusion**

Agro-forestry is a method of land use that has been practiced successfully in several tropical countries such as Burma, Java, India, Malaysia, and Nigeria. Its success in the Congo will depend initially on the solution of certain technical and educational problems.

From a purely technical point of view, it is essential that foresters and agronomists carefully select the species to be intercropped. This choice must naturally take into consideration the nature, requirements, and optimum ecological conditions of the agricultural and forest species being considered. From this point of view, the intercropping of limba with cocoa in Mayombe is not advisable for several reasons:

- From the climatic and edaphic point of view, Mayombe is far from suitable for cocoa farming;
- Like limba, cocoa is a perennial and very demanding as far as soil is concerned;
- The limba sheds its leaves during the dry season, thereby exposing the cocoa to the harsh, dry weather; and
- Because of the perennial nature of cocoa, certain silvicultural treatments—such as thinning—are difficult to carry out.

The intercropping of limba with banana, however, is relatively promising inasmuch as banana is a shorter-lived perennial than is cocoa and has a shallow root system.

After suitable species have been identified for intercropping, it is important to perfect plantation management techniques (opening up of the land, burning, time of planting for both crops, type of maintenance, and so on), which are necessary to the success of the operation. Burning should be prohibited.

Inasmuch as this method of regeneration is closely linked to the rural areas, it is vital that an effort be made to educate and inform the people, to give them an understanding of the value of, and prerequisites for, success with the new planting techniques.
An example of agro-forestry for tropical mountain areas

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Abstract

This paper gives a short survey of the Projet Agro-Pastoral in Rwanda, which in 1976 incorporated an extension programme to integrate trees in local smallholders' agriculture. The tree-integration programme of the project is regarded as an essential part of a low-input strategy for the re-establishment of self-sustaining agriculture in this severely degraded and over-populated area.

Introduction

The economy of Rwanda depends on agriculture; 95 per cent of the population earns its living from agriculture. No important industries exist, and mineral resources are limited to lime. Methane gas is present in substantial amounts in the Kivu Lake, but it has not yet been exploited. The average annual income per person is US$180. About 90 per cent of the exports are agricultural products; of US$92 million in exports in 1977, $66 million was from coffee, $9 million from tea, and $7 million from minerals, with the remaining $13 million from miscellaneous other products.

Rwanda is composed of scattered settlements of individuals whose average land holdings are about 1 ha. Hardly any land reserves are available in the country. The desperate economic and social situation finds its expression in the fact that Rwanda is among the poorest of the developing countries.

Rwandese development efforts must focus on agriculture; the lack of mineral resources and of competitive industries limits other possible paths to development. A further obstacle with strong impact on the national economy is the restricted access to international markets. Agriculture has not only to meet the growing food demands but also to serve as a driving force for the development of other sectors of the economy.

The key to progress must be through improved practices by smallholders. The basic aim is to meet the food demands on the farms and to produce a surplus to be marketed. With assistance, the agricultural sector can have a considerable impact on the development opportunities.

The prerequisite for integrated rural development is an improved farming system that will be able to capitalize on the under-exploited potential of the area. At present, land use is characterized by low productivity and rapid destruction of the natural resources. The predominant cause of degradation is soil erosion on cultivated fields and grazing land. Because of over-grazing and the lack of effective erosion control, this process has reached crisis proportions.

In the last centuries Rwandese agriculture has switched from shifting cultivation to permanent land-use practices. With the growth in population the average farm size is continuously shrinking, as are the periods when the land is left fallow. Contributing to the crisis is the deforestation of the hilly countryside. The people are suffering from a lack of firewood, and the destruction of the forests is causing negative impacts on the hydrological cycle and the local climate.

Still, there are some positive aspects to be found in the traditional farming systems. The farmers generally practice multiple cropping, especially cultivation under bananas. Mulch is used on nearly every farm in the well-maintained coffee plantations Of special interest are the traditional farming methods of raised-field agriculture, which allow the use of the widespread swamps. Unfortunately, against the background of rapid ecological destruction all over Rwanda, the positive aspects of traditional agriculture are of minor significance.

The Projet Agro-Pastoral, Nyabisindu, started in 1969 with the re-organization of the collapsed Dairy of Rwanda and its milk-collecting scheme. An extension unit-the aim of which was to improve the smallholders' fodder cropping-and a veterinary service were attached to the project. From the beginning, the project constantly widened its aims and in 1981 it covered all aspects of the local farming systems and rural development, including agriculture, animal husbandry, forestry, agro-industries, rural infrastructure, and farmingsystems research.

Since 1976, the goal of the project activities has been the development of a new farming system for smallholdings, which are continuously threatened by ecological crisis in the region on account of erosion, soil degradation, deforestation, etc. The ultimate goal is to overcome the economic obstacles facing both the smallholders and the national economy. The integration of agriculture, animal husbandry, and forestry makes feasible a self-sustaining and productive farming system. Recycling and a balance of inputs and outputs are the main features of such a system, thus minimizing costly inputs such as chemical fertilizers while maintaining soil fertility.

The project region, lying in central Rwanda, consists of seven intensively managed communes with about 43,000 holdings and a population density of 200-450 people/km². In these communes, the project oversees all activities in agriculture, animal production, and forestry. Furthermore, 14 communes have been provided with tree nurseries, multiplication centres, and demonstration plots.

The altitude of the project region varies from 1,500 m in the east to 2,000 m in the west. The climax vegetation is a transition from tree savanna to montane forests. The average annual rainfall ranges from 900 mm in the east to 1,200 mm in the west.

The high productivity of the natural ecosystem in the humid lowland tropics often misleads people into believing that the soils are fertile. High temperatures and precipitation have deeply weathered the soils and left little mineral reserves. The weathering process has...
resulted in a high proportion of two-layered clay minerals (kaolinite is predominant) with a cation exchange capacity (CEC) of only 3-15 meq/100 g of soil. Under these conditions, mineral fertilizers soluble in water, which are the basis of modern agriculture, are leached from the soil and quickly become unavailable to the crops. In addition, monocropping encourages decomposition of humus, degradation of soil structure, and the spread of diseases and pests. In contrast, intercropping and relay cropping of complementary crops can help control pests and maintain soil fertility.

In humid, mountainous areas, the soils often have better mineral reserves than in the lowlands; however, the soils are usually shallow and particularly susceptible to erosion. Under these conditions, the returns from modern agricultural techniques do not cover the costly inputs.

The initial search for farming systems that would be acceptable to smallholder farmers and make optimal use of the land was characterized by efforts to modernize agriculture in the project region. These efforts consisted of introducing high-yield varieties in combination with mineral fertilizers and pesticides. These first attempts were totally unsuccessful, with one reason being that the project was often cut off from transport for several months and supplies could not be guaranteed. Also the costs of such imported means of production were prohibitive. Even the establishment of a credit system and the formation of co-operatives failed, as the smallholders were unable to refund the credits. Most of the yields were needed to cover their families' nutritional needs. Besides the high costs in foreign currency and the dependence on foreign inputs, this approach to agriculture did not take into account the special conditions of tropical ecosystems.

In the second phase of the search, the study of the indigenous farming systems in East Africa was of great help. The works of Ruthenberg and, especially, of K. Egger, who became consultant for the project in 1976, were the basis for the integrated concept now used in Nyabisindu.

The East African highlands are the home of many traditional farming systems producing considerable outputs with local resources on a long-term basis. One example of these forgotten African farmers who developed their farming systems without foreign help is the Wakaras, on the island of Ukara in Lake Victoria. Within a few generations the Wakaras were able to set up a self-sustaining agriculture on the granitederived, poor soils of Ukara. Their farming system sustained a modest living for 500 inhabitants on a single square kilometre.

The main components of such permanent farming systems are:

- Integration of trees in agriculture (multistorey farming);
- Integration of animal husbandry (stall feeding, fodder cropping);
- Use of organic fertilizers like dung, compost, and green manures;
- Use of diverse crops and sophisticated cropping tech niques (relay cropping, mixed cropping, etc.); and
- Effective erosion control by contour planting, mulching, etc.

Observations of the traditional agriculture in Rwanda and the neighbouring regions of East Africa were the basis for the elaboration of a new farming system. In combination with the results of modern agricultural and ecological science, a development strategy that is consistent with the conditions in Nyabisindu was designed.

Low-Input Strategy

The first step towards the development of new farming systems adapted to local conditions was the definition of realistic aims for the project. The aims were to:

- Cover subsistence needs;
- Enable a surplus to be sold at local markets (monetary income);
- Reclaim and maintain soil fertility; and
- Minimize costly external inputs.

The target group was the smallholder farmers, with special attention being given to those with submarginal holdings.

The second step was the practical evaluation of different agricultural methods and technologies which seemed to be suited to the locale. After five years of experimental work under field conditions, a survey was taken which allowed a first synthesis of a complete farming system.

To devise a complete farming system, it was necessary to determine which methods had components that met the project aims. The methods were examined according to economic factors (cost-benefit, access to means of production); ecological factors (soil conservation, external effects); and socio-economic factors (source of know-how, adaptability).

### TABLE 1. Hierarchy of Methods

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<thead>
<tr>
<th>Methods</th>
<th>Techniques</th>
<th>Benefits</th>
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<tbody>
<tr>
<td>Vegetative Structure</td>
<td>Trees in erosion-control strips and hedges (for wood, fruit, and browse)</td>
<td>Integration of forest functions in agriculture (high and long-term stability)</td>
</tr>
<tr>
<td>Subdivision of plots by</td>
<td>Mixtures of root, fruit, leguminous, and other crops</td>
<td>Better micro-climate, lower soil temperatures, unlocking of mineral reserves in deep soil layers, better trapping of nutrients, and water-retention capacity</td>
</tr>
<tr>
<td>erosion-control strips,</td>
<td>Erosion-control strips</td>
<td></td>
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<tr>
<td>woodlots, permanent crops, and gardens</td>
<td>Wood lots</td>
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</tbody>
</table>
Erosion control and mulching

Habitat for pest predators

Permanent crops (coffee, etc.)

Production of firewood, timber for construction fruits, forage, mulch, etc.

Improved labour management and planning

2. Crop-Planning System

High diversity of crops, products, and auxiliary plants

Multiple cropping with legumes, cereals, and tuber crops

Lessened risk with regard to pests, climate, and markets

Use of resistant and improved varieties

Relay cropping with seasonal and annual crops

Better biological control of weeds, pests, and diseases

Crop rotation with multiple and relay cropping and intensive fallows

Fallow (1-2 seasons) to regenerate soil fertility using Mucuna, Vicia, Crotalaria, Tephrosia, Cajanus, etc.

Higher degree of soil cover, preventing soil erosion, preserving humus and soil structures, and improving water-retention capacity and cation-exchange capacity

Selective weeding

Natural regeneration of soil fertility (fallow)

3. Organic Manuring

Mulch, green manure

Mulch in gardens and permanent crops from weeds, hedges, tree leaves, fallows, and crop residues

Recycling plant nutrients

Compost

Lower leaching losses

Animal manure

Raising humus content

Compost

Improving soil structure, water infiltration, and water-retention capacity

Mulch in gardens and permanent crops from weeds, hedges, tree leaves, fallows, and crop residues

Improving cation-exchange capacity

Animal manure

Reducing pest and disease infections

Manure of cows, sheep, goats, rabbits, etc.

4. Integration of Animal Husbandry

Fodder crops

Production of fodder in fields, hedges, anti-erosion strips, and browse trees

Transformation of low-yielding pastures into fodder-cropping plots

Stables or pens

Profitable use of manure (see 3 above)

Manure

Better control by veterinary service

5. Mechanical System

Labour saving tools

Introduction and improvement of tools and garden implements (distribution with subsidized prices)

Improved labour productivity

6. External Fertilizers

Ground rock

Ground lava, chalk

Addition of nutrients not supplied by farm manure, compost, etc.

Rock phosphate

Phosphorus, potassium, trace elements

Mineral fertilizers

Application in several doses

Faster recovery rates on plots that need to be reclaimed

Minimized leaching losses

7. Plant Protection with Biocides

Selective application

Prevention of total crop losses

Treatment of storage pests

Re-establishment of equilibrium

Protection of seedlings in nurseries

On the basis of the criteria, a hierarchy (table 1) was formed; it defined preferences in the choice of elements for the synthesis of the farming system, and it pointed to the most adaptable and cheapest combination of the different elements with respect to the specific conditions of every site. Although it did not definitively rank different methods, the hierarchy was a guideline for the extension service, and the criteria are suited to many marginal regions in Third World countries.

If farmers respect the rank of the methods, they may profitably apply costly inputs like mineral fertilizers. The elements of the farming system promote soil conservation and high humus content, and thereby create the preconditions for good fertilizer response. Thus there would not be a heavy dependence on outside inputs, and the system would not break down if the regular supply were cut off. To implement the programme, the project staff established a number of services (Appendix 1), one of which is concerned with integrating tree crops.

Integration of Trees

This paper focuses on practical experience with the integration of trees. The project is now starting a research programme that will give a solid scientific basis for its recommendations.

Interdisciplinary research in the field of agro-forestry has been neglected in the last decades, probably partly because of the length of time required for research involving trees and partly because of the barriers between the disciplines of agriculture and forestry. Those who see the necessity for, and the promising possibilities of, agro-forestry will understand why the project in Nyabisindu did not wait for precise research results.

The tree programme of the project is based on the 170 tree nurseries that are spread throughout the project region. These decentralized tree nurseries are the key to effective extension work. In 1979, the annual capacity amounted to 5 million trees, including fruit trees (30
per cent) and coffee seedlings (6 per cent). All tree seedlings are produced in plastic bags.

**Afforestation, Fruit Trees, and Roadside Plantings**

The overall tree programme incorporates afforestation of the denuded hilltops in areas that are not suited to agriculture or grazing; the aim is to improve the landscape and increase tree production. In 1979, 650 ha were afforested by communal work service (cost per hectare using seedlings produced in the nurseries was US$200).

The main genera used are Eucalyptus, Cupressus, and Pinus. The seriously degraded hilltops are suitable only for Eucalyptus, but, on the more fertile hillside, a mixed stand of Grevillea robusta, Pinus patula, Cupressus spp., and Eucalyptus sp. has been planted. The Eucalyptus monoculture has turned out to be very exhausting for soils. Many of the older Eucalyptus forests are adversely affected by soil erosion because no shrubby or weedy species will grow in Eucalyptus stands.

Losses of about 40 per cent of the trees occurred, mainly because of poor planting practices by the community service. Although afforestation with paid labour is far more effective, it was rejected for psychological reasons. The self-help efforts of communal services should be encouraged as long as there is no national forestry service to guarantee sustainable forests.

Another part of the overall tree integration programme is a project for the planting of fruit trees. Farmers in Rwanda have hardly ever planted fruit trees, even though the value of fruit in the human diet cannot be over-emphasized. The project made great efforts to spread fruit-tree growing in the region. About 30 per cent of the total nursery capacity has been reserved for fruit trees, with the most important being avocado, guava, papaya, and custard apple (Annona). Altogether about 5 million fruit trees have been given to the farmers in the project area as compensation for their communal work; 80 per cent of all farmers so far have planted fruit trees. This project has, therefore, touched more farmers than any other activity.

Tree integration is also aided by a government programme to plant trees along the roadsides, the trees being provided by the project nurseries. Rwanda is densely populated, and has a complex road system. The fact that the trees are always planted on farmland alongside the roads has helped accustom the farmers to tree integration in agriculture. Side-effects are the creation of shade for the pedestrians, many of whom carry large containers on their heads. Also, the wood from these trees is to be made available to consumers in the near future. The main species used along roadsides are Grevillea robusta, Cedrela serrate, and P. patula, as they do not interfere with crops under them. In school areas, fruit trees are planted, with the fruit to be picked by the children on their way to school. Trees have already been planted alongside about 450 km of road.

In many parts of the project region the holdings include severely degraded plots which are not suitable for cultivation or grazing. To prevent further damage, and because of the limited capacity of individual communes to plant large areas, the project provides for the afforestation of these areas. Besides wood production, the trees help rehabilitate the soil and create some grazing for cattle. The main species used are G. robusta, P. patula, Cupressus spp., and Eucalyptus spp. It is planned to integrate browse trees also. Up to now, however, farmers have been oriented to the fast-growing Eucalyptus species.

**Trees in Fields**

The main point of the tree integration efforts in Nyabisindu was to establish trees in the fields that protect cropping areas. Although agricultural scientists argue that shade trees reduce yields of undergrowing crops through competition for light, water, and nutrients, there are many arguments in favour of tree integration. Trees provide:

- Protection from raindrop or splash erosion;
- Fortification of anti-erosive cropping strips;
- Light shading of the soil and thus reduced soil temperatures, evaporation, and humus decomposition rates;
- Unlocking of mineral reserves in soil layers not accessible to the shallow root systems of crops;
- Formation of nutrient traps, as the tree root systems stop the loss of nutrients through leaching; and
- Production of firewood, construction material, and mulch.

Thus, tree cover plays a paramount role in soil conservation, maintenance of soil fertility, and production of urgently needed wood.

Ecological sciences emphasize all aspects of productivity rather than focusing solely on yields. Climate, soil properties, vegetation structure, and biological diversity are variables in productivity. Intelligent management of them increases productivity in terms of both biomass and useful products. A complex vegetation structure with high diversity, rapid accumulation of biomass, and strong inner recycling of nutrients contributes to the productivity of natural ecosystems. Increased biomass production (perhaps through higher turnover rates) can partially be converted into agricultural production by a wide range of cultivation methods and technological inputs. Before the nutrients leave the cropping area in the form of agricultural products, they may have been recycled in the agro-ecosystem, building the tree canopy (soil protection), serving the purposes of fallow (regeneration of fertility), etc. Agricultural production appears only as a by-product of the functioning of the whole system.

If the processes in natural ecosystems can be imitated by cultural systems, productivity may not only be raised but also stabilized in the long term. Although lower yields may be obtained from the crop understorey, these losses are compensated by the benefits created by the overstorey wood for timber and fuel, fruits, soil protection, nutrient enhancement (tree legumes, unlocking of reserves), etc. (Appendix II).

When shade trees are used in the field, the main concern of agronomists is the competition with other crops for light. This problem can be minimized if some general rules are followed, as has been shown by the practical work at Nyabisindu. Only trees that allow intercropping are used in the field. Eucalyptus spp., Cupressus spp., black wattle (Acacia mollissima), and Croton spp., which hinder intercropping because they emit substances toxic to plants or have too dense a canopy, are not used. G. robusta, Sesbania sesban,
Cedrela serrate, and Leucaena leucocephala have been used with great success in Nyabisindu. Observations of the traditional agriculture of Rwanda and other countries in East Africa indicate that Albizia spp., Acrocarpus fraxinifolius, and Millettia laurentii are also promising trees. Generally one should look for species that produce little shade and high rates of litter production.

In hedges, the choice of species is greater than for open fields. The following species have been shown suitable: Psidium guajava L., Morus alba, Cassia spectabilis, Entada abyssinica, Croton macrostachys, Marcamia lutea, Erythrina abyssinica, etc.

In Nyabisindu, trees for anti-erosive purposes are generally planted 3.5-4.5 m apart. On the basis of a 10-m distance between strips and taking into account the outside hedges, the number of trees is between 250 and 350 per hectare, that is, about 10 per cent of the density of normal afforestation. Grevillea is planned to be cut on an eight-year rotation, allowing the yield of 30-43 trees per year.

If the trees create too much shade, they should be cut or the branches pruned regularly. Trees tolerate the loss of up to 60 per cent of their branches without suffering reduced growth. The branches can be used for firewood or mulch. In Nyabisindu, early figures for production from G. robusta in the field and in the forest have been encouraging (table 2). These indicate that trees interplanted in cultivated plots produced 3.4 times the stemwood of trees grown in plantations. Wood production of branches was 4.4 times that of trees in the neighbouring plantation. The weight of leaves produced (litterfall) was about three times that of the forest trees (18 kg versus 6.3 kg per tree).

TABLE 2. Wood Production in Integrated Tree Plantations. The production of stemwood, branches, and leaves of Grevillea robusta planted in November 1976 was measured in March 1981. Results were compared to trees of the same age planted in "classical" reafforestation under similar soil conditions.

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Height (m)</th>
<th>Stemwood (m³)</th>
<th>Volume of branches (m³)</th>
<th>Leaves (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>4.25</td>
<td>8.32</td>
<td>0.048</td>
<td>0.025</td>
</tr>
<tr>
<td>B</td>
<td>4.25</td>
<td>6.60</td>
<td>0.014</td>
<td>0.005</td>
</tr>
</tbody>
</table>

A - trees in cultivated plots
B - trees in classical afforestation

By planting about 350 trees per ha in an eight-year rotation in an agro-forestry system, the average farmer could harvest 43 trees per year. His annual wood harvest would be roughly 7 m³, whereas the annual wood production of a comparable "classical" afforestation at 350 stems/ha would be only 1.5 m³. In other words, the need for fuelwood, given in Rwanda as 1 m³ per person per year, and presuming an average family of five to six persons, could be met at 148 per cent or 123 per cent, respectively. The differences in heating value between Eucalyptus and Grevillea, however, have not been taken into account.

A special question is the arrangement of the crop understorey. In Nyabisindu, mixed cropping is practiced, with the crop distribution patterns depending upon their shade tolerance. Light-consuming crops like maize and sorghum are placed away from the trees while crops like beans, cocoyam, and sweet potatoes are planted in the shade of the trees.

Research

Still the question of what is the best mix of the crops is far from answered. An important task for researchers is to test the different crops and varieties for their tolerance of shade and also to search for tree species that are suitable for integration. The ease with which trees are multiplied differs from species to species, and this should be a consideration in the identification of suitable species. Where farmers reject tree planting in the fields, the integration of bananas or plantains is recommended for the initial phase in order to accustom them to multistorey cropping. Also fruit trees, like papaya and Prunus salicina, which produce little shade but profitable returns, are appropriate.

Appendix 1. Services Provided by the Project

Plant Production

- Installation and maintenance of 170 tree nurseries in 23 communes with a total capacity of 5 million trees per year. About 30 per cent of the total capacity is dedicated to the production of fruit trees;
- Multiplication of fodder plants, anti-erosive plants, cash crops, vegetables, fruits, and spices (Tripsacum, Pennisetum, Setaria, Mucuna, Desmodium, Vicia, bananas, Capsicum annuum, etc.) in 116 multiplication centres on 96 ha of communal land; and
- Establishment of demonstration farms in each commune, also used for multiplication purposes.

Animal Production

- Mobile veterinary service held periodically at 19 centres (9,500 treatments annually);
- Stationary veterinary service with dispensaries (9,000 treatments annually);
- Provision of emergency veterinary service on weekends (800 emergencies annually);
- Introduction of tick control with seven to ten dips—altogether 510,000 treatments annually;
- Testing of immunization against east coast fever;
- Reinstallation and running of a 33 ha state cattle farm;
- Improvement of breeding in farmers' areas with 12 bull centres with selected local and crossbred bulls; and
- Construction of improved slaughter houses (two completed, one under construction).

Processing and Marketing
• Revival of Dairy Nyabisindu, with milk collection in 1969 of 156,700 litres and in 1977 of 1,076,100 litres;
• Construction of milk sales centre in Kigali and Butare and a new factory and offices for the main dairy;
• Construction of a soybean processing plant in 1979 with a daily capacity of 500 kg beans (55 litres oil, 350 kg flour);
• Introduction of sugar cane (including processing). The first pilot plant was constructed in 1976, with three further plants built since 1980. The sugar-cane plantation amounts to more than 20 ha; and
• Development of 16 communal and co-operative warehouses to date.

Other Services

Two forms of extension are under way—individual and group. In the individual extension work, more than 4,000 farmers have been approached, and 700 farmers have adopted important elements of the extension programme.

The group extension work is based on the communal labour service. Every person over 16 enters this service, thereby participating in the nurseries, multiplication centres, and demonstration farms of the project. Thus, the population is directly involved in the project. Regular meetings are held, with the participation of all farmers to discuss the project activities.

In connection with the re-organization of the milk-collection scheme, about 70 bridges and 20 km of new roads were built.

In 1980, the project established a small research unit to carry out a partial analysis of the farming systems and to generate further development. Three scientists (a forester, an agriculturist, and an economist) are employed. A small laboratory is under construction.

Appendix 11. Recommended Tree Species in the Project Region

<table>
<thead>
<tr>
<th>Species</th>
<th>Forest</th>
<th>Roadsides</th>
<th>Hedge</th>
<th>Field integration</th>
<th>Fruit</th>
<th>Mulch</th>
<th>Browse</th>
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</thead>
<tbody>
<tr>
<td>Eucalyptus gummifera</td>
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<td>E. resinifera</td>
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<td>E. saligna</td>
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<td>E. camaldulensis</td>
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<td>E. cloeziana</td>
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<td>E. grandis</td>
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<td>E. microcorys</td>
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<td>E. robusta</td>
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<td>Cupressus lasitanica</td>
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<td>C. benthamli</td>
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<tr>
<td>Grevillea robusta</td>
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<td>G. banksii</td>
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<tr>
<td>Pinus patula</td>
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<td>P. caribaea</td>
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<td>Cassia spectabilis</td>
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<td>Albizia gummifera</td>
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<td>Acrocarpus fraxinifolius</td>
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<td>Cedrela serrate</td>
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<td>Cassarina equisetifolia</td>
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<td>Entada abyssinica</td>
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<td>Millettia laurentii</td>
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<td>Acacia sp.</td>
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<td>Podocarpus milanjianus</td>
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<td>P. usambarensis</td>
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<tr>
<td>Jacaranda sp.</td>
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</tbody>
</table>
Erythrina abyssinica
Leucaena leucocephala
Sesbania sesban
Macadamia ternifolia
Morus alba
M. nigra
Carica papaya
Passiflora edulis
Psidium guajava
Annona cherimola
A. reticulate
Persea americana
Cyphomandra betacea

Dash indicates tree was not used for that purpose.

Intercropping tree and field crops

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Abstract

This paper describes an experiment started in 1978 in the humid forest belt of Ghana that attempted to demonstrate to farmers how they can establish plantations of economic tree species and, at the same time, produce food crops by means of judicious intercropping. A population density of 625 plants/ha of a fast-growing tree species, Gmelina arborea, was established at four different spatial arrangements. The stands were interplanted with an important West African food crop, plantain (Muse cultivar), at various spacings (densities ranging from 536 to 1,588 plants/ha). The minimum plant-toplant distance was 2.0 m, and the maximum was 2.8 m. Both species are being assessed periodically by standard forestry and agricultural methods. The implications of the results so far are discussed along with the objectives of the experiment and projected future experiments.

Introduction

One of the problems facing manufacturing industries that have been set up in developing countries has been the difficulty of obtaining raw materials and, quite often, the inadequacy of these raw materials. If the pulp and paper industry in Ghana is not to be bedeviled by this sort of problem, then attempts must be made to ensure sustained supplies, in requisite quantities, of tree species suitable for the industry, and local farmers must be encouraged to supplement the production from factory-owned plantations. In this regard, estimates of farmers' production must be reliable, based on an accurate enumeration by region or district of not only the farmers engaged in forest tree cropping but also the stands their farms carry.

Gmelina arborea is a medium to large fast-growing deciduous tree, capable of growing successfully in mixed forests of moist regions, such as the humid forest belt of Ghana. Usually grown in plantations at spacings of 2.0 x 2.0 m (Streets 1962), it is one of the species recommended for a proposed pulp and paper industry in Ghana.

The establishment by farmers of forest tree crops, although known in Ghana, has not been very popular, mainly because of the long time it takes for the farmers to realize any income from the operations. However, if this desirable practice were somehow combined properly with food cropping, it would probably gain popularity as a prospect for almost immediate and sustained income or savings on food costs.

On account of its ease of establishment, mode of growth, and time of maturity, as well as the demand for it as a staple item in local diets (Purseglove 1972), plantain (Muse cultivar) was selected as the food intercrop for the initial experiments with G. arborea.

The two species can be planted at a minimum distance of 2.0 m (1:1 rectangularity). When interplanted, the rapid growth and development of effective canopies and roots, yield of leaf litter, and the number of suckers that plantain develops as it grows were all considered to be favourable for the maintenance of soil fertility (even if not its build-up), and for early protection against soil erosion, particularly that caused by splash and runoff.

It was the objective of the experiment described in this paper to establish 625 trees/ha of G. arborea. Plantain was interplanted at various spacings so that the minimum distance between and within rows (Gmelina-Gmelina; Gmelina-plantain; plantain-plantain) was 2.0 m, and the maximum distance was 2.8 m, distances at which either species can be planted in a 1:1 arrangement. In the first two years, maize (Zea mays) and cocoyam (Xanthosoma sagittifolium) were planted in the spaces between the young plants of Gmelina and plantain. Although they were not included in the study, they could provide additional sources of income and food for the farmers.

This experiment therefore served as both a quantitative scientific study, and a demonstration to farmers of the advantages of intercropping trees with food crops, both of which would have ready markets.
Materials and Methods

The South Fomangsu Forest Reserve was chosen for the study, and the research site, which is about 80 kilometres from Kumasi on the Kumasi-Nkawkaw road, is at the western end of the reserve. The land was cleared and burned during the 1977-1978 dry season, and it was ready for planting by April 1978. Meanwhile, seedlings of G. arborea had been raised for the experiment by early 1978, and bigfruited (Apanu) plantain suckers had been purchased from February to April.

A Gmelina tree population of 625/ha was maintained, and the spacings used in the four different treatments were 4.0 x 4.0m (1:1); 5.7 x 2.8m (2:1); 6.9 x 2.3m (3:1); and 8.0 x 2.0m (4:1).

Where the between-row or within-row distance from one Gmelina plant to the next was 4.0 m or more, a plantain sucker was planted so that the distance from any one plant (Gmelina or plantain) to the next measured at least 2.0 m but not more than 2.8 m. Thus, for every four Gmelina plants in the 4.0 x 4.0 m spacings, there were five plantain plants; for every four Gmelina plants at 5.7 x 2.8 m spacings, there were only two plantain plants; for every four Gmelina plants at 6.9 x 2.3 m spacings, there were also four plantain plants; and for every four Gmelina plants at 8.0 x 2.0 m, there were six plantain plants. Planting started in May 1978 and continued for about one month.

The layout for each treatment was as follows: (1) each plot measured 32.0 x 28.0 m, with nine rows of Gmelina plants along the 32.0 m axis and eight Gmelina plants within each row, interplanted with plantain so that there were nine rows of Gmelina/plantain alternating with eight rows of plantain, each only 2.0 m from the next; plantain plants numbered 183; (2) each plot was adjusted to measure 34.5 x 27.6 m, with six rows of Gmelina plants along the longer axis, each with 13 plants; between the two adjacent rows of Gmelina were two rows of plantain plants, 2.3 m apart with 11 plants apiece (total 66 plantain plants); (3) each plot was adjusted slightly to measure 34.5 x 27.6 m, with six rows of Gmelina plants along the longer axis, each with 13 plants; in between every set of two adjacent rows of Gmelina were two rows of plantain plants, 2.3 m apart (i.e., ten rows of plantain plants, each with 13 plants); and (4) each plot measured exactly 32.0 x 28.0 m, with five rows of Gmelina along the longer axis, each with a population of 15 plants; between the two adjacent rows of Gmelina were three rows of plantain plants, a total of twelve such rows, 2.0 m apart, each with 15 plants.

Thus, for a Gmelina population of 75±3 trees per plot, the plantain population varied from a low of 66 in the second spacing to a high of 183 in the first spacing. The four treatments were replicated six times in a randomized complete block design, with 24 plots in each treatment.
Assessment of the plantains (all the plants except those in the outer rows) involved height measurements; grouping of plants into small, medium, and large; enumeration of the number of functional leaves per plant; determination of the lengths and the widest breadths of the oldest functional and newest (but completely unrolled) leaves; enumeration of the number of suckers produced per plant; and yield and components, i.e., mean number of hands per bunch, mean number of fingers per hand, and mean weight of individual fingers.

**Results and Discussion**

The first and second years' assessment data of G. arborea are available, but only those for the second year, taken at the end of 1980, are presented in table 1. Although the data have not been statistically analysed, to date there is little evidence that one treatment is markedly superior to another in the parameters evaluated. It is possible that two years of growth is too short a period for treatment differences to be shown. Streets (1962), in fact, suggests that a minimum of four years is required for the manifestation of differences as a result of interference between trees and crops. Even if no differences are detected in the near future, this work will have shown the ability of Gmelina trees to successfully withstand competition from other trees and plantain plants at the spacings used.

Because the trees are destined for the paper and pulp industry, an important consideration is the production of those parts useful as raw material under the conditions of the experiment. Also, the claim of plentiful natural regeneration is to be carefully examined from about the fifth or sixth year onwards.

In May 1979, when the Gmelina and plantain were assessed, only a few of the plantains in each plot had produced mature bunches. Four plants per plot were harvestable so their yields were determined.

An analysis of variance of the bunch yield did not show any significant treatment effects on yield. Yet, when the yields were resolved into their components—the mean number of hands per bunch, the mean number of fingers per hand, and the mean individual finger weight—it was found that the block effect on the mean individual finger weight was significant ($P = 0.05$). Thus, the consistently higher yields obtained in one block can only be due to this higher component. This point has been stressed because the mean weight per finger is an important component of yield in plantains and must be studied in future data analysis. Mean weight per finger is dependent on the number and size of functional leaves and their exposure to sunlight during the period of fruit filling (osafio, unpublished).

At this early stage and on the basis of only four plantains per plot, not much can be expected with respect to treatment differences. However, within a year of the planting date, some food was obtained from the operation as well as sizeable quantities of maize and cocoyams, and this fact can be used by extensionists to canvass farmers. If, as indicated by the preliminary yield data for 1980, nearly all the plantain stands have produced mature bunches after a year, then farmers may be convinced to take up this sort of agro-forestry practice.

It is thought that, after four years or so, plantain suckers will be produced in abundance, the Gmelina trees will be producing seeds, and natural regeneration will be noticeable. Then it may be necessary to thin the plantain stands to promote both growth and yield. This possibility assumes that under the conditions of the experiment, the Gmelina trees will grow to heights of 15 m or more and form dense canopies that will interfere with light interception by the plantains. The competitive effects would need careful assessment on the basis of crown exposure scoring and enumeration of canopy-forming agents.

To date, it has not been possible to follow up the soil aspects of this study because of financial difficulties and scarcity of competent technical staff. However, the plans to assess soil effects have not been abandoned.

The final choice of an agro-forestry system should be made by the farmer, and this will depend on what combination of trees and crops leads to the most enduring benefits in terms of food production, wood output, and maintenance of soil fertility. Answers with regard to combinations of Gmelina arborea with plantain may not be forthcoming until the experiment has run, and been assessed yearly, for a minimum of eight years.

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Promising trees for agro-forestry in southern Nigeria

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Abstract

In Nigeria, several tropical trees are suitable for agro-forestry because of their multiple uses as sources of food, animal feed, timber, firewood, stakes, chewing sticks, and soil fertility restorers. Adequate information on the suitability of different species, however, is lacking or is not readily available. The scope of work, results, and achievements obtained at the Forestry Development and Investigation Branch, Enugu, where substantial tree crop improvements have been carried out during the past ten years, are noteworthy. The work reported here is a basis for selecting some tree species that are promising for agro-forestry. The selected species are given in two broad categories of fruit/food trees and non-food trees. Suitable species are suggested for each category, for both compound and outlying farm types, within the tropical forests and derived savanna. An ongoing study of natural fallows to elucidate their efficiency in restoration of soil fertility in southeastern Nigeria is briefly mentioned.

Introduction

The importance of indigenous trees as direct sources of food in Nigeria, such as leafy vegetables, fruit, alcoholic drinks, edible fats and oils, is being increasingly, though not adequately, recognized and documented (Anakwenze and Ettah 1974; Okafor and Okolo 1974; Okafor 1975b, 1978, 1980 a, b; Okigbo 1975; Roche 1974). The important roles and applications of trees in the agriculture-cum-forestry production systems for food and wood production have also been amply recorded in the literature (Ball 1977; King 1968; Okon 1973; Okafor 1975c, 1980c; Okigbo 1976; Iyamabo 1979). The roles range (in addition to food production) from supply of timber, firewood, pulp and fibre through fodder, gum, drugs, and dyes to restoration of soil fertility.

Despite the general acknowledgement of the roles of trees in agro-forestry systems, there is as yet limited precise information on how these roles are fulfilled or on the suitability of the species involved. Recently, Nair (1980) has discussed in general terms the characteristics of species suited for agro-forestry. According to Nair the species should give economic yields in a relatively short time; they should tolerate partial shade when intercropped; they should be easy to manage; they should withstand adverse climatic and managerial conditions; and they should yield marketable and locally used produce. Nair (1980) presented "crop sheets" of plant materials that can be used in agro-forestry covering major economic groups; namely, cereals, pulses, roots and tubers, fruits, oils and fats, beverages, fibres, spices, nuts, condiments, stimulants, medicines, and aromatic plants. Detailed information was provided for each species with respect to its uses and economic importance, origin, distribution, characteristics, ecology, physiology, composition, agronomy, yield, pests and diseases, and agro-forestry potential. Although some trees were included, such as cocoa, cashew, rubber, coconut, oil palm, breadfruit, shea butter, etc., the crop sheets dealt mostly with herbaceous and shrubby plants rather than trees and fodder species.

This paper will, therefore, focus attention on tree species with agro-forestry potential. The basis of selection was their importance in traditional farming and diets, extent of geographic and ecological distribution, adaptability, and ease of propagation and regeneration.

The Forestry Development and Investigation Branch

The objectives and scope of the work being carried out at the Forestry Development and Investigation Branch (FDIB), Forestry Commission, Ministry of Agriculture and Food Production, Enugu, are noteworthy in the selection of promising trees for agro-forestry. The main areas of research are production of food from wild and semi-wild fruit and food trees; production of wood and wood products from
fast-growing exotic and indigenous species; biological aspects of soil-erosion control; and the components of the Nigerian flora, including the establishment and maintenance of the Enugu Forest Herbarium (EFH).

Within the first area of research, FDIB is executing a project on indigenous fruit-tree production (Okafor 1975b). The aim of the project is to increase and diversify available food supply in the country through the selection, multiplication, domestication, improvement, and conservation of edible wild and semi-wild woody plants. The scope of this project includes the identification of wild woody plants in the Nigerian forest zone of nutritional importance; the adaptation and conservation of edible wild and semi-wild woody plants; and large-scale production of improved seedlings for sale to farmers throughout the country.

Research is under way on the development of suitable propagation methods and techniques for the fruit- and food-producing woody plants; taxonomy of principal species, with the collection, preservation and documentation of herbarium specimens; ecology of the species, with surveys to determine the occurrence, abundance, and distribution; seasonality and economics of the species (through market surveys); phenological records and estimates of yield of various edible plants; food values by proximate analysis (carried out in cooperation with the Project Development Institute [PRODA], Enugu); the industrial potential of the edible parts (carried out in cooperation with PRODA and the Food Investigation Project, Enugu); and the wood value and other socio-economic roles of the woody plants, especially in the traditional farming systems, by means of laboratory and questionnaire assessments.

The results and achievements so far have been previously reported (Okafor 1975a, b, 1978, 1980a, b; Okafor and Okolo 1974). The results that are relevant to this paper can be summarized as follows:

- Suitable techniques of vegetative propagation with buds and stem cuttings have been developed for about 30 species of indigenous woody food plants including Irvingia gabonensis (wild mango, "ugiri/ogbono"); Treculia africana (African breadfruit, "ukwa"); Pentaclethra macrophylla (oil bean tree, "ugba/ ukpaka"); Chrysophyllum albidum [local star apple, "udala"]; Dacryodes eeu/is (African pear, "ube"); Par*ia clappertoniana (locust bean tree, "dorowa"); Azel*ia africana ("akpalata"); Ceiba pentandra (silk cotton tree); Dialium guineense (velvet tamarind); Myrianthus arboreus ("ujuju"); and Precarpus spp. ("ora");
- The fruiting age and frueting height of some fruit trees, such as Irvingia gabonensis, Treculia africana, Pentaclethra macrophylla, Chrysophyllum albidum, and Dacryodes edulis, have been drastically reduced, frueting being as early as two to four years and at breast height or less;
- Researchers have been able to produce, within three years, viable fruits at ground level from stem cuttings of T. africana
- New varieties have been described in some principal species (I. gabonensis, T. africana, D. eeu/is); this information will facilitate identification and enhance complete collection and conservation of germ plasm (and utilization) of the economic trees;
- Pilot seed orchards and conservation plantations of about 60 ha have been established in various parts of Anambra State;
- J. africana has been shown to be promising for pulp and paper making;
- A total of 150 edible wild and semi-wild woody plants have been identified within the Nigerian forest zone through a national survey recently concluded with the financial support of the Federal Ministry of Science and Technology; and
- Determination of nutritional values has also been carried out for a large number of wild fruits and vegetables.

Selected Agro-forestry Species

Based on extensive field observations made during the ecological survey of woody plants of nutritional importance (in which non-food plants were also noted) within the traditional farming systems of the lowland humid tropics in Nigeria, FDIB personnel consider several indigenous species to be promising for agro-forestry. The selected species have been classified into fruit and food trees, and non-food trees. Both categories are further divided by ecological zone-forest and derived savanna vegetation subtypes. Within each subtype, the species suited to compound farms and outlying farms are indicated, making a total of eight categories. Each of these is considered in depth in the following section.
Fruit and Food Tree Species for Compound Farms in the Forest Area

The species in this group are either cultivated or semi-wild and protected (Okigbo 1975; Okafor 1975b, 1980a, b, c). They are planted or retained as farm trees and interplanted with arable crops, in close proximity to the homestead where they are protected.

The fruits of Treculia africana are an important food item that is cooked and eaten in many parts of southern Nigeria. The roasted nuts are also eaten in conjunction with palm kernel or coconut. The wood is very popular as fuel. The fruit mesocarp is commonly fed to domestic animals such as goats and sheep. The tree is amenable to pruning, which is often necessary for the control of shade; the pruned branchlets and leaves are palatable browse for domestic animals. Propagation is easy from both seed and buds. The latter results in fruiting within four years at reduced height. The species (variety inverse) has great prospects for plantation development as a source of pulp (Okafor 1980a). Because it coppices readily and vigorously, it does not have to be replanted from seed after the first rotation. Thus, it is promising as a planted, productive fallow, with great potential for the restoration of soil fertility.

Two varieties of Irvingia gabonensis have been described- gabonensis and excelsa (Okafor 1975a)-and are considered noteworthy. The kernel of excelsa is important economically and is used in soup as well as a complement to fufu, cocoyam, and gari. The pulp of gabonensis is sweet and edible, suitable for jams and fruit juice. The wood is durable and is used for farm tool handles. The species can be propagated from seeds and buds, with viable fruiting within three years for gabonensis and five years for excelsa.

Dacryodes edulis produces fruits that are softened in hot water or hot ash and eaten in conjunction with boiled or roasted maize, especially during the "hungry season" when the staples, such as yam and cocoyams, have been exhausted. The kernels and leaves are fed to domestic live. stock. The species is easily propagated from seeds. If the leading shoots of planted trees are pruned, the crown will spread. Pruned trees have fruited within 2.5 years.

Chrysophyllum albidum fruits are widely eaten in southern Nigeria, being especially popular with children and women. The fruit pulp is suitable for jams. The wood is suitable for domestic utensils and tools. It can be propagated from seeds and buds, though the latter is not easy.

Cola acuminate (cola) is highly important economically on account of its edible seeds, which also fulfil cultural roles throughout Nigeria. Pruned leaves are fed to domestic livestock. The trees can tolerate partial shade and are, therefore, suitable for agro-forestry.

Elaeis guineensis (oil palm) is the most widely planted and protected tree as well as the most economic and useful tree within the traditional farming system in south-eastern Nigeria. The wide range of useful products-palm oil, kernel, palm wine, palm fronds (structural material!, brooms, etc.-and the possibility of pruning leaves to reduce shading make this species especially appropriate for agro-forestry practices. Most of the farmers' needs are obtained from their own trees. Improved varieties are now available from many sources, including the Ministry of Agriculture and agricultural institutes.

Pterocarpus soyauxii, P. mildbredii, and P. santalinoides are important sources of leafy vegetables, especially during the dry season when conventional vegetables are scarce. They yield the cam wood of commerce. Propagation from stem cuttings is easy, and plants can be established on relatively poor sites with good growth.

The importance of some species of Ficus (fig trees) in agro-forestry derives from their usefulness as leafy vegetables (F. capensis) and browse. They are also used as roosts by bats which are hunted or trapped.

Spondias mombin (local hog plum) produces edible fruits that are popular with children. The leaves serve as good browse. The trees are used for fencing and in the construction of yam storage barns. Propagation is from seeds and buds.

Garcinia kola (bitter cola) is the source of edible seeds that serve as cola. The wood is used for chewing
sticks, utensils, and tools. Propagation is easy from seeds.

**Fruit and Food Trees for Outlying Farms in the Forest Zone**

The recommended species of trees for use in outlying farms in the forest area include Pentaclethra macrophylla, Canarium schweinfurthii, Myrianthus arboreus, Afzelia belle, Dialium guineense, Napoleona imperialis, Blighia sapida, and Raphia spp.

Although these species have edible fruits and vegetables, they are generally less important economically than are those suggested for compound farms and do not require as close protection. Some of them require tedious processing and fermentation (e.g., seeds of Pentaclethra macrophylla) before they can be eaten as food supplements. Perhaps their more significant role in agro-forestry is the supply of wood, farming materials such as stakes and mulch, and as natural fallow species for fertility restoration. For example, Dialium guineense and Napoleona imperialis are predominant in natural fallows in most parts of south-eastern Nigeria. They supply edible fruits as well as stakes, chewing sticks, and browse. P. macrophylla is a good source of firewood, stakes, and mulch. Leafy vegetables are obtained from Myrianthus arboreus and Afzelia belle variety belle (used after fermentation). Edible fruits are also obtained from Canarium schweinfurthii (eaten after being softened in hot water) and Blighia sapida, both of which are good sources of timber. Raphia spp. are of high economic importance, being a source of palm wine, stakes (poles), piassava, raffia, and mats for construction of farm huts. P. macrophylla and D. guineense are easy to germinate, and both can be propagated vegetatively from buds, with viable fruiting in 3.5 years. C schweinfurthii grows well over a wide range of sites, including poor ones.

**Fruit and Food Trees for Compound Farms in Derived Savanna Zone**

Few species suitable for agro-forestry are commonly observed around compound farms in the derived savanna: Adansonia digitata, Ceiba pentandra, Moringa oleifera, and Tamarindus indica are noteworthy. Edible vegetables are obtained from A. digitata, C. pentandra, and M. oleifera; the flowers end young pods of M. oleifera are also used as vegetables. Fruits of T. indica and A. digitata are edible and are used in the preparation of local drinks. The wood of M. oleifera is very useful on the farm as stakes and fence material. C. pentandra is a source of lumber, and its kapok is extensively used for stuffing of pillows and mattresses. Live C. pentandra fences commonly surround farms and compounds in the derived savanna. Leaves of all these species are extensively used as browse for domestic livestock. C pentandra and A. digitata can be planted from cuttings (Okafor 1980b).

**Fruit and Food Trees for Outlying Farms in the Derived Savanna Zone**

Most of the fruit and food trees suitable for outlying farms in the derived savanna fall into the categories of semi-wild and protected species in cultivated farmland. Few are cultivated. The selected species are Borassus aethiopium, Afzelia africana, Butyrospermum paradoxum, Parkia clappertoniana, Prosopis africana, Detarium microcarpum, Brachystegia eurycoma, Nauclea latifolia, Vitex doniana, and Ficus spp.

All these species are important sources of food (Okafor 1980b), ranging from staple items (e.g., moulded fruit pulp of P. clappertoniana), condiments (e.g., see P. clappertoniana, A. africana, P. africana, D. microcarpum, B. eurycoma), leafy vegetables (V. doniana, F. capensis), and edible fruits (B. paradoxum, B. aethiopium, and, marginally, M latifolia and F. capensis). Oil is extracted from the kernel of B. aethiopium and from B. paradoxum. In terms of supplying wood and wood products, such as timber and stakes, B. aethiopium is the most important. Browse material is obtained from P. clappertoniana and F. polite.

As reported by Okafor (1980a, b), it is possible to propagate vegetatively, from buds, A. africana, P. clappertoniana, P. africana, D. microcarpum, and V. doniana Most of the species, especially the legumes, enrich the soil with nitrogen through the bacterial root nodules as well as serving as "nutrient pumps," bringing up nutrients that have been leached to soil horizons deeper than the topsoil, and eventually releasing them in the form of leaf litter and decaying organic plant residues. Apart from their role in restoring soil fertility, the trees also provide much-needed shade. For instance, some farmers report that...
the performance of several crops is better around and under the shade of P. clappertoniana.

**Non-food Trees for Compound Farms in the Forest Zone**

Few non-food trees are retained in compound farms, but there are some that have widespread distribution for production of browse and supports for yam vines (Ricinodendron heudelotii and Newbouldia laevis). N. laevis is also used in yam storage barns, in boundaries and fences, and for religious purposes; leaves of Hymenodictyon pachyantha are used as wrappers and for water collection in some areas.

**Non-food Trees for Outlying Farms in the Forest Zone**

The non-food species considered suitable in outlying farms within the forest vegetation are Chlorophora excelsa, Berlinia grandiflora, Anthonotha macrophylla, Acioa barter), and Alchornea cordifolia. Their suitability for agro-forestry is based on their production of timber and structural materials (C. excelsa, B. grandiflora, A. barter)), stakes (A. barter), A. cordifolia), wrapping leaves (A. macrophylla, A. cordifolia, B. grandiflora), utensils (C. excelsa and A. barter)), tool handles (A. barter)), and browse (C. excelsa). Apart from C. excelsa, the species are predominant in natural fallow where they fulfill the important role of restoration of soil fertility. A. barter) and A. macrophylla are sometimes planted for this purpose.

**Non-food Trees in Compounds and Outlying Farms in the Derived Savanna**

The species that happen to be dominant in an area of the derived savanna and that satisfy the farmers needs for wood, stakes, browse, wrapping leaves, provision of shade, and restoration of soil fertility include Anogeissus lelocarpus, Daniellia oliveri, Albizia spp.-all of which yield fodder Erythrophleum suaveolens for utensils, and Uapaca spp. for firewood and supply of wrapping leaves.

**Discussion and Conclusions**

Trees are an integral part of the traditional farming system and the combined forestry and agricultural multiple land use in southern Nigeria. Food production has been combined (at least for the first two years) with the raising of timber trees, such as Gmelina, teak, and Terminalia, in taungya and agrisilvicultural systems in many part of southern Nigeria. Emphasis in such systems has been on wood production. The present concept of agro-forestry attempts to place equal emphasis on food production over the same piece of land, especially in fragile ecosystems (King 1979).

The use of fruit and food trees in providing both food and wood has been suggested by Okafor (1980c). Suitability of various species of fruit, food, and non-food species for agro-forestry depends not only on their isolated roles as sources of food and other useful products but also on their compatibility in mixtures with other crops, ability to withstand pruning and shade, and efficiency in restoring soil fertility. This last consideration calls for a detailed study of natural falls, which have remained the dominant feature and tool in fertility recovery in the traditional farming system. Such a study has recently been jointly initiated by FDIB and the International Institute of Tropical Agriculture (IITA) over a transect in south-eastern Nigeria; it aims at elucidating, among other things, the structure and specific composition of natural falls of different ages and cropping history, their soil fertility status, and relative efficiency of the dominant species in nutrient recycling and restoration of soil fertility. A comparative study of the effectiveness of different types and ages of fallow natural and planted-with respect to the restoration of soil fertility within the traditional farming system is also envisaged.

**Food crop yield under teak and cassia siamea in south-western Nigeria**

P.R.O. Kio, S.O. Bada, and D.U.U. Okali
Abstract

Maize yields on land that had borne plantations of teak and Cassia siamea of varying ages in south-western Nigeria were evaluated. Soils and standing crop biomass of the experimental plots differed between and within sites. Without the application of fertilizer, maize yields from the more humid sites with clayey soils tended to be higher than from other sites. There was indication that yields were greater on soils that had borne Cassia than on those that had carried teak. Fertilizer application has been recommended for successful agro-forestry practice on marginal soils. Improved maize yields were obtained in seasons after fertilizer application, with particularly heavy harvests in the season immediately following that in which fertilizers were applied. Management problems encountered in the study and the possible significance of the results are discussed.

Introduction

Existing forest plantations provide several advantages for investigation of problems that are likely to arise from the widespread adoption of agro-forestry. First, they give an indication of site productivity, as their ages are usually known and the standing crop biomass can be determined. Second, because their history is usually known, they provide an immediate means of assessing the effects of tree species, tree density, cultural practices, plantation age, and tree harvesting practices on sites. Third, they are available for investigation of methods of coppice-shoot management for successful intercropping with various food crop species. Many nearby communities have participated in their establishment and would welcome the opportunity to farm the plantation land again. Such communities can readily serve as a setting for undertaking studies of farmers' attitudes to the intercropping of trees with food crops on a long-term basis.

Besides these advantages for investigating problems of agro-forestry, forest plantations, together with plantations of cash crops such as cocoa, cola, citrus, oil palm, and rubber, cover a sizeable area of land in southern Nigeria (Allen 1981). This land is potentially available for the practice of agro-forestry, particularly as the plantations become due for felling and replanting. Although the major impact of agro-forestry is ultimately expected to be made through widespread adoption by smallholder farmers, the potential contribution of food from these larger plantations cannot be ignored.

Recognition of the contribution that can be made by studying existing plantations prompted us to undertake a pilot research project in 1977 on agro-forestry sponsored by the International Development Research Centre (IDRC). The plantations investigated were teak (Tectona grandis) and Cassia siamea.

Study Areas

The project sites were located in Gambari Forest Reserve, Alalubosa, and Eleiyele plantations, and Iwo and Ede forest areas. These study sites spanned the three major ecological zones of Oyo State but were restricted to an area within about 50 km of Ibadan. The main reason that the project was restricted to this area was the ease of accessibility from the University of Ibadan and, hence, the potential for adequate supervision. Gambari Forest Reserve is at the southernmost end of the area studied, and Iwo marks the northern end. Ede is on the north-eastern tip, Eleiyele plantations are a little northwest, and Alalubosa lies a little to the south-west. The part of Oyo State in which the sites are located is of uniform relief (though with some scattered inselbergs), consisting of a gently undulating plain on basement complex rocks.

Two plots in both Ede and Alalubosa carried stands of Cassia siamea while the remaining plots in Ede and Alalubosa, as well as all the plots in the other three study sites, carried only teak. The Cassia stands in Ede were established in 1935, whereas the teak plantations were established in 1960. In Alalubosa, the teak stands were planted in 1913 and 1925, and the Cassia in 1925. Much younger farms were examined in Gambari Forest Reserve and Iwo forest areas. The two farms in Gambari were Busogboro, established in 1967, and Onipe, established in 1968. At Iwo, one of the two plantations examined was established in 1960 and the other in 1963. All the tree crops were planted at an initial spacing of 1.83 m.
Data Collection

In each study area, a boundary survey of each plantation was carried out from which an area map was produced. Sample plots were selected from a table of random numbers. Usually plots that fell on marshy areas, hilltops, or rocks were rejected. Each experimental plot was 30 x 30 m with a 3 m border to protect against shading. The plots were clear-feiled, burned, and planted with maize at 30 cm along the row and 1.83 m between the rows. At Iwo, some of the plots were artificially fertilized because of the poor initial performance of the crops.

Soil sampling was undertaken early in each plot at 0-15 cm, 15-30 cm, and 30-45 cm. The samples were mixtures from a minimum of 16 auger points per plot. After soil analysis, the trees in the plots were tallied and measured for diameter at breast height (1.3 m) before being felled. Stems were burned, the larger ones being removed. Weeding and other tending operations were regularly carried out in all plots after the sowing of maize. The agronomic data collected included periodic maize plant height up to tasselling, leaf area, weight of maize cobs with and without sheath, grain yield, and plant dry weight at harvest. Maize grains were subsampled for nutrient analyses.

Results

Results of soil analyses have been published elsewhere (Kio and Bada 1981), as have figures on biomass accumulation and maize yield (Kio and Bada 1981). Briefly, Iwo soils are loamy sand with the percentage of sand in the topsoil (0-15 cm) often greater than 80 per cent. In contrast, Gambari soils are sandy loam, with relatively high clay values (10.8-18.8 per cent) in the top 0-15 cm; the silt values for the same depth range between 17.6 and 23.6 per cent. Alalubosa soils vary from sandy loam to loamy sand, although the soils in this area may have been sandy loam at the time of conversion from natural forest to plantations (between 1913 and 1925); because the Cassia plantations have been coppiced several times, the soil texture has tended towards loamy sand as a result of exposure, erosion, and disturbance (compaction) during past coppice extractions. Clay values generally increased with depth in all sites whereas sand decreased. In addition to receiving a higher annual rainfall with a relatively longer rainy season, Gambari soils had higher water-holding capacities.

Though variations in soil acidity between the three sites are not significant, Iwo soils were generally more acid (pH 6.57.6) than Gambari soils (pH 7.2-7.6) in the top 0-15 cm. Significant pH differences between Cassia and teak soils were not observed in Alalubosa.

Organic carbon and total nitrogen in the top 0-15 cm varied markedly between and within sites. For example, in the Gambari forest area, organic carbon for the 1967 plantation ranged from 0.95 per cent, whereas values of 1.39 and 1.50 per cent were obtained for the same depth (0-15 cm) in the 1968 plots. Equally large within-site variations were observed in plots of the same age at Iwo. The variations in organic carbon have resulted in similar differences in the carbonnitrogen (C:N) ratios for most plots. According to Kadeba (1976), a high C:N ratio is an indication of soil impoverishment often associated with grass cover. Higher C:N ratios were obtained for two plots in Gambari forest that were burned more regularly than two others in the same forest. In the Alalubosa forest area, the mean organic carbon in the Cassia plot was 1.0 per cent, and values of 1.50 and 2.41 per cent were obtained for the plots that carried teak. The mean C:N ratio for the teak plots was 6.9, whereas the value for Cassia was 6.0 (0-15 cm).

Like organic carbon, available macronutrients varied greatly within and between plantations as a result of past cultural practices, the tree species, and soil properties. In Alalubosa, teak soils had a mean value of 3.69,ug/g of available phosphorus with a range of 2.58-4.80,ug/g; calcium was 1,050-1,545,ug/g; and potassium was between 105 and 210,ug/g. Cassia soils had the lowest mean values of available phosphorus (3.30 ug/g) and calcium (660 ug/g). Generally, low values of available phosphorus and manganese were observed in Gambari soils, though a clear pattern of nutrient variability according to age could not be established. The highest values of the extractable cations were in a single plot; these values were Ca (1,800 ug/g), Mg (122 ug/g), Mg (122, ug/g), Mg (122,ug/g), and K (90 ug/g).

In Iwo, the mean available P was 5.10,ug/g (3.6-6.6,ug/g); Ca was 1,648,ug/g (1,455-1,830,ug/g). Higher
K values were recorded in Iwo soils because the shallow, less-weathered soils have higher total exchangeable potassium ratios than deeper, more-weathered soils such as those in Gambari. Better tree growth could still occur in Gambari than in Iwo because the high ratio of total potassium may be an indication of potassium reserves within the soil and not an indication of the amount of potassium available for plant growth (Akin 1979).

The biomass estimated for the young (1968) teak plantation was greater than that for the older plantations at Gambari. Whereas the two plots in the 1968 farm had mean standing crop values of 213 t/ha and 219 t/ha, plots planted in 1967 had values of 131 t/ha and 204 t/ha respectively. Similarly, in Iwo forest area, the highest biomass value per hectare was recorded in one of the young (1963) plots, although the situation was not as clear-cut as in Gambari.

The two Iwo plots planted in 1963 had mean biomass values of 162 t/ha and 52 t/ha, whereas those planted in 1960 had values of 95 t/ha and 50 t/ha. Biomass mean annual increments also varied between the plantations and may be a reflection of soil differences and previous cultural practices.

The maize yields that can be most meaningfully compared are those for 1979 before fertilizer was applied to plots in Iwo and Ede. During this season, maize yield was generally higher in the moister Gambari plots (520-1,217 kg/ha). The maize in Cassia plots in Ede showed some initial promise but was subsequently destroyed in particular by livestock and also by rodents. One plot under teak in Ede failed completely as a result of soil impoverishment as well as severe rodent attacks. Pest attacks occurred in all the plantations. The crops in Gambari were destroyed by antelope and primates, whereas those in Iwo were attacked by grasscutters and other wildlife. No direct and consistent relationship could be established between plantation age and maize yield, though some of the older plots gave greater yield than others. For example, in Gambari one plot planted in 1967 gave the highest yield (1,217 kg/ha), whereas another plot with similar history and the same soil type produced the lowest yield (520 kg/ha). Maize yields in Iwo and Ede areas were tremendously increased by fertilizer application. Though fertilizers were applied only once (during the 1979 late maize season), the residual effects on maize yield in the cropping season that immediately followed were very great. Of all the sites, the 1935 Cassia plot in Ede produced the highest maize yield of 4,279 kg/ha. Furthermore, the Cassia plots consistently performed better than teak plots in Ede forest area. In Gambari forest, where fertilizers were not applied, there was a general decline in maize yield from one crop to the next.

Some Management Problems

During the course of the studies, a number of problems were encountered. One was the timing of the planting of maize. Late planting can result in losses of almost 50 per cent. There was also the problem of pests: maize plants were attacked by pests of various types. In some sites, rodents such as grasscutters and rabbits constantly cut back the maize shoots, and others were attacked by antelope and other game. In Ede (Cassia plots) in particular, the plots were heavily damaged by livestock that regularly fed on the green maize plants. In Gambari Forest Reserve, various primates not only attacked the green plants but constantly fed on the ears before they matured. Climatic cycles posed equally serious problems to maize production. Crop yield was greatly reduced by delayed or unsteady rainfall because the plots were not irrigated. In addition, excessive rainfall (as occurred in September 1980 around Ibadan), destroyed many farms by washing away the maize plants.

Conclusions

The findings suggest some basic conclusions:

1. Though the soils in all the study sites had been broadly classified as Iwo Association, it was observed that the Gambari soils were slightly sandy to clayey loam, whereas soils in the drier Iwo and Ede were loamy sand. This difference by implication conferred an advantage of higher water-holding capacities and higher fertility on the Gambari soils.

2. Higher total potassium was obtained in the Iwo soils. However, available potassium was probably much lower in Iwo than in the moister Gambari soils.
3. Cassia soils were consistently more productive than soils under teak stands in Ede forest areas, even though the Cassia plantations were much older than the teak and had also been coppiced several times before the initiation of our studies.

4. Improved maize yields were obtained in Iwo and Ede during subsequent seasons after fertilizer application, with particularly heavy harvests being recorded in the season immediately following that in which fertilizers were applied. On marginal soils, fertilizer applications in agro-forestry operations must be considered inevitable.

5. Careful attention must be paid to local agronomic practices in surrounding non-forest tree fallows when developing agro-forestry practices involving first and subsequent tree crop rotations.

Agro-forestry possibilities in oil palm plantations in the Ivory coast

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Abstract

Cocoa, coffee, banana, Hevea, coconut palm, and oil palm are important industrial crops in the Ivory Coast, and, although they are usually monocultures, some of these are traditionally grown together in a taungya system. In tropical forest zones the need for food crops, on the one hand, and the shortage of protein, on the other, have tended to encourage consideration of complementary uses of large forest plantations. In particular, use of the adventitious vegetation in oil palm plantations as forage for cattle is being considered as well as the introduction of food and cash crops among the trees. Palatable species have been identified in the vegetation, and some crops, such as cocoa, offer promise as intercrops.

Introduction

The oil palm (Elaeis guineensis Jacq.) is an African tree native to the Gulf of Guinea. Its distribution in West Africa extends from Senegal to Angola, where the natural populations have always been exploited by the native people for many purposes, including food, handicrafts, pharmaceuticals, and religious uses.

In the Ivory Coast, palm groves establish themselves naturally in the traditional plantations of cocoa (Theabroma cacao L.) or coffee (Coffee spp.) and constitute a very valuable by-product. They also grow among food crops as a result of the exploitation and development work of humans and dissemination by numerous animals partial to the palm's fruits and seeds (monkeys, rodents, and birds).

Industrial plantations of oil palm were first developed in 1920-1926 by the Union Tropicale des Plantations (UTP) and the Societe des Plantations et Hulleries de Bingerville (SPHB). Cultivation of the oil palm, however, experienced its greatest growth in the Ivory Coast after the Institut de Recherche pour les Huiles et Oleagineux (lRHO) developed a very productive hybrid form—the tenera—by crossing aura and pisifera. In fact, until 1964, before the creation of the Societe d'Etat pour le Developpement du Palmier a Huile (SODEPALM), industrial palm groves occupied only 10,000 ha. By the end of 1966, SODEPALM had planted almost 19,000 ha, and oil palm plantations occupied a total of nearly 30,000 ha. By 1970 this area had increased to 76,000 ha, and in 1980 it reached 100,000 ha.

In view of such growth, optimal use of the land occupied by these palm groves has attracted considerable interest. Economically feasible ways of intensifying the use of these areas could occur either by grouping the palms with other crops (industrial crops such as coffee and cocoa, or food crops such as cassava and maize), or by growing feed for cattle. Two stations were selected to study the adventitious vegetation; one, belonging to the Societe des Plantations et Huileries de Bingerville (SPHB), is located on sandy soil in the Bingerville region, and the other, belonging to the Institut de Recherche pour les Huiles et Oleagineux (I RHO), is located on clayey soil in the La Me region.
The Vegetation

The forests of the Ivory Coast belong to the humid, tropical region of Africa, and the climate can be classified as subequatorial; from the viewpoint of plant geography, they belong to the Guinea-Congo forest massif. The original vegetation is a dense, ombrophilous, evergreen forest, which contains a number of tree savannas and grassy lagoon savannas: the Adiake, Moossou, Bingerville, Dabou, and Grand-Lahou savannas. The industrial palm groves are found on three types of soil: sandy; more compact clayey-sandy; and compact, essentially clayey (which retains a great deal of water).

The two stations selected for study were originally covered by very distinct types of vegetation. The Bingerville station is situated in the heart of the dense, psammohygrophilous evergreen forest dominated by Turraeanthus africanus and Heisteria parvifolia (Mangenot 1954). In addition, one sees here and there some expanses of savanna consisting of Brachiaria brachylopha and Anadelphia africana (Adjanohoun 1962). The La Me region belongs to the dense, pelohygrophilous evergreen forest consisting of Mapania spp. and Diospyros spp. (Mangenot 1954).

The adventitious vegetation consists of various plants distributed in the following proportions: phanerophytes (56.5 per cent), therophytes (17.9 per cent), and chamaephytes (14.5 per cent). Hemicryptophytes are rare (17.4 per cent), and geophytes are negligible (3.7 per cent).

The vegetation beneath the palms is varied. Its most striking aspects are: its vitality-phanerophyte and chamaephyte vegetation that is always green; flowering and fruiting limited to a few herbaceous plants; its floristic composition, both heterogeneous and uniform depending on whether one considers isolated plots or the whole plantation area; and its gregariousness, which frequently allows local enrichment of the flora with a particular species-this is a characteristic that is most marked for certain herbaceous and ligneous species that propagate by means of suckers. Clusters of the following species have been observed: Dissotis rotundifolia; Aspilia africana; Melanthera scandens; Eupatorium odoratum; Thaumatococcus danielli; Axonopus compressus; Commelina nudiflora, C. forskalasi, C. africana, and C. condensate; Imperata cylindrica; Rottboellia exaltata; Nephrolepis biserrata; Pteridium aquilinum; Anchomanes diffomis; Acroceras zizanioides; Paspalum scrobiculatum var. commersonii and P. conjugatum; Panicum repens and P. brevifolium; Sporobolus pyramidalis; Borrelia latifolia; Diodia rubricosa and D. scandens; Eleusine indica; Mariscus umbellatus and M. flabelliformis, often mixed with Cyperus sphaelatus; Palisota hirsute; Asystasia gangetica; Selaginella myosurus; Scleria barter) and S. naumanniana; and Setaria megaphylla and S. chevalieri.

The distribution of these numerous clusters is related to farming operations-clearing the land, ploughing, and so forth-that cause either abnormal concentrations of a given species at certain points, or their dispersion over the whole cultivated area. Local ecological conditions may also come into play and favour the growth of certain plants.

Possibilities for Agro-forestry

Oil Palm with Cattle

Phytosociological, floristic, and agrostological studies were conducted to assess the suitability of palm groves for cattle raising. These led to the identification of species having a high forage value by virtue of their palatability, biomass, and position in stable and profitable associations. The most important species are:

- Axonopus compressus and Paspalum conjugatum (photograph no. 7);
- Eleusine indica and Sporobolus pyramidalis;
- Asystasia gangetica and Commelina spp. (C. nudiflora, C. forskalasi, C. benghalensis, etc.); and
- Diodia rubricosa and Desmodium adscendens.

From attempts to assess the biomass and regeneration of the vegetation within various associations, it appears that for young plantations (one to seven years old) the often large amount of vegetable matter per
unit area (nearly 100 tons/ha in certain cases) diminishes considerably with increasing age. Likewise, the regrowth of the vegetation, vigorous at first, becomes practically nil when the canopy closes. The vegetation within palm groves that are from eight to eighteen years old is increasingly sparse and poor (photograph no. 6). It grows back progressively with the clearing of the woodland vault after the eighteenth year.

Many factors other than age affect the composition and physiognomy of the vegetation under oil palms; among these are human activities, climate, and the degree and type of herbivory.

**Oil Palm with Crops**

In the Ivory Coast it is possible to consider cultivation of the oil palm in association with other industrial crops such as Hevea, coffee, and cocoa. Many studies have already been undertaken of the palm-cocoa association. There are two main reasons for favouring this combination:

- In traditional plantations a large population of oil palms is heavily exploited, yet the development of cocoa does not seem to be inhibited; and
- Reputed to be a shade-loving plant, cocoa should be able to thrive in the understorey of the palm groves.

In the traditional village plantations the oil palm-cocoa association constitutes a viable system, as the oil palms are not being planted by the farmer but simply maintained at a certain density. However, experience has shown that the same is not true of industrial plantations, where the density is calculated for maximum yield and becomes an obstacle to the proper development of the cocoa. In fact, the hybrid cocoa plants that are now common are more heliophilous than sciaphilous. In addition, the size of the palm roots in the soil is such that, despite the differences between the two root systems, the cocoa grows poorly and may perish (photographs 8 and 10).

Any food crop can be grown in the spaces between the rows of a young plantation (photograph no. 11). None can be grown in the palm groves when the crowns meet. The only precaution to be taken is to ensure adequate control of species whose remains after the harvest can develop into quickly spreading weeds and inhibit, to a considerable extent and for a long time, the young palms. This is the case, for example, with cassava (Manihot utilissima) (photograph no. 9). Once the canopy closes, the only spaces that can be developed for food crops are those that have been cleared by natural decay or where, for some particular reason, there is an absence of palms.

**Conclusion**

Cattle raising in the palm groves, although possible in terms of available palatable plant species, is worthwhile only on a large scale, and, even then, it would require bringing in a substantial quantity of additional feed. This is especially true for the older plantations, where regeneration of the vegetation is very slow and difficult. With regard to associated crops, only species whose lifetime is at most seven to ten years can be cultivated without special measures in existing plantations. In existing industrial palm groves profitable associations with other perennial crops are not possible for purely ecological reasons.
Effect of food crops on tree growth in Tanzania

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Abstract

Village afforestation must meet the needs of farmers for quick tangible returns. The growth of food crops among trees appears to be a promising incentive. Research to ascertain appropriate species and mixtures, and appropriate espacements and rotations to maximize production, are described.

Good food crop yields are obtained in the first year of intercropping but fall off in the second and subsequent years with trees at close espacement. Wider tree espacement is likely to prolong useful food cropping. Trees intercropped with food crops show growth as good, or nearly as good, as trees grown under clean-weeded conditions and much superior growth to trees raised under spot-weeded or unweeded conditions.

It is recommended that similar trials be established for various tree and food crops over a range of ecological sites. These will serve also as valuable demonstration plots.

Introduction

King and Chandler (1978) emphasize that the term agro-forestry may be applied to a wide spectrum of land-use combinations. These range from taungya (or agrisilviculture) to the selective use of trees as shelterbelts in a predominantly agricultural system.

Many traditional farming systems already include the permanent cultivation of a balanced mixture of tree species and agricultural crops. The trees often provide an immediate economic return in terms of direct products in addition to the indirect benefits of improving the ecological conditions for the food crops and animals.

Examples in high rainfall areas are the integrated farming systems developed in Latin America, where Cordia alliodora and Cedrela odorata are grown over lemon, bananas, and plantains, which are in turn underplanted with coffee, or the Kandy spice gardens of Sri Lanka, where tree crops such as nutmeg, cloves, and jackfruit are underplanted with coffee, bananas, pepper, and vegetables (cf. the paper by Watson in this volume, pp. 6-12). In Africa a good example is the land use on the slopes of Mount Kilimanjaro, where coffee, bananas, and annual food crops are intermixed with timber trees such as Grevillea robusta.

Trees have also been combined with a more limited agricultural cropping programme. For example, the taungya system was designed primarily for the establishment of permanent timber crops. It was most successful in areas where there was a shortage of good agricultural land. King (1968) expresses concern that the peasant labour involved is exploited because the forest services benefit from their efforts and pay no remuneration. However, it is noteworthy that despite dilution with the tree crop, per hectare yields to the farmers are higher than on land available to them outside the reserves. In fact, Hofstad (1978) has calculated that in north-eastern Tanzania the value of the food crops grown under the taungya system may far outweigh the discounted value of the subsequent tree crops.

Peasant farmers in all countries are naturally conservative: change usually involves risk, and they are unwilling to undertake change without convincing evidence of guaranteed personal financial or material advantages. They have very limited capital reserves to sustain them; thus, change should provide immediate, or short-term, returns. Furthermore, peasant farmers belong to closely integrated communities that are economically interdependent. Suggested changes should benefit the whole community and cause minimal disruption to existing social structures and customary practices.

The "felt needs" of a rural community are for a sustainable system of land management that will produce acceptable food for people and animals, maintain fertility and water balance, and provide a renewable source of firewood and building poles within walking distance of the village. A successful agro-forestry system for a farming community must meet specific needs in these areas, must provide obvious short-term personal advantages for the farmer, and, as far as possible, should be consistent with local traditional working habits and patterns of family labour.

Intercropping of selected tree species and agricultural crops may be competitive or collaborative. Traditional systems have developed over time to select effective mixtures; development of new systems will require research into many factors, including appropriate species and mixtures, and appropriate spacings and rotations to maximize production.

The Division of Forestry at Morogoro, Tanzania, is currently initiating research to assess the effects and productivity of intercropping selected tree species with staple food crops over an extended period.
Agro-forestry Research at Morogoro, Tanzania

The rainfall at Morogoro is about 800 mm a year, falling mainly between March and May, but sometimes with a substantial amount in November. Unfortunately for the farmer it is very unpredictable in its regularity. Although Morogoro does not lie within the humid tropics, the research being carried out is of wider application. The investigations are simple in design, the field work is easy to carry out and applicable over a wide range of ecological conditions. Very important also, this type of trial gives quick interim results that can be easily seen and understood.

Trials of Eucalyptus melliodora with Different Crops

The layout of the trial and early results have been previously described by Maghembe and Redhead (1981). Container-grown Eucalyptus melliodora were planted in February 1978 in farmland that had been ploughed and harrowed. The tree seedlings were planted at a spacing of 2.5 x 2.5 m and intercropped with maize, sorghum, and beans, which were planted at 90 x 30 cm, 60 x 15 cm, and 40 x 20 cm, respectively. The same three crops were planted again in 1979 and 1980. Yields of maize and beans were recorded; sorghum was not harvested as the crop was eaten by birds. Both weed-free and unweeded plots of E melliodora were also grown as controls. No fertilizers were used, and the experiment was arranged as a latin square. Each plot contained 5 x 5 trees, and the central core of 3 x 3 trees was periodically measured. The area was clear-felled in March 1981, and the leaf litter and standing biomass assessed. The same food crops were sown again so that yields along with coppice could be ascertained.

The yield of maize was 1,280 kg/ha in the first year and 100 kg/ha in the second year. In the third year it did not flower. Sorghum followed a similar pattern, although yields were not recorded. At 2.5 x 2.5 m spacings, the trees were too close to permit sufficient light for maize and sorghum to grow after the first year. The yields of beans for the three years were poor; in the first year, when good yields were expected, the crop was badly attacked by an unidentified fungus. In the second year the beans appeared healthy but the yield was only 150 kg/ha. In the third year the beans were etiolated and the yield was insignificant. At the time of the first harvest, the mean height of the Eucalyptus in unweeded plots was significantly lower than Eucalyptus in intercropped or weed-free treatments, in which heights did not differ significantly. The trees in the beans and clean-weeded plots were noticeably more robust and more heavily branched than the trees among maize and sorghum, which were spindly due to competition for light (figs. 1-2). Survival of the trees has been approximately 90 per cent, except in the unweeded plots, where half died during the first two years.

FIG. 1. Mean Height of Eucalyptus melliodora Intercropped with Maize, Sorghum, and Beans, Compared with Clean-Weeded and Unweeded Trees, Morogoro, Tanzania

FIG. 2. Volume of Eucalyptus melliodora Intercropped with Maize, Sorghum, and Beans, Compared with Clean-Weeded and Unweeded Trees, Morogoro, Tanzania

At three years of age, the stand has yielded more than 1,000 poles/ha suitable for house building and more than 6 m³/ha of fuelwood. The mean size of trees grown among beans is not significantly different from that of those grown in weed-free plots, and the trees intercropped with maize and sorghum are two-thirds the size of clean-weeded trees. The maize and sorghum yield would clearly make up in value for the reduced volume of the tree crop.

It was apparent from this trial that normal yields of agricultural crops could be expected in the first year with little effect on the tree crop in the case of Eucalyptus melliodora, but for food production in subsequent years wider spacing of the trees is necessary.

Trials of Trees at Different Spacings with Crops

It was primarily to determine how far apart the trees could be and still produce an acceptable volume of firewood or appropriately shaped poles that a series of more elaborate long-term investigations was laid down in 1980. Another objective was to test tree species that would provide both fuel and fodder. Four trials were established: (1) Eucalyptus camaldulensis (planted for fuel and pole production) with maize and beans; (2) Acacia albida (planted for fodder and fuel production) with maize and beans; (3) Leucaena leucocephala (planted for fuel production) with maize and beans; (4) Leucaena leucocephala (planted for fodder production) with maize and beans.

The layout of these investigations has been described by Maghembe and Redhead (1981). Briefly, tree seedlings were container-grown and planted in ploughed and harrowed land. Each investigation has a split-plot layout with food crops (maize or beans) and weeding treatments (spot-weeded or clean-weeded) forming the main plots, and tree spacings forming the sub-plots. The maize was planted at 75 cm x 30 cm, leaving a circle of 50 cm radius around each tree; fertilizer was applied at a rate of 400 kg/ha ammonium sulphate and 200 kg/ha triple superphosphate, in two applications. The beans were planted at 40 cm x 20 cm, leaving a circle of 20 cm radius around each tree seedling; fertilizer was applied at a rate of 200 kg/ha ammonium sulphate and 200 kg/ha triple ammonium phosphate, with the former applied when the beans were well established. Clean weeding was done by harrow, supplemented by hoeing; no fertilizer was applied in these plots. Spotweeding was done by hoe in a circle of 50 cm radius around each tree, as in normal Tanzanian forestry practice; no fertilizer was applied. This main-plot treatment was omitted from trials 2 and 4.
With regard to the spacing, trials 1 and 3 had sub-plots with trees at 3 x 3 m, 4 x 4 m, and 5 x 5 m, respectively. In trial 2, the 3 x 3 m spacing was replaced by a 6 x 6 m spacing in order to maximize fodder production. Similarly, in trial 4, the Leucaena leucocephala was planted in rows 3, 4, 5, and 6 m apart to maximize fodder production. Trees within rows were only one metre apart. In all four trials sub-plots without trees were planted as controls.

Long term soil studies are in progress so that soil under Eucalyptus, Acacia, and Leucaena can be compared with soil under fallow and under pure food crops. The nitrogen-fixing activity of the Acacia and Leucaena is being measured with a portable gas-liquid chromatograph.

The trees in all investigations were too young to have had a marked effect on the maize and bean yields during the first cropping season apart from the space they occupied. Differences are expected to show up from the second year onwards, when the canopy starts to close. Unfortunately, the yield of maize and beans was normal in only one set of plots combining Leucaena. In this case, the mean yield of maize was 1,645 kg/ha, which compares favourably with yields obtained on the university farm and is over twice the national average in Tanzania of 670 kg/ha (Acland 1971). The mean yield of beans was 401 kg/ha, an average yield by peasant standards (Acland 1971).

In the other investigations the planting time and tasselling time of maize coincided with a severe drought, and growth yields were very poor and uneven. The drought caused great variation in the interaction between the food and tree crops and masked the significance of the results.

In contrast with the little effect the trees had on the food crops, the maize in particular has had a marked effect on the trees because it is a tall crop casting considerable shade (figs. 3-6). In all investigations, at the time of maize harvest, the trees among maize were taller than those in other treatments-24 per cent taller in both stands of Leucaena and 20 per cent taller in the Eucalyptus. The height differences were statistically highly significant except in the Acacia plots, where the maize-grown trees were only 13 per cent taller. After harvest, the clean-weeded trees grew best, and in all cases their height surpassed that of trees in other treatments by the end of the year. The spot-weeded treatment has proved much inferior to the other treatments, as the trees are only two-thirds of the height of clean-weeded trees and approximately 20 per cent less in height than trees intercropped with either maize or beans. These growth trends are emphasized even more by the differences in root-collar diameter (fig. 7).

**FIG. 3. Mean Height of One-Year-Old Eucalyptus camaldulensis Intercropped with Maize and Beans Compared with E. camaldulensis Grown CleanWeeded and Spot-Weeded, Morogoro, Tanzania. The vertical bars indicate differences significant at P = 0.05; N.S. indicates differences not significant at P = 0.05.**

**FIG. 4 Mean Height of One-Year-Old Acacia albida Intercropped with Maize and Beans Compared with Clean-Weeded A. albida. The vertical bar indicates a difference significant at P = 0.05; N.S. indicates differences not significant.**

**FIG. 5. Mean Height of One-Year-Old Leucaena leucocephala Grown for Fuel and Intercropped with Maize and Beans Compared with That of L. leucocephala Grown Clean-Weeded and Spot-Weeded. The vertical bars indicate differences significant at P = 0.05.**

**FIG. 6. Mean Height of One-Year-Old Leucaena leucocephala Grown for Fodder and Intercropped with Maize and Beans Compared with That of L. leucocephala Grown Clean-Weeded. The vertical bars indicate differences significant at P = 0.05; N.S. indicates differences not significant.**

**FIG. 7. Mean Root-Collar Area of One-Year-Old Trees Intercropped with Maize and Beans Compared with That of Clean-Weeded and Spot-Weeded Trees, Morogoro, Tanzania. The vertical bars indicate differences significant at P = 0.05; N.S. indicates differences not significant.**

**Discussion**

The results demonstrate that good food yields can be obtained, at least during the first year of intercropping with trees. The trees benefit more from the weeding associated with growing food crops than they do from the Tanzanian standard practice of spot weeding. Moreover, spot weeding allows a dense growth of grass to grow in the intervening spaces, and this is a serious fire hazard. Clean weeding gives the best growth, but it is not realistic to expect this in community afforestation projects.

It will be interesting to monitor the subsequent yields of food crops at the wider tree spacings. If a valuable pole and fuel crop is nearing harvest by the time food yields drop seriously, agro-forestry in this form could become a standard practice in community afforestation projects. Should tree intercropping prove beneficial in improving soil fertility, this will have great significance for areas where a shortage of land precludes a long natural fallow.

It is suggested that trials of similar design be established for a range of tree and food crops over varied ecological sites in tropical Africa. These will serve as valuable demonstrations and at the same time yield useful data for afforestation.
Selection of leguminous trees for agro-forestry in Cameroon

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Abstract

From 1977 to 1981 the Institute of Agronomic Research (IRA), through its Centre for Forestry Research in Edea, Cameroon, conducted a project with the objectives of: identifying the climatic and ecological factors of Edea (from literature, meteorological services, and soil analyses); studying the farming systems and the utilization of forest products in the dense humid forest zone (through farmer surveys and observations); and selecting leguminous forest species of agronomic and forestry interest (through elimination trials). The soil analysis confirmed that the soil is nutrient-poor. The study of farming systems showed that, in Edea, the peasant farmers cultivate 0.5-4.2 ha and that collective farming is atypical. Furthermore, the farming system is essentially a shifting agriculture involving a fallow of three to seven years. Mixed cropping is common, and the farming practices involve very simple technology (cutlasses, hoes, and fire). Land used by the community is often subject to erosion. Finally, the peasant population thrives principally on cassava, taro (Colocasia esculenta), maca (Xanthosoma sagittifolium), yams, sweet potatoes, bananas, and plantains. Also planted are maize, groundnuts, and beans. The forest trees associated with traditional farming systems were found, as in the case of the humid forest zone of Western Nigeria (Getabun 1980), to be Leucaena leucocephala, which is planted on cocoa and coffee farms as a shade tree, and Treculia africana, Irvingia gabonensis, Dacryodes edulis, Samanea (Pithecolobium) saman, Cassia siamea, and Pterocarpus soyauxii. Tree elimination trials led to a preliminary selection (made on the basis of mean height growth attained after 18 months), in order of descending importance, of Albizia falcataria, Samanea saman, Albizia lebbeck, Leucaena leucocephala, and Pterocarpus soyauxii as suitable for use in subsequent experiments in Edea because of their potential for yam-supports, shade trees, improvement of soil, and pulp production - a matter of prime importance to CELLUCAM, the pulp manufacturing company established in Edea.

Introduction

The importance of agro-forestry research as a tool to improve agricultural production, and therefore the standard of living of the people, in the humid tropical zone was brought home to the research sector (the National Office for Scientific and Technical Research at the time) in the United Republic of Cameroon in 1976 by the International Development Research Center (IDRC). This importance was stated to lie in the possibility that research could formulate agro-forestry systems to replace the shifting agriculture that is prevalent in many humid tropical zones. In particular, agro-forestry systems promised that the use of trees-especially leguminous forest trees- to replace the bush fallows could ensure the improvement of the soil and, at the same time, provide forest produce that could yield revenue to the peasant farmers.

An agro-forestry project was, thus, conceived and agreed upon by IDRC and the United Republic of Cameroon in 1976. The first phase of the project was to last three years (i.e., until April 1980), but in fact it did not end until March 1981. This was due, in large part, to the delay in purchasing the project vehicles.

Objectives

The objectives defined for the project were: to identify the climatic and ecological factors of Edea, which is located in the dense humid forest zone of Littoral Province; to study the farming systems and the utilization of forest products in this zone; to select leguminous forest species that would be of agronomic and silvicultural interest in the zone being studied and to determine the propagation techniques for such species; and to establish experimental plantations with the object of studying the effects of leguminous species on soil impoverished by shifting cultivation.

Methods

The study of climatic and ecological factors was carried out partly through a review of existing literature, partly through contact with the meteorological services at Edea, and partly through analysis, in the soils laboratory at Ekona, of soil samples taken from the principal soil types of Mangombe, Edea. With regard to the latter, six samples of upland, sandy soil (30 cores were bulked to yield a sample) from Mangombe (under forest, under food crops, and under fallow) were taken and analysed in the laboratory at Ekona. Again, in May 1978, 15 samples were taken at different depths under natural secondary forest, food crops, five-year old fallows, and leguminous forest species (Afzelia pachyloba, Piptadeniastrium africanum).* The soil studies of May 1978 were repeated in May 1979 to cover the upland as well as the other two subtypes of Mangombe, i.e., gravelly and hydromorphic soils.

The study of farming systems was essentially an exercise in enumeration. Randomly selected peasant farmers were asked to address themselves to standard questionnaires on their farming activities. These data were supplemented by the inspection and measurement of the farms owned by the farmers. Difficulties were encountered by the lack of a suitable researcher to undertake a detailed socio-economic study of Edea and its environs. In the study of the utilization of forest products in
traditional farming, staff observed and recorded the species of the shade trees planted in traditional cocoa and coffee farms and the multipurpose trees found in the permanent compound farms.

The selection of leguminous forest species of interest for agro-forestry was made in elimination trials that were aimed at identifying local or exotic species that would thrive in the ecological conditions of Edea. A search was undertaken for mature leguminous seed bearers at Edea and at Kumba, while seeds of exotic leguminous species were acquired from various individuals and forestry research institutions. The availability of seeds and problems in germinating certain species severely limited the scope of the elimination trials.

The first elimination trial was planted in August 1978 and covered 2 ha. It involved leguminous species from only eight seed lots; five of the seed lots were planted according to a statistical design (complete randomized blocks, five treatments, four replications) at a spacing of 4 x 4 m in plots measuring 40 x 25 m (66-70 plants/plot). The remaining three seed lots, because of seed shortage, were simply planted in unreplicated plots. The seed lots planted in the 1978 trial were: Pterocarpus soyauxii, P. osun, Afzelia pachyloba, Acacia sp., Tetrapleura tetraptera, and three lots of Leucaena leucocephala.

The 1979 elimination trial involved 23 seed lots that were sown between February and April 1979 and planted out in July 1979. The plantings were made in an area slightly less than 2 ha. As a result of the low germination rates for many of the seed lots, planting was not carried out according to a strict statistical design. Still the principle of replication was maintained, with 23 plots in each block corresponding to the different seed lots. The spacing was 3 x 2 m, but, as a consequence of the limited planting material, two sizes were adopted for unit plots: small plots (each measuring 36 m²) and large plots (each measuring 72 m²). There were 21 plants per large plot, whereas the number of plants in each small plot ranged from one to nine. The 23 seed lots included one of the seed lots (Tetrapleura tetraptera) employed in the 1978 trials.

The site preparation for both the 1978 and 1979 trials consisted of felling the big trees, clearing the underbrush, burning, staking, and hole digging. The planting stock for the 1978 trial consisted of striplings, wildings, and stumps. For the 1979 trial, however, only seedlings raised in polythene pots were used.

Results

Climatic and Ecological Factors

Mangombe (in Edea) is at latitude 4°00'N and longitude 10°15'E. Its altitude is 32 m above sea level. The mean annual rainfall is 2,600 mm. The rainfall distribution is generally regular, there being some rainfall even in the dry season (November-April). The temperatures are high; the mean monthly maximum and minimum temperatures were 27.8°C and 23.2°C, respectively, in 1978.

According to a study carried out by CTFT (1969), there are three distinct soil types in Mangombe:

- Sandy solis, situated on the uplands, which are deep, stone-free and suitable for plantations; these soils cover about 60 per cent of the area;
- Gravelly soils, situated on the slopes, with lateritic gravel or quartz or altered rock (mica schist or gneiss); these are unsuitable for plantations and cover about 30 per cent of the area; and
- Hydromorphic soils, situated on valley bottoms, often gravelly, frequently moisture-laden in the vicinity of water courses; these soils are also unsuitable for plantations and cover about 10 per cent of the area. The field work carried out by our forestry research centre confirmed these results.

Laboratory analysis showed that the upland (sandy) soils were acidic (pH 4) and varied little between the two depths 1020 cm, 40-60 cm). In general the physical properties were quite good. Soil water was well distributed except during heavy rainfall; clay particles were 35-40 per cent under forest, 45 per cent under food crops, and 37-40 per cent under fallow. There was a good distribution of the fine and heavy particles, and stones were absent.

Soil chemical properties were poor, probably because of heavy leaching. According to the 1977 analysis total nitrogen showed a tendency to increase with depth, from 0.09-0.14 per cent and 0.09-0.13 per cent, respectively, for soils under forest and under food crops. The sum of exchangeable bases was, on the whole, low, as was available phosphorus. In the 1978 study the content of organic matter decreased with depth in sharp contrast to the trend exhibited in the 1977 samples. Nitrogen also decreased with depth in the 1978 samples (i.e., from 0.1 per cent at the surface to 0.06 per cent at 110 cm depth). The contrasting results on organic matter and nitrogen levels in 1977 as compared with 1978 are confusing unless the 1977 result is erroneous. This possibility is supported by results from the May 1979 samples.

Soils under leguminous forest species (Afzelia pachyloba and Piptadeniastrum africanum) exhibited slightly higher amounts of organic matter (1.51-1.22 per cent at 0-40 cm) than was found in soils under forest, food crops, and fallow.

Farming Systems

The farmers in and around Edea have holdings of about 0.54.2 ha. Farming on a collective basis is rather rare, although there is one example, the Groupe des Agriculteurs Modernes supported by FONADER (Fonds National de Developpement...
Rural; often referred to as the farmers' bank).

The farming system is essentially a shifting agriculture involving a fallow period of three to seven years. Mixed cropping is common, and the cultural practices of field preparation are partial or complete clearing and burning, making such land subject to erosion.

The peasant population depends principally on cassava, taro (Colocasia esculenta), macabo (Xanthosoma sagittifolium), yams, sweet potatoes, bananas, and plantains. Maize, groundnuts, and beans are also planted. The two principal industrial crops of Littoral Province are robusta coffee and cocoa. The Sanaga-Maritime Division (Edea) is third among the divisions of Littoral Province for the production of both coffee and cocoa. Rubber and oil palms are also found as industrial crops in Sanaga-Maritime Division.

The forest trees associated with traditional farming systems were found, as in the case of the humid forest zone of western Nigeria (Getahun 1980), to be Leucaena leucocephala, which is planted in cocoa and coffee farms as a shade tree, and Treculia africana, Irvingia gabonensis, Daecyodes edulis, Samanea saman, Cassia siamea, and Pterocarpus soyauxii, which are multipurpose trees present in permanent compound farms.

Selection of Leguminous Forest Species

Mean height was the only measurement taken after 18 months in the elimination trials. No statistical analysis was undertaken to determine whether or not the difference between the mean heights for any selected pair of seed lots was significant. Nevertheless, the results (table 1) seemed to justify some conclusions:

- *Albizia falcataria* (which recorded 9.1 m) grew significantly faster than any of the other species, with the next species in height performance (*Samanea saman*) attaining only 5.5 m;
- There seems to have been little difference among the *Leucaena leucocephala* provenances from Hawaii; they showed a height growth ranging from 4.2 m (for K132) to 4.4 m (for K6); and
- *Piptadeniastum africanaum* and *Acacia eburnea* exhibited the slowest growth rates (1.32 and 1.15 m respectively).

Conclusion and Recommendations

From the work carried out by the agro-forestry project, it seems that the leguminous species *Albizia falcataria*, *Samanea saman*, A. Iebeck, *Leucaena leucocephala*, and *Pterocarpus soyauxi* should be provisionally selected as trees that will thrive in the humid zone of Edea. It is immensely important to the future of the agro-forestry research project in Edea that the majority of the species selected from our elimination trials were found to exhibit a great natural capacity for nodulation. *L. leucocephala* is the only species likely to be used in our future work that did not appear to nodulate in our experiment either in the nursery or in the field. These aspects are worthy of further investigation. Given the potential of these selected leguminous species for soil improvement, use as shade trees, and pulp production, they should be given first consideration in the choice of species to be used for the establishment of experimental plantations.

In view of the great role that is likely to be played by CELLUCAM in the socio-economic development of Edea in the near future, the choice of species to be used for the establishment of the experimental plantations should also include pulp species (e.g., *Pinus caribaea*, *Eucalyptus urophylla*, *Gmelina arborea*) which have been chosen for use in the next five-year reforestation programme of CELLUCAM.

The specific objectives for the experimental plantations should include:

- Study of the effect of tree plantations on the restoration of soil fertility in soils depleted by farming;
- Study of the effect of spacing on the production of wood and food crops; and
- A preliminary inventory of the tree-insect/fungus/virus associations so that tree species which act as hosts to the pests of agricultural crops in the Edea region can be identified.

Acknowledgement

Immense thanks are due Patrick Shiembo, the agro-forestry research assistant at Edea, for kindly accepting to carry out the final measurements of the 1979 elimination trial.

**TABLE 1. List of Seedlots Sown in 1979: Their Germination, and Height (m) at 18 Months**

<table>
<thead>
<tr>
<th>Species</th>
<th>Date Sown</th>
<th>Date of Germination</th>
<th>No. Sown</th>
<th>No. Germinated</th>
<th>Mean Ht. (m) at 18 months</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abrus precatorius</td>
<td>13/2/79</td>
<td>17/2/79</td>
<td>22</td>
<td>3</td>
<td>(creeper)</td>
</tr>
<tr>
<td>Acacia eburnea</td>
<td>13/2/79</td>
<td>17/12/79</td>
<td>24</td>
<td>14</td>
<td>3.36</td>
</tr>
<tr>
<td>Adenanthera pavonina</td>
<td>13/2/79</td>
<td>17/2/79</td>
<td>18</td>
<td>4</td>
<td>0.48</td>
</tr>
<tr>
<td>Species</td>
<td>Date Planted</td>
<td>Date Harvested</td>
<td>Weight 1</td>
<td>Weight 2</td>
<td>Seed</td>
</tr>
<tr>
<td>----------------------</td>
<td>---------------</td>
<td>----------------</td>
<td>----------</td>
<td>----------</td>
<td>-------</td>
</tr>
<tr>
<td>Albizia falcataria</td>
<td>13/2/79</td>
<td>17/2/79</td>
<td>700</td>
<td>690</td>
<td>9.1</td>
</tr>
<tr>
<td>A. lebbeck</td>
<td>13/2/79</td>
<td>20/2/79</td>
<td>500</td>
<td>4</td>
<td>5.0</td>
</tr>
<tr>
<td>A. procera</td>
<td>13/2/79</td>
<td>17/2/79</td>
<td>600</td>
<td>593</td>
<td>2.54</td>
</tr>
<tr>
<td>A. saponaria</td>
<td>13/2/79</td>
<td>17/2/79</td>
<td>45</td>
<td>1</td>
<td>3.51</td>
</tr>
<tr>
<td>C. surinamensis</td>
<td>13/2/79</td>
<td>17/2/79</td>
<td>48</td>
<td>32</td>
<td>2.6</td>
</tr>
<tr>
<td>Cassia alata</td>
<td>13/2/79</td>
<td>17/2/79</td>
<td>200</td>
<td>3</td>
<td>(died)</td>
</tr>
<tr>
<td>C. mimosoides</td>
<td>13/2/79</td>
<td>17/2/79</td>
<td>600</td>
<td>10</td>
<td>(weed sp.)</td>
</tr>
<tr>
<td>Dalbergia retusa</td>
<td>23/4/79</td>
<td>30/4/79</td>
<td>696</td>
<td>650</td>
<td>3.0</td>
</tr>
<tr>
<td>Ervthrophleum suaveolens</td>
<td>13/2/79</td>
<td>18/2/79</td>
<td>13</td>
<td>9</td>
<td>3.3</td>
</tr>
<tr>
<td>Leucaena leucocephala (K6)</td>
<td>23/2/79</td>
<td>28/2/79</td>
<td>150</td>
<td>149</td>
<td>4.42</td>
</tr>
<tr>
<td>L. leucocephala (K8)</td>
<td>23/2/79</td>
<td>28/2/79</td>
<td>150</td>
<td>150</td>
<td>4.33</td>
</tr>
<tr>
<td>L. leucocephala (K67)</td>
<td>23/2/79</td>
<td>28/2/79</td>
<td>150</td>
<td>148</td>
<td>4.32</td>
</tr>
<tr>
<td>L. leucocephale (K132)</td>
<td>23/2/79</td>
<td>28/2/79</td>
<td>150</td>
<td>147</td>
<td>4.26</td>
</tr>
<tr>
<td>Leucaena sp. (Stat Cruz Porrillo)</td>
<td>14/2/79</td>
<td>21/2/79</td>
<td>22</td>
<td>22</td>
<td>2.0</td>
</tr>
<tr>
<td>Piptadeniastrum africanum</td>
<td>14/2/79</td>
<td>22/2/79</td>
<td>500</td>
<td>480</td>
<td>1.32</td>
</tr>
<tr>
<td>Samanea saman</td>
<td>23/4/79</td>
<td>30/4/79</td>
<td>854</td>
<td>800</td>
<td>5.52</td>
</tr>
<tr>
<td>Tetrapleura tetraptera</td>
<td>14/2/79</td>
<td>22/2/79</td>
<td>500</td>
<td>480</td>
<td>1.51</td>
</tr>
</tbody>
</table>
Forestry aspects of agro-forestry practice in Nigeria

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Abstract

There is an increasing demand for land for various uses, all of which have to be satisfied. Agro-forestry, which is defined as the integration of agriculture, forestry, and animal husbandry on the same land, appears to offer a solution to the problem of land shortage. It is also a potential solution to the demandsupply crisis for forest products. Analysis indicates that the remaining pockets of high forest in Nigeria will be exhausted by 1995, but demand will keep rising. The demand for more land for farming can be met by further encouraging the taungya system in areas earmarked for plantation establishment. The use of a plantation fallow as part of the shifting cultivation cycle is recommended, as it considerably increases the area of land available for planting tree crops and discourages dereservation.

Introduction

The concept of multiple use of the land is becoming more widely accepted because of the increasing demands on the land for agriculture, forestry, industrial development, urban settlement, and recreation. This is especially true of countries that depend heavily on the produce from the land to support their economy. The land area is fixed in relation to the increasing demand on it. The tendency, therefore, is to seek ways of utilizing the available land area efficiently to the benefit of various land users.

Land constantly put under crops loses its fertility. The fertility is, however, restored if the land is left fallow from five to ten years. As a result of increasing pressure on the land due to the rising population, the fallow period has been reduced to three or four years or even less. The land, therefore, does not always have enough time to replenish its fertility. Lands under forest cover are fertile and have become targets by farmers for farming. Foresters are reluctant to release forest lands for farming because the land available for forestry activities is equally limited. This is the general picture in most countries in Africa.

Agro-forestry Systems

Agro-forestry is a land management technique which, according to Combe and Budowski (1979), implies the combination of forest trees with crops or with domestic animals, or both. The aim of agro-forestry with respect to agriculture is to increase crop yields; with respect to silviculture (forestry), to give emphasis to the forest; with respect to pasture land, to manage grazing (Dosne 1979). It appears, therefore, that agro-forestry offers a solution to the problem posed by the high demand on the land. The object of this paper is to examine the whole issue of agro-forestry practice vis-a-vis the extent to which it has satisfied the forestry component, particularly in Nigeria. Furthermore, suggestions are made on how to achieve maximum results in the forestry sector by taking advantage of the opportunities offered by agro-forestry.

A comprehensive review of agro-forestry systems is provided by Combe and Budowski (1979). The review provides a classification scheme by types of agricultural output, functions of the forestry component, and distribution in time and space. The first covers the type of agricultural products combined with forest, namely farm crops, animals, or both crops and animals. The second indicates the principal objectives of the tree component in a non-forest environment-production, protection, or services. The third relates to the rotation of both the agricultural and forestry crops as well as the spatial distribution of the species.

Agro-forestry may be practiced either within or outside forest reserves. Within forest reserves, the object is to establish plantations of selected species to replace the natural understorey. The emphasis here is on
the production of tree crops while satisfying the demand of farmers for fertile land, i.e., the taungya system. According to King (1968), the taungya system results in the establishment of plantations that do not demand heavy investments. It offers a solution to the problem of shifting cultivation and reconciles the often conflicting interests of the tropical foresters and farmers.

When agro-forestry is practiced in agricultural lands outside forest reserves, the principal object is food crop production. Tree crops play only a secondary, though important, role.

If the trees used are legumes or other species able to fix nitrogen, there is an increase in soil fertility. Forest crops may be raised with both food crops and farm animals. Trees are planted for fodder, shade, or as live fences.

Nigeria's Forest Resource

At the beginning of this century, the high forest in Nigeria was very extensive and rich in large trees. With the increase in human population, the area of the high forest started to diminish as a result of demand on forest land for farming and other forms of land use. Gradually, all the forests disappeared except those in reserved areas. In 1978, the total area of reserved forest was 20,443 km², excluding both the freshwater swamp and mangrove forest, which amounted to a total of 778 km² (FAO 1979). The bulk of usable timber for industrial purposes comes from the reserves of the moist tropical forest. In a study carried out on the silviculture and management of the high forest zone of Nigeria, and using the results of the indicative inventory of the reserve high forests, FAO (1976b) reported that the total area of forest reserves in Ogun, Oyo, Ondo, Bendel, Kwara, Anambra, Imo, Cross River and Rivers states was 2,549,523 ha. Of these, 128,053 ha were plantations, 608,545 ha were unproductive, and 1,766,290 ha were potentially available for production. Later (FAO 1979), this information was supplemented by a study of the overall production system of the Nigerian forestry sector. The findings were that felling of existing natural forest over a 20-year period ranged from 436,000 ha to 1.4 million ha and the rate of plantation establishment in the moist lowland forest zone was 15,000 ha/year between 1975 and 1980, with a projected increase to 20,000 ha/year by 19901995. Together, these data indicate that the remaining natural forests of Nigeria will be exhausted by 1995 if demand follows the high forecast.

Nigeria is committed to supplying the raw material for two pulp mills, each requiring 100,000 tons annually. Only the large-scale establishment of pulpwood plantations will ensure the constant supply of this raw material.

Accompanying this mounting pressure to increase productivity from the forest areas is the competing demand for forest lands by agriculture, industrialization, urban development, etc. Quite often the political climate and the desires of politicians determine the success of resistance to dereservation. Most government functionaries favour agriculture over forestry because of the faster rate of returns (not necessarily higher rate of returns) from planted stock.

On the other hand, FAO (1978b) states that no country should completely liquidate that part of its natural heritage represented by the flora of the high forest and the habitat provided for indigenous fauna. It has, therefore, recommended that an area of 1 per cent of the high forest be reserved in perpetuity. At present, Nigeria has no such reserve, and the high forest is being clear-felled at a staggering rate.

Recommendations

The current practice of plantation establishment by taungya should continue, as it reduces the dangers to monoculture at the early stage of plantation establishment. FAO (1979) has, for instance, recommended that combinations of agriculture with plantation establishment should be encouraged and expanded, and, in particular, that the traditional taungya scheme be encouraged while other forms of agrisilviculture are being developed. More emphasis should be given to the production of food and trees in forest reserves.

The area of land available to forestry could be considerably increased if fallow areas-as part of the shifting cultivation cycle-were used for tree plantations. It is estimated that 3 million ha of such land is readily
available in the moist forest zone (FAO 1979). The amount of plantation trees available could also be increased if incentives were provided for private and commercial forestry operations in areas outside forest reserves.

**Summary of discussion: Current agro-forestry activities**

Since the papers presented covered a wide variety of ideas and techniques, the discussion also touched on a number of topics, many of which had been discussed previously but in a different context. In particular, a number of comments on plant-plant interactions were made, and these again served to emphasize the need for further research and observations. Great care must be taken when interpreting results, and an example was cited where the tending had had a greater effect on the maize yield than the presence or absence of a tree crop. In another example the growth of Gmelina arborea was found to vary according to the annual crop, but this could have been due to the different weeding practices for maize and cassava rather than the type of crop. Cassava, in particular, was noted to be weed-tolerant and to have a negative effect on tree crops when planted too close. In short, management provides yet another set of variables that must be examined when evaluating agro-forestry practices.

Experience with intercropping Terminalia superba with cocoa, coffee, and banana was found to be relatively similar in Gabon, Congo, and Sierra Leone. Cocoa performance under T. superba in the Congo was particularly poor after 20 years because of excessive shading. As in Sierra Leone, both the overstorey timber crop and the understorey tree crop will be clear-felled after 40 years.

The better performance of food crops under former teak (Tectona grandis) plantations as compared to Cassia siamea stimulated much discussion. A number of factors were mentioned which could have caused this result, and these included the nitrogen-fixing ability of Cassia, the faster breakdown of Cassia leaves as compared to teak leaves, the relative abundance of ground fires in teak plantations, and the fact that the Cassia had been coppiced several times, a management operation which leads to more herbaceous growth, higher levels of soil organic matter, and greater soil aeration.

The successful introduction of improved varieties in southern Nigeria was further expounded upon. The basic technique used was to graft adult buds of fruiting trees on to young stock, and this led to early fruiting at reduced heights. At present the work is concentrating on native species, and the demand from the local people for improved material exceeds supply. Since the new varieties are intended for use in combination with other food crops, there is no substitution of fruit products for essential food crops. It was noted that relatively few crops have been successfully introduced, but since agro-forestry aims at sustainability rather than high, short-term yields, it may prove to be a more successful vehicle for introducing new crops or varieties. In the case of Rwanda, the dissemination of agro-forestry techniques to the local farmers was simplified by the fact that they were required to work on demonstration plots in each community. In this way they were exposed to new techniques and new crops, and over time many of the farmers adopted these.

In response to questions on the role of animals and forage species in agro-forestry systems in the humid tropics, one speaker noted that pasture and browse species could play an important role in reducing erosion and fires, but this depended on proper management and species selection. In the case of erosion one must maintain a sufficiently dense groundcover under the forest canopy and control grazing accordingly. The possibility of competition between browse and forage species was raised, but at least in the case of Gliricidia sepium this was not felt to be a problem, probably because of its relatively deep rooting habits. The use of leguminous species for browse was also discussed, with particular attention to the question of toxicity. In general it was felt that the problem could be avoided by including the protein-rich legume with a variety of other feeds; specific tolerance levels had to be set for each animal with regard to each leguminous species. Toxicity can also be reduced by processing and plant breeding, and location is still another important variable.
In noting the high loss through volatilization of certain nutrients, particularly nitrogen when Leucaena cuttings are used as mulch, it was suggested that crop residues and other plant material might best be fed to ruminants. This would allow more efficient use of nitrogen and perhaps the organic matter as well.
Considerations for the future development of agro-forestry

Agro-forestry production systems: Putting them into action

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Abstract

The paper views agro-forestry as a production system deriving from the combination of people's needs and resource situations. It suggests that implementation of agro-forestry as a development strategy must advance from current experimentation and demonstration efforts to full-scale project activity. It argues that while considerable research endeavour and support have been applied to define the big-physical dimensions of agro-forestry systems, other parts have been overlooked. These are the institutional, administrative, political, and socio-economic circumstances that will ultimately provide the framework for an agro-forestry production system. In order to understand this framework and react to it, local implementation must begin; a threshold for takeoff in agro-forestry has clearly been reached.

The paper elaborates the component parts of an agro-forestry production system. At the core of implementation are government policy decisions and a recognition of agro-forestry as a land-use alternative. What is needed are short-, medium and long-term goals and programmes. To assist the decisionmakers, an expanded, diversified information base will be necessary. In defining the needs and wishes of the rural populations, people's participation and organization cannot be over-emphasized. To carry out the programme at the field project level, administrative integration leading to co-operation and co-ordination among government agencies will be required. Enabling legislation and regulations are necessary. Financial resources to carry out plans and programmes must be secured. Appropriate education and training for staff, organized in an effective extension programme, are required. Where peasants are being asked to take risks with their tenuous hold on economic stability, incentives, guarantees, and subsidies should be considered.

Some characteristics of an agro-forestry techniques package are also discussed in general terms. Economic analysis of agro-forestry projects under field conditions is of vital importance. Such analysis must be carried out with due regard to opportunity costs to be incurred for socioeconomic destabilization and environmental degradation.

In a final section the paper briefly reviews the activities of FAO's Forestry Department in the field of agro-forestry. Regular programme and gild programme activities as well as the trust-fund financed Forestry for Local Community Development Programme are highlighted.

Introduction

Agro-forestry, as the name indicates, combines agriculture and forestry within a farming or production system. As a land-use formula, it owes its origin to the diverse needs of the farmer and the natural resources available to him, as these cannot be reconciled solely by traditional open-furrow food crop...
production schemes. The aims include improvement of the standard of living of subsistence farmers through more productive use of land and tree resources, and replacement of production schemes that hinder rather than enhance soil and water conservation.

This latter focus, particularly as it applies to shifting agriculture, holds broad promise for the future. The challenge is not to obliterate shifting cultivation as a practice or ban it from the extensive forest areas in which it is now practiced but, rather, to develop sustainable land-use systems that supply people's needs for food and other basic necessities while maintaining critical environmental stability. The potential of agro-forestry is most apparent in upland watershed areas where shifting cultivation is destroying forest cover. The effects are felt well beyond the confines of the frugal homestead of the rural poor who must cut and burn the forest to produce their food. Downstream, agricultural development schemes as well as hydroelectric projects may be threatened by unstable water supplies and heavy siltation. In the past, efforts were made to turn shifting cultivators out of the critical forest watersheds; some programmes attempted resettlement elsewhere. The scarcity of suitable land for resettlement and the socio-cultural unacceptability of many such programmes have led policy-makers to consider settlement in situ a viable possibility if the cultivators' production schemes not only meet their basic needs but also conserve soil and water resources.

Agro-forestry as a development formula may fulfill these requirements. Its potential for meeting basic needs is great. Strict adherence to the dichotomy between agricultural and forestry lands has meant, for example, that wood-poor areas have been created throughout the world. In many arid lands remnants of tree cover have been decimated and cannot supply local needs for rural energy, i.e., fuelwood and charcoal. Agro forestry can solve the fuelwood problem, and the trees may provide environmental amelioration and subsequent support to agriculture, for example, by providing a windbreak that slows evaporation of field moisture. Trees add organic matter, through litterfall, to the soil and may, in providing firewood, allow valuable agricultural wastes and manure to be returned to the system as fertilizer. While strengthening the relatively fragile ecosystem of the arid lands on which agriculture depends, it may also help meet fodder needs, provide rural building materials, and supply raw material for forest-based local industries (as in the case of gum arabic).

Considerable attention has been devoted to assembling information about, or identifying the biological combinations of, trees and crops essential to developing appropriate land-use alternatives. The time has come to add the other necessary dimensions that will enable agro-forestry to take its rightful place as a viable production system.

Agro-forestry - Its Component Parts

The components of a legitimate agro-forestry production system are found well beyond the boundaries of the fields where the earth is ploughed and the seeds sown. They include governments which must adopt the policy and the will to support agro-forestry schemes. Government programmes currently focus on forest exploitation or agricultural colonization in the humid tropics. The forests, however, have often been exploited in a destructive way and their continued productivity as foreseen in management plans (the sustained-yield concept) is unrealistic. Tropical forest ecosystems are not sufficiently understood, and selective timber exploitation contrasts sharply with the diversity within these forests. Land clearing for agricultural purposes in colonization schemes in the humid tropics has rarely meant more than institutionalized subsistence farming, poverty, and shifting cultivation. Government policy must seek to achieve appropriate forestry and agricultural schemes whose basic axiom is the stewardship of the land and its resources.

A government policy for integration of agriculture and forestry must clearly recognize that agro-forestry is an alternative in land-use planning. Land-use planning that categorizes land as capable of supporting either agriculture or forestry must be reevaluated. Re-evaluation is important in the lowland humid tropics where the capability of the fragile soils would classify them as suitable only for forest cover, while more and more forest land is cleared for agriculture. In the upland catchment areas of the tropics, sloping lands are routinely described as forestry lands despite the practical disappearance of all but the last vestiges of
the forest cover. A clearer understanding of the role of trees and forest cover can lead to land-use planning that allows for the careful balance required to meet food, fuel, fodder, and agricultural needs. An innovative approach to land-use planning that takes account of agro-forestry can reconcile the needs of the local people with society's need for environmental stability measures such as erosion control, watershed protection, and halting of desertification. At present, attempts to introduce stability are scattered and are unlikely to reach a critical mass before rehabilitation, rather than land management, becomes the only course of action.

For the practical application of land-use planning, the information base available to decision-makers will have to be expanded. Traditional data bases such as forest inventories and soil maps need to be complemented with more precise information on the demographic pressure in target areas, current use patterns, rate of alienation of forest land, as well as on the rural people's practices, needs, and aspirations. Land-use planning must take into account the people who use the land. There is no better way to discuss people's needs than to ask them; similarly, the best way to achieve a useful dialogue is to involve people so that they can help to structure efficient systems for the delivery of technical and support services. The World Conference on Agrarian Reform and Rural Development called for development agencies to encourage rural people's participation and organization in efforts to promote a self-reliant rural population. People are at the core of agro-forestry, and only by involving them from planning through implementation can government agencies, especially the forest services, hope to meet the needs of what may potentially be their largest client group.

The government agencies involved in promoting agro-forestry must co-ordinate their activities. The agriculture-forestry dichotomy, which can trace its origins to legislative articles enacted years ago, is a major obstacle to agro-forestry schemes. For example, some rural people practicing agriculture on forestry lands are disqualified from the technical and support services they require to undertake agro-forestry. In other cases shifting cultivation is summarily dismissed in laws and is targeted for eradication rather than amelioration. Such laws are counter-productive and need to be replaced by enabling legislation for agro-forestry. As a first step, countries can examine existing legislation with a view to determining whether it impedes or promotes the practice (cf. the paper by Adeyoju in this volume, pp. 17-21).

If agriculture and forestry are seen as competitive land-use alternatives, the government agencies responsible for them are often also competing. An affirmative government policy to pursue agro-forestry development must overcome these difficulties if it is to succeed. Furthermore, as a step toward integrated rural development, agro-forestry promotion may also involve, in addition to the agriculture and forestry agencies, such others as the planning ministry, the agrarian reform authorities, the agricultural/forestry research institutes, the agricultural credit institutions, etc. All these institutions, where appropriate, must be drawn into a holistic approach to implement agro-forestry beyond the demonstration and experimental activities now ongoing in many countries. Coordination and co-operation must extend through the ranks, especially down to the extension officer, so that competition for the interest and meagre resources of the peasant clientele can be avoided. Espousing agro-forestry as a development policy means that financial resources to carry out plans and programmes must be secured.

Perhaps the greatest inroads that can be made in overcoming the agriculture-forestry dichotomy can be made by universities and training centres. At present, foresters and agriculturalists are trained with little or no awareness of the potential of agro-forestry or their possible involvement in it. At the university level, support for agro-forestry through curriculum changes should reflect government policy decisions, field activities, and current research findings. Appropriate training is most important for technical personnel who, because their training is often more practical than theoretical, find greatest difficulty and probably greatest occasion to respond to requests outside the defined spectrum of their roles. For graduating generalists, either foresters or agronomists, an overview of agro-forestry may be sufficient. For specific programme implementation, community level extension officers should undergo more explicit training concerning the programme they will ultimately be expected to deliver, including a clear introduction to the place of agro-forestry in national rural development schemes, their individual role in that effort and the role of others, and the technical and support packages to be applied.
Although well-trained staff are fundamental to the success of agro-forestry promotion schemes, their work must also be carefully organized in an extension programme. This point is emphasized because all too often well-conceptualized technical programmes are not able to bridge the communications gap existing between government services and the rural poor. Shifting cultivators or other disenfranchised groups are unlikely to accept that from one day to the next their antagonists—those who were clearly trying to drive them out of the forest—have now become their benefactors; an extension programme designed to achieve two-way dialogue and people's participation can help. The basic philosophy of an extension programme should be to educate rather than to reform. Programme objectives must be well defined and these conveyed to, and understood by, the rural people involved; the need for participation and a two-way dialogue cannot be overemphasized. The key to a functional programme is well-trained and motivated staff who understand their responsibilities to their rural clients. The socio-cultural context of agro-forestry in the local community should be taken into account. Programmes should aim not to disrupt the peasant's tenuous hold on economic stability, or where this is a risk, guarantees, incentives, and subsidies should be provided. The education elements of a programme should be backstopped by appropriate demonstrations.

Putting together a package of agro-forestry techniques for dissemination to rural people should begin with a review of the actual practices of the people. Radical change may be necessary, but, where it seems warranted, other constraints to rural development may be operating and should be investigated. Agro-forestry is not a panacea; other problems such as inequitable land distribution, disorganized distribution and marketing systems, lack of rural infrastructure, and larger national development issues cannot simply be set aside. The local community structure and the economics of an area must not be taken for granted. Short-, medium-, and long-term goals for programme development and implementation are necessary, and these should reflect the needs and potential for continued improvement of the standard of living of the people involved. An agro-forestry package should be complemented by tropical forest management systems so that the full capacity of a forestry and agriculture land-use mosaic can be realized. Distribution and marketing systems for the agricultural and forestry products are also necessary if peasant practitioners are to rise above subsistence level undertakings.

Data on costs and returns for agro-forestry activities are still lacking and are needed as a basis for calculations of internal rate of return, elaboration of credit schemes in support of agro-forestry, and projection of large-scale investments, whether these be national or international. Preliminary figures are encouraging, particularly when viewed in light of the opportunity costs, such as economic destabilization of large numbers of the rural poor, and environmental degradation with its downstream effects. More data on peasant economic activities in the tropical forests, such as fuelwood consumption, basic wood products use, unimproved agricultural production, and minor forest products supply and demand, is necessary to complete the economic analysis of agro-forestry projects which is fundamental to large-scale implementation.

**FAO Support to Agro-forestry**

Although intricately related and mutually supportive, FAO's activities in agro-forestry can be divided into two categories: regular programme work—essentially that carried out by and through headquarters—and field programme activities or country projects executed by FAO under a range of external and internal funding sources.

**Regular Programme**

Agro-forestry has long received support under the regular programme of the FAO Forestry Department. Indeed, in the early sessions of the FAO Committee on Forestry Development in the Tropics (1967 and 1969), the potential of agro-forestry systems to ameliorate shifting cultivation was cited. In the late 1970s, agrosilviculture and forestry for community development were adopted as subjects for concerted sub-programmes under the Forestry Department's regular programme. These sub-programmes were part of a larger effort to consolidate a programme of forestry for local community development in the Department, of which agro-forestry is an important component. The decision to strengthen work in this area of forestry has been taken in recognition of the very important role that forestry can play in
alleviating the condition of the rural poor in developing countries. More than 1,500 million people depend upon wood for fuel with which to cook their daily food. Hundreds of millions of people live in the forest and depend upon it for food itself. Properly managed, forests can meet many basic needs, can enhance income and well-being, and can help maintain the environmental conditions necessary for continued production of crops and livestock.

During the 1978-1979 biennium emphasis was placed on developing a sound information base on forestry for rural community development for future work, and on disseminating this information. Two publications, "Forestry for Local Community Development" and "Forestry for Rural Communities," were issued, the latter in three languages and the former in four languages, including Arabic. A recent stocktaking exercise revealed that more than 14,000 copies of these two documents have been distributed worldwide. Three seminars, for Spanish-, English-, and French-speaking countries respectively, were held to increase intercountry exchange of experience and information. Agro-forestry was a prominent theme in all these undertakings. More specific studies analysing the technical, economic, and social factors responsible for successful existing agrosilvopastoral systems were initiated for selected systems in South Asia and Central Africa; the reports are now with FAO. Agro-forestry experiences were highlighted in study tours carried out for developing country foresters in Asia and Latin America.

In late 1979, a large-scale FAO/SIDA (Swedish International Development Agency) Trust Fund programme, Forestry for Local Community Development, became operational. The programme, expected to last five years, is designed to assist countries to stimulate community forestry development through small-scale project activities of a catalytic nature. Three categories of activity are foreseen: small-scale, quick-action field projects to initiate or strengthen larger-scale projects or programmes; seminars, workshops, and training courses to accelerate the transfer of knowledge about community forestry; and support for FAO's work in developing reference and teaching materials for use in the field and in training sessions. The types of field activity that could be supported through the programme include:

- Establishing farm or village tree plantations in wood-poor areas dependent on wood fuels for cooking and on poles and timber to meet local fencing and building needs;
- Developing stable joint tree-crop, tree-pastoral, or tree-crop-pastoral systems to permit agricultural production and animal husbandry in areas that must be kept primarily under forest in order to prevent unacceptable environmental deterioration;
- Establishing shelterbelts, soil conservation structures, dune stabilization, and other measures needed to rehabilitate or upgrade land for crop or animal production;
- Encouraging local involvement in harvesting and processing forest products;
- Promoting income earnings from smallholder production and sale of wood and other products; and
- Improving the socio-physical and economic situation of people living in the forests, or otherwise dependent on the forests, and providing assistance in managing those forests for renewable use.

Requests for assistance under the programme have now been received from more than 35 countries, and to date 22 projects have been approved and are in operation.

In addition to documentation, seminars, study tours, and field projects carried out in conjunction with the programme, information dissemination and supporting activities are being undertaken. These include:

- Detailed case histories of successful community forestry programmes to provide a comprehensive published source of information about them; three studies are underway and more are planned;
- Preparation of a document on guidelines for assessing local energy needs and wood fuel supply and use possibilities;
- A series of pamphlets on tree species that provide both food and fuel has been prepared and is being printed;
- Filmstrips for use in extension work in upland and arid areas are being produced, and more are planned;
- Guidelines for charcoal production by local artisans are being prepared;
- A review of forestry legislation and its effect on forestry for rural community development is being
carried out;
- A forestry extension manual is being written; and
- A short publication providing guidelines on assessing the impact of forestry projects on rural women is under preparation.

The FAO/SIDA Forestry for Local Community Development Programme is to continue for a number of years. Field projects, information dissemination, and supporting activities will continue to be developed, and agro-forestry will remain an important component of the programme.

During the biennium 1980-1981, Forestry for Rural Development was elevated to full programme status in recognition of the importance accorded by the World Conference on Agrarian Reform and Rural Development to the diversification of rural economic activities, including integrated forestry development. The programme objective has been to develop and strengthen forestry and forest based activities that contribute to sound rural development and to meeting the needs of the rural poor.

Although considerable attention has been devoted to the problems of an institutional nature that circumscribe forestry for rural development activities, agro-forestry has maintained its prominence. The most pertinent element of the programme is a long-term study on the production of food from the forest. Tropical land-use planning is the subject of a manual now being prepared. In addition, considerable effort has been devoted to wildlife utilization and the management of wildlife resources at the village level, thereby expanding the horizons of forestry support to rural development. Much of the regular programme resources for agro-forestry is being channelled into support of the large-scale trust fund activities.

Planning of the programme and budget for the biennium 1982-1983 reflects the continued focus on forestry for rural development and agro-forestry. Programme objectives clearly demonstrate FAO's broad approach to these important development directions. These include:

- Identification and development of community level systems that enable rural people to best meet those of their needs that are based on forest outputs;
- Strengthening of government and nongovernment institutions that support and service forestry activities for rural community development; and
- Establishment of land-use systems that integrate trees and agriculture in a manner that is both environmentally sound and optimally productive for rural people.

A preliminary outline of the plan of action for this biennium focused on the systems approach being adopted by the FAO Forestry Department for promoting community forestry. Work will continue on identifying effective systems for forestry at the community level. The case studies of successful community forestry experiences will be extended, and the process of comparative analysis initiated to clarify principles and requisites for success. Earlier work on project planning will be extended to develop guidelines for design and implementation of community forestry projects. These guidelines will be supported by case studies. Case studies will also be undertaken as part of the work to develop guidelines for strengthening the role of village, tribal, and other rural institutions in forestry activities. The participation of rural people in self-help forestry projects will be strengthened through further work on incentives and extension. Two workshops on incentives will be held in Africa and Asia for managers of upland conservation projects. Films and filmstrips on fuelwood production and small-scale wood-based industries will be produced for use by extension workers. Artisanal activities based on the forest will be encouraged through preparation of guidelines on production, processing, and marketing of oleoresins, and through a study to assemble information on the role of medicinal plants in Africa and Latin America.

A sub-programme for agrosilvopastoral development calls for joint forestry and agricultural land-use practices that are both environmentally sound and of direct productive benefit to rural people. The development of better land-use planning practices will also be promoted. A study will be carried out to assemble all experience in Africa with systems to replace shifting cultivation practices so that these can be improved. Models of agro-forestry production systems that embody conservation practices will be developed and tested in pilot areas. Guidelines for new approaches to silvapastoral management in arid
areas will also be developed. Extension aids will be prepared for programmes to integrate trees into dryland agriculture. Reports on forest trees that provide food will be published.

Field Programme

FAO's extensive field programme—being carried out in the form of projects in developing countries—contains many examples of agro-forestry. At present, there are 22 FAO/UNDP- and 11 WFPO- (World Food Programme) assisted projects engaged, partly or wholly, in agro-forestry development. What follows are highlights that should illustrate the field programme.

In Thailand, the pilot demonstration watershed of the Mae Sa Integrated Watershed Management and Forest Land Use Project (THA 76/001) combines agro-forestry, soil conservation engineering, rural extension, and improved agricultural practices as a training and demonstration activity of broad relevance to much of the northern part of the country. In the Philippines, the Multiple Use Forest Management Project (PHI 77/011) has a strong agro-forestry component to improve small farmer cultivation practices in upland watershed areas; the aim is to promote fruit, coffee, and fodder crop species in combination with erosion control measures. In Honduras, a recently completed FAO Project on Integrated Watershed Management (HON 77/006) devoted considerable attention to tree cropping in combination with agriculture on the sites released from traditional agriculture. Several watersheds were involved, including one in which over-exploitation of hillsides through traditional open-furrow bean and corn crops combined with a hurricane to provoke disastrous flooding with subsequent loss of life and property. Forest protection through plantations of cashew along the compartment lines in the Forest Protection and Development Project in Casamance, Senegal (SEN 78/002) provides local villages with food, income from cashew nut sales, and impedes uncontrolled forest burning. The Community Forestry Development Project in Nepal (NEP 80/030) is planting trees specifically to meet the demands for forest produce of the local people and thereby contain widespread deforestation and erosion. The species have been selected to provide fruit, nuts, animal fodder, fuelwood, and rural construction materials. In Morocco, FAO is executing a project designed to promote community development through silvopastoral management. In Haiti, agro-forestry plays an important role in the Limbe Watershed Protection and Management Project (HAI 77/005) because of the high population pressure and need for food production in this essentially mountainous area. In Upper Volta, an FAO forestry resources development project (UPV 78/004) is carrying out a survey of village fuelwood needs so that trees can be integrated into agricultural production schemes in the area. In the Sudan, an FAO project getting under way in the Kordofan area is aimed at helping local people to understand the current decline of their gum arabic systems and how to cope with the pressures on the system.

Under the trust-fund-financed FAO/SIDA Forestry for Local Community Development Programme, a number of agro-forestry demonstration and pilot projects are under way. For instance, in La Paz, Bolivia, a pilot-stage rural community development project aims at improving the peasant's standard of living through the introduction of agrisilvicultural practices for soil and water conservation and greater productivity of food, forage, and rustic wood products. In Cuba, a project to identify and promote stable agrosilvopastoral systems in the Sierra Maestra will contribute to a large-scale programme to improve the rural economy of the area and prepare projects for external assistance to implement these. The integrated forestry development project in Darien, Panama, is expected to help introduce pilot agro-forestry practices in a tropical area under pressure from land colonization. An agrosilvopastoral development project in Nueva Segovia, Nicaragua, is under way.

National level agro-forestry projects executed by FAO are expected to expand considerably in the coming decade. As countries reach a take-off threshold in agro-forestry, FAO is promoting a large-scale regional project for agro-forestry demonstration and training to take advantage of the great potential in this field for technical co-operation among developing countries (TCDC). A preliminary project document for the Latin American Region has been drawn up and submitted to a donor. Similar efforts for Africa and Asia will follow, as well as an expected effort to link all three regions.
Agro-forestry: View from UNEP

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Abstract

Trees are the dominant vegetation in tropical areas, and deforestation leads to a variety of other problems. Deforestation is largely a result of economic deprivation, for trees are traditionally an integral part of rural life. Agro-forestry provides one solution that is widely applicable. In UNEP's view there are several problems hindering the development of agro-forestry. Among these is the lack of co-operation between those working in different geographical areas and between foresters and agriculturists. However, the greatest need is to collect and disseminate existing research results to field operators. UNEP would also like to see a coordinated programme to develop agro-forestry methods and technologies that are consistent with traditional practices.

Introduction

Longman and Jenik (1974) have stated that the tropical forest contains the earth's largest biomass, and that its total primary production is greater than that of any other ecological region. In addition to wood fibre, the forest yields fruit, nuts, leaves, flowers, resins, gums, bee products, and drugs, all of which are useful to human beings.

Borlaug (1976) has emphasized that trees are the dominant natural vegetation in most tropical ecosystems and must to a large extent remain so if production from the available land is to be maximized. Only 11 per cent of the land in the tropics is flat enough to be worked with the plough. One-quarter of the land surface is too infertile to produce conventional crops. The remaining area, that forms more than one-half of all land in the tropics, although too dry, too steep, or too rocky to be classified as arable land, is suitable for growing trees and crops interspersed with trees (Bene et al. 1977). The balance in the tropical forest can be irreversibly upset by forest clearance, intensive grazing, or burning.

The problem of deforestation is now recognized by governments and international organizations. Some of the problems include rapid siltation of reservoirs, reduction of water supply for human and agricultural use, decrease of electrical power-generating capacity, intensified flooding, loss of badly needed wood products and firewood, loss of valuable plants and animals, and the permanent loss of plant nutrients through leaching.

The largest loss of tropical forests is due to the transfer of forest land to food production. This is done in several ways, such as indiscriminate shifting cultivation and exploitation for fuelwood as well as poles for shelter. The people who inhabit the areas and are involved in the process of deforestation are, on average, the poorest in the country. Thus, tropical deforestation is largely a result of economic deprivation. Any solutions designed to solve the problem must take this fact into consideration. The basic needs of the people compel them to over-exploit a resource that they will need always, or at least in the foreseeable future- a resource, the very existence of which influences not only the lives of the exploiters, but those who occupy areas far removed.

The World Bank (1978) has stressed the need to give much higher priority to the protection, conservation, and wise use of forests on a long-term basis, and to consider forestry as an important component of integrated rural development programmes. The World Conference on Agrarian Reform and Rural Development (WCARRD) held in 1979 recognized the importance of diversification of rural economic activities, including integrated forestry development, as an essential component of a broad-based rural development programme. The 78th session of the FAO Council approved "A Forestry Strategy for Development," which lays emphasis on an approach that integrates the protective, productive, and social functions of forestry activities within agriculture.

Bene et al. (1977) have pointed out that, in most of the tropical zones, trees and agricultural crops usually
do best in combination. All through history, people have depended on trees for food and feed, and to maintain the productivity of the land. In the humid tropics, trees are a very productive crop and yet remove relatively few nutrients from the soil. Also, in very dry areas deep-rooted trees such as Anacardia sp. (cashews) grow large volumes of valuable food where nothing else will thrive. Between these extremes of climate and land quality, trees, agricultural crops, and animal raising, if carefully planned, can be combined to the best advantage in terms of output.

Bene et al. (1977) and King and Chandler (1978) have described agro-forestry as "a sustainable management system for land that increases overall production, combines agricultural crops, tree crops, and forest plants and/or animals simultaneously or sequentially and applies management practices that are compatible with the cultural patterns of the local population." There is enough evidence to indicate that trees were used in combination with farming and animal husbandry thousands of years ago. Unfortunately some of this knowledge has been forgotten. A study of oral history among certain communities supports this view.

Shifting agriculture (also variously known as swidden cultivation, slash-burn agriculture, kaigin, ladang, chena cultivation, etc.) has been practiced traditionally by communities with strong historic, social, and economic roots in the forests. Customs and knowledge of the development of both crops and trees ensured a relatively stable balance with the ecological environment. Because of population pressures, the interval between cropping periods has been shortened in many areas, the soil does not fully recover, and the ecosystem rapidly deteriorates.

Agricultural systems that may at first glance seem haphazard are found throughout Africa and Latin America. However, different crops are grown in mixtures because the species have root systems that tap different layers of the soil for nutrients and water, they possess different solar energy requirements, they stimulate the many-storeyed physiognomy of natural tropical forests, and in general complement rather than compete with each other.

In Kenya, for example, such a system of agrisilviculture has been demonstrated. At Kijabe there was sporadic failure of seedlings in several compartments at the time of planting out, and in these no replanting was done. Now 11- to 16-year-old plantations of Eucalyptus spp. with gaps in their canopies are intercropped by local farmers, who report that there have been no reductions in their yields since the establishment of the plantations.

Nair (1979) has demonstrated that tree crops established in the manner normally followed in most forestry operations do not utilize available nutrients, water, and solar energy efficiently in the early growth stages of the plantation. Accordingly, the intercropping of these plantations with suitable food species and cash crops-especially during establishment-more efficiently utilizes the available nutrients, water, and solar energy.

Land is a limited resource that is becoming very scarce because of the current population increase. Bene et al. (1977) reckon that one needs 2-3 km² of unmanaged rain forest to feed one human being, whereas traditional methods of shifting agriculture will sustain 30-50 people on 1 km². Unfortunately, the high-yielding crop varieties that are being promoted for use in the tropics often require costly inputs such as fertilizers, water, pesticides, and energy, which few developing countries can afford. Also, suitable areas for growing and producing these high-yielding cereals are quite limited in tropical areas. This type of agriculture alone, therefore, cannot be relied upon to produce enough food for the populations; other alternative production systems must be explored. Agro-forestry stresses the planning and upgrading of shifting agriculture with a view to maximizing sustained production on less well-endowed land, whether the produce is food, feed, fuel, building material, or products of commercial value.

Charrean and Poulain (1963), for example, have demonstrated that in regions of seasonal rainfall (250 mm or more a year), careful interplanting of Acacia albida trees with millet increases millet yields by 500-600 per cent. Allowing livestock to graze on the grasses between trees and on the tree leaves and pods is a system that maximizes available land for optimal production.
The View of UNEP

UNEP recognizes the existence of opportunities such as these to increase production and improve efficiency by growing trees in combination with other crops or livestock; these practices promote environmental health and should be encouraged within national development plans. Certain problems, however, need to be overcome if programmes on agro-forestry are to be developed for maximum benefit to the human race.

First, there is an apparent lack of co-operation between workers in similar or related fields in different parts of the world. There are many cases where operators in one region remain completely ignorant of some very successful but undocumented agro-forestry trials and practices in other regions. Second, there seems to be a serious communication gap between those who carry out research and those who need to apply the results. Third, research workers in agriculture and those in forestry tend to operate in complete isolation as if the two fields have nothing in common.

UNEP believes strongly that these serious communication problems must be overcome before a sound programme can be established in agro-forestry. The wealth of scattered and un-coordinated research information must be assembled and disseminated in appropriate form to all that are involved in this work, i.e., scientists, technicians, decision-makers, and the general citizenry. Ongoing and planned research programmes must be closely integrated with national development programmes in order to ensure that they are aimed at satisfying the people's aspirations.

In the vast majority of developing countries, only a very small proportion of the results from research establishments ever reaches the people who are supposed to apply them. Quite a sizeable amount of research in agriculture and forestry, albeit in isolation, has been carried out in most of these countries over the years; unfortunately, the bulk of these results is shelved away in various annual reports, with nothing ever reaching those who need the information most - the farmers.

It is UNEP's view, therefore, that probably the greatest benefit developing countries can derive from various research activities is the identification of methods for the efficient collection and timely dissemination of existing research results to field operators. This is particularly urgent with respect to the information on various research projects designed to demonstrate the feasibility of integrating forestry with agriculture and animal husbandry. Most developing countries have very efficient extension services in agriculture and livestock husbandry; in forestry the services are almost non-existent; extension services that would develop integrated programmes in agriculture, livestock husbandry, and forestry do not even fail within the planners' world view. If properly developed, co-ordinated extension services that embody forestry, agriculture, and livestock production could play a major role in the transfer of existing knowledge to the field operator at the professional, technical, and peasant farmer levels.

In the past, forestry and agriculture have been so effectively separated that the two fields have developed in total isolation. Until recently, there were grain surpluses in industrial countries and virtual self-sufficiency in most developing countries because of the existence of a lot of fertilizer and seemingly unlimited cheap energy. Foresters were therefore concerned with nothing but forest conservation and the production of timber and any programme that involved opening parts of the forest for agricultural production was unwelcome. This attitude, therefore, effectively isolated the foresters from the farmers in developing their respective industries.

Over the last few years, a combination of factors has led to serious shortages of food, especially in developing countries, and in those countries self-sufficiency in food has become a priority. Coupled with the increasing numbers of landless people, this trend places a lot of political and economic pressure on governments to open rich, forested areas for agricultural cultivation. There is less appreciation of the fact that clearing forests for farms will not be the answer to the problem.

UNEP would like to see a co-ordinated programme designed to develop methods and technologies necessary for maximizing the use of available land. Application of agro-forestry systems on marginal lands and a planned system of intercropping of agricultural crops with forest trees are regarded as
important.

UNEP believes strongly that close co-operation between forestry and agricultural research workers must be developed and that a careful assessment of the potential of different trees, shrubs, grasses, and other crops is needed so that the most suitable combinations for agro-forestry can be identified. A close study of existing practices in agro-forestry, and their modification where necessary, will not only improve outputs but also reveal important gaps in knowledge and opportunities for improving the systems. It is UNEP's belief that relevant national and international agencies must be entrusted with the important task of carrying out the necessary research to secure this new knowledge and that these agencies must take the lead in researching various combinations of trees, crops, and livestock.

Although agro-forestry systems are not the answer to all problems of tropical forestry development, they are low-input systems that are designed for fragile ecosystems. They are therefore complementary to, rather than a replacement for, traditional forestry development practices. Through dynamic growth forestry can play a significant role in a sustained improvement of social welfare. The forestry industry, as an important component of integrated forest management, needs a still greater emphasis so that it can meet the everincreasing demand for forest products.

UNEP places a high priority on the development of agro-forestry systems compatible with traditional practices in given areas. This priority is demonstrated by UNEP's programmes covering 1981, 1982-1983, and 1984-1989. Various projects in multiple land-use systems are either in progress or soon to be initiated. UNEP is collaborating very closely with other relevant United Nations agencies such as FAO and UNESCO in the development of agro-forestry systems. UNEP's future plans stress the importance of even closer co-operation with other UN agencies, international organizations, and relevant national institutions in the development of agro-forestry systems.
Agro-forestry developments in Kenya: Prospects and problems

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Abstract

The paper argues the case for adopting agro-forestry in Kenya, with the emphasis being on marginal lands. Developments in the agricultural and forestry sectors are highlighted, particularly their parallel but heretofore unintegrated natures. The future of taungya as an agro-forestry subsystem is discussed. Recommendations regarding the various factors to be taken into consideration when developing an agro-forestry package are given. Finally the paper emphasizes that the "magic agro-forestry tree or animal" approach is unlikely to prove successful.

Introduction

Historically, Kenya has adopted a sectoral approach to agricultural and forestry management and production. There has been a near total lack of co-ordination at the policy level for the two sectors. For instance, the three major agricultural development plans (the ALDEV plan in 1945, the Swynnerton plan in 1954, and the Agriculture Act of 1967) have all dealt with agricultural production quite in isolation from forestry developments; there has even been a tendency to relegate forestry development to a service in increasing agricultural productivity. More significantly, there has been a great imbalance in the planned and realized contribution to national socio-economic development between the forestry and agricultural sectors, with the scale tilting heavily in favour of agriculture. The fact that the two have continued to be implemented by two different government ministries has further hindered co-ordination of activities that could lead to the development of agro-forestry systems.

The sectoral strategy is unlikely to continue to yield success in Kenya for three main reasons:

- The rapidly changing concepts in forestry management-i.e., the move of foresters away from traditional sustained-yield ideas to multiple-use policies, including agro-forestry;
- The ecological precariousness of Kenya's productive land surface-only about one-third of Kenya's land surface receives sufficient precipitation to sustain recurrent cropping; closed indigenous forests and forest plantations, mainly of fast-growing exotic species, are found within this very limited productive land surface. Any future expansion in forestry development must, therefore, directly impinge on agricultural production. Furthermore, traditional agricultural practices, including shifting cultivation, are land destructive and can only be tolerated at low human population levels. An integrated forestry-agricultural production system like agro-forestry appears the most logical strategy; and
- The extension of agriculture and forestry production to marginal lands-in much of the marginal lands of Kenya, soil degradation and destabilization have progressed to such a level that agro-forestry (most likely some forms of silvopastoral systems) remains the only hope.

Given this background, this paper attempts to review the prospects and problems of agro-forestry developments in Kenya.

Forest Production

The dominant forest policy in Kenya is the protection of forests for the preservation of the water-catchment function, although the sustained supply of wood-based products like fuelwood, timber, pulp and paper, etc., has become more prominent in recent years. Natural and cultivated forests cover some 2 million ha, i.e., less than 3 per cent of the national land base. Of this, about 0.5 million ha are already planted with fast-growing exotic monocultures, mostly of Cupressus lusitanica, Pinus patula, Pinus
radiate, Eucalyptus saligna, and Eucalyptus grandis.

Consistent with Kenya's wide altitudinal variation, there is a wide variety of natural forests, ranging from the lowland forests on the east coast to the alpine moorland boundaries on the snow-covered peaks of Kenya's mountains. Thus, five different biomes and nine subtypes have been identified among Kenya's forests (Lamprey 1977). Compensatory forestry practice is currently confined to the high altitude, high potential lands and incorporates the shamba or taungya subsystem.

The last three years have seen a great shift in national emphasis to forest development in the arid and semi-arid parts of Kenya. In these efforts, important lags in the development of appropriate methods have been analysed (Owing 1980). In general, the experience already gained tends to suggest that tree crops alone, no matter how fast they grow, cannot be economically attractive to the smallscale farmer and that some package combining trees and crops, or trees and livestock, or trees and crops and livestock is more desirable in arid areas of Kenya.

**Agricultural Production**

Kenya has an agricultural economy and relies heavily on exports of high-quality tea and coffee. The country has a fairly well developed beef and dairy industry with substantial exports to neighbouring countries and overseas. The production of staple cereals and beans to meet internal demands is reasonably efficient, and these commodities are imported only when drought or flooding hits the country. Agricultural production activities are organized on both a large scale (co-operatives and large-scale farmers) and a small scale, with the national average for agricultural land holding per family about 1.25 ha.

Traditionally, a few trees have been left on the farm even if there is no apparent use. In general, however, there is little rationalized agro-forestry in the country.

**Current Agro-forestry Practices**

Taungya is the most conspicuous example of an agro-forestry system in Kenya. It has been estimated that annual maize production under this subsystem averages 4.5 t/ha and that about 10 per cent of the total national maize production comes from this forest development practice (Wanyeki 1980). However, this forestry practice is very labour-intensive and is rapidly being phased out because of labour costs and settlement implications.

There are other, much less spectacular examples on the Kenyan coast. These include coconut palm-crop mixtures, coconut palm-grazing mixtures, cashew nut-grazing mixtures, and cashew nut-legume mixtures. Other combinations in other areas include Albizia gummifera and grazing in the highlands, Acacia albida and cereals in the arid areas to the north, Balanites aegyptiaca and grazing in Baringo and Samburu districts, etc.

The dominant conclusion from such a survey is that the existing agro-forestry examples are those that have evolved in traditional agriculture as a result of constraints in given localities and they are in the experimental stages. This clearly suggests that the next important step in agro-forestry development in Kenya should be the further identification and scientific rationalization of the most appropriate agro-forestry packages for the different ecological zones.

**Future Prospects**

Although there is a plausible case for agro-forestry as a realistic land-use system in Kenya, one is still faced with the real and large problem of how to sell an appropriate agro-forestry package to the farmer or the individual landholder. It must be recognized that the farmers, just like the professional agriculturalists or foresters, carry out land productivity operations with a polarized mind. There are major barriers to be broken down before they can readily accept agro-forestry proposals, and these barriers have been created by the discipline's short history and the more remote history involving the evolution of cultural values. There are important socio-economic factors that are often specific to a locality and ethnic group.
Given the Kenyan situation, I believe that a systematic development of sound agro-forestry systems should be undertaken through a critical appraisal of the:

- Cultural predisposition to trees and agricultural crops: the cultural value of individual tree species differs markedly from one part of the country to the other, but most farmers have at least a few indigenous and exotic trees on their farms. This fact can be a good starting point in a programme to convince farmers to adopt agro-forestry systems, i.e., developing agro-forestry along the line of least cultural resistance;
- Size of the operation: the traditionally trained foresters are used to operating in large blocks of hundreds of hectares. Farm and rural forestry are very recent ideas that still require experimentation and experience. Farmers, on the other hand, see trees as useful for windbreaks and hedges. There is an urgent need for trials with different tree planting designs for different sizes of land holdings, and the determination of the minimum land size for effective agro-forestry operations given specific productivity objectives;
- Economic returns: most of the recommendations for agro-forestry have been based on the big-physical complementarily of the total production system, including soil quality improvement and stabilization. Relatively little attention has been given to the economic returns from the proposed systems. Economic justification of a proposed agro-forestry system is a prerequisite for acceptance;
- Land capability and its dynamics: the ecological zones recognized for agricultural productivity in Kenya differ in some important respects from those recognized for forest productivity. Land capability classification for agro-forestry systems will differ even more markedly, and needs to be carried out;
- End-product diversity: the existing agro-forestry systems have little diversity of end products. These include fodder, timber, nitrogen fixation, shade, edible seeds, and fruits. It is necessary to investigate other uses for the other plant parts—e.g., tannins, medicine, essential oils, latex, etc.;
- Stability of the productive system: in general, agricultural plantations and forest monocultures are unstable production systems and are maintained at high cost. The recent drive among agriculturalists to return to older, mixed-crop systems should lead to more stable production systems. Agro-forestry systems should prove even more stable. In arid parts of Kenya, the stability of the production system over time is an important factor in the settling of nomadic ethnic groups.

**Conclusion**

In conclusion, nothing much can be accomplished from a recount of agro-forestry practices, either indigenously evolved or exotic, including the splashing here and there of the "magic" agro-forestry plants and animals. A more systematic development is needed that takes into account socio-cultural factors, scale of operation, economic returns, land capability, end-product diversity, and stability of the productive system. Such an approach would probably result in an agro-forestry package that is readily acceptable in different parts of Kenya.

**Barefoot agro-foresters: A suggested catalyst**

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Agro-forestry is meant to be a concept for the solution of the tremendous land-use problems in the tropics. In many parts of the tropics agro-forestry schemes, or at least starting points for them, have developed spontaneously. The problems in the extension, optimization, and adaption of such autochthonous techniques are many. The exclusive application of scientific methods to the investigation of existing techniques and the synthesis of new agro-forestry techniques are not feasible because of the costs, time, and staff required. For the development of traditional schemes and the improvement and extension of agro-forestry techniques, I suggest the introduction of "barefoot" agroforesters with a role in agro-forestry similar to that of barefoot doctors in the health services in China—namely, researchers in the field who are
also extension workers. In this way they can apply simple and effective scientific methods to local starting points in agro-forestry and thus make an impact without major financial inputs.

These barefoot agro-foresters would serve as catalysts, undertaking field research and publication and extension work, using local knowledge and experience, and applying the most elementary scientific methods like observation, comparison, and systematization. Although there are problems in agro-forestry that call for sophisticated research instruments, in many cases small-scale science may be more efficient.

Barefoot agro-foresters will also need a good understanding of the local population's problems, conditions, and mentality. Therefore, they should be limited to areas where the basic conditions of life, ecology, social, cultural, and economic structure are relatively homogeneous from the agro-forestry point of view. The size of the area must be small enough or accessible enough for them to visit regularly. Close contact enables the co-operation between farmer and catalyst necessary for effective improvements.

Important functions of catalysts are to introduce know-how (e.g., simple methods for wood preservation, useful pruning tools); to establish contacts (e.g., sources for seeds or planting material, outlets for produce); and to analyse the deficits of the institutional and legal framework. In the case of alder with pasture, for example, the forestry law of Costa Rica does not take agro-forestry into consideration at all. People are needed to draw the attention of the authorities to this deficiency. Other paragraphs of this law, concerning tax reductions, etc., could be beneficial to farmers, but the farmers are not aware of them. A guideline for the catalysts' work must be to begin where the farmers are and move forwards from there. Techniques that have been developed on trial plots and in laboratories often do not comply with this rule.

Since the problems of tropical land use are growing at a speed that traditional scientific procedures cannot keep up with, fast-working, efficient, and low-input measures are required if agro-forestry is to play a positive role in development. Observations and experience within Costa Rica suggest that the introduction of such catalysing personnel could multiply several-fold the importance of agro-forestry within a few years, and thereby contribute to meeting the basic needs of the local people.

**Gliricidia sepium: A possible means to sustained cropping**

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C.F. Yamoah  
University of Ibadan/IITA, Ibadan, Nigeria

**Abstract**

*Gliricidia sepium* is a small leguminous tree of tropical American origin. It is currently used on farmers' fields in several locations in Oyo State, western Nigeria, where it seems farmers value this introduced woody legume in restoring soil fertility. Despite its widespread use here, and farmers' acceptance, there is hardly any study or account of this woody legume, especially in this West African subregion. This paper reports the major observations made during a field survey in the Ibadan area. Leaf protein content was calculated to be 23.6 per cent and soils under *G. septum* fallow had higher nutrient status than comparable sites under natural bush fallow.

**Introduction**

With increasing population, the traditional shifting cultivation system tends to break down, for the natural bush fallow becomes too short to fully restore soil fertility. A substitute system is therefore essential, and a
planted tree fallow is one possibility. Leguminous woody plants such as Cajanus cajan, Tephrosia candida, and Leucaena leucocephala are fastgrowing and improve soil fertility in a shorter time than does the natural regeneration. Farmers in the Ibadan area claim that the small leguminous tree Gliricidia septum has the potential of maintaining and even improving land productivity under continuous arable cropping. The purpose of this study was to investigate that claim.

Gliricidia septum was introduced into Nigeria during the colonial days by the Department of Forestry. Its original use was for fences, but now it is also used as supports for yam vines, erosion control, shade in forestry and agricultural nurseries, feed for livestock, fuelwood, and as a soil improvement agent.

Methods

A field survey was made in a number of locations within Ibadan, including Polytechnic, Eleyele, Ahmadiya, Nihort, Jericho, the Forestry Research Institute, Apata, and Ring Road. Interviews and personal observations were the methods employed to determine how Gliricidia septum is used in the farming systems. Soil and leaf samples were collected, digested with H2SO4, and autoanalysed. Nitrogen obtained was multiplied by 6.6 to estimate protein content. In all, 14 soil samples were collected at 0-15 cm and were analysed for pH (Beckman pH meter with soil:water ratio 1:1), percentage of organic carbon (Walkley-Black method), percentage of total nitrogen (micro-Kjeldahl method), available phosphorus (Bray-1P), extractable cations (by 1 N NH4OAc), and total acidity (extraction by NaOH with phenolphthalin as indicator).

The farmer interviewed at Polytechnic said that the land had been continuously cultivated with yams for four years, and Gliricidia was used as support for the vines. It was then left under Gliricidia fallow for five years. Two soil samples were collected, one bulk sample from the fallow area (sample 1) and the other (sample 2) from an adjacent site cultivated with yams, vegetables, and maize.

Eleyele was a farm belonging to the Ahmadiya secondary school. Gliricidia was planted two years ago as a support for yams. Two soil samples, one (sample 3) from the farm and the other (sample 4) from nearby natural bush, were collected.

On a farm near Ahmadiya school, the land was reported to have been continuously cropped for three years without fertilizers. Two soil samples were collected, the first (sample 5) from this farm, where Gliricidia was being intercropped with maize and cassava, and the second (sample 6) from an area free of Gliricidia.

No farmer was found to be interviewed in Nihort. However, observations indicated that Gliricidia had been growing for one to two years, and it was assumed to have been used as yam stakes. One soil sample (7) was collected from the area under Gliricidia.

The farmer in Jericho claimed he had been using the land for the past 12 years to cultivate yam, maize, and vegetables. He said that he planted yams ten years ago using Gliricidia as stakes and that he prunes the Gliricidia periodically so that there is space to plant maize and vegetables. One soil sample (8) was collected.

Gliricidia was found to be on two fallows at the Forest Research Institute: one fallow was two years old and the other three years. Soil samples (10, 11, and 12) were taken from the sites under Gliricidia. One sample (9) was taken from the same area but from a different plot where Gliricidia is intercropped with yams, maize, and vegetables as follows: yam is planted in November with Gliricidia stakes serving as supports for the yam vines; maize follows in March after the stakes have been pruned; finally cassava is planted in July.

The farmer at Apata has cultivated the land continuously for three years, intercropping Gliricidia with maize, cowpeas, and cassava. He pruned the shrub before each planting. One soil sample (13) was collected. The location on Ring Road was a thick bush of Gliricidia, and many earthworm casts were observed. No farmer was interviewed but a soil sample (14) was collected. Leaves were collected from all
Potential for Agro-forestry

The following facts about the legume emerged during the survey:

- The shrub is fast-growing and covers the land very quickly;
- The fallen leaves add organic matter to the soil. The organic matter, besides checking erosion, supplies nutrients like N, K, Ca, and Mg on decomposition;
- The deep rooting system helps in recycling nutrients from lower depths;
- Cuttings of Gliricidia will take root, nodulate, and fix atmospheric nitrogen;
- Fuelwood is another benefit derived from Gliricidia, and it can produce about 30 t/ha;
- The commonest use of the shrubs in the farming system is for the support of yam vines, the farmers planting them beside the yam mounds; and
- Gliricidia is one of the shrub legumes suitable for forage production for livestock.

TABLE 1. Results of Soil Analyses for 14 Soil Samples

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>pH</th>
<th>Organic Carbon (%)</th>
<th>Total N (%)</th>
<th>Available P (µg/gm)</th>
<th>Exchangeable Cations (µg/100 gm)</th>
<th>Total Acidity (µg/100gm)</th>
<th>CEC (Meq/100 g)</th>
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</thead>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Ca</td>
<td>Mg</td>
<td>Mn</td>
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<td>1</td>
<td>6.1</td>
<td>1.59</td>
<td>0.256</td>
<td>15.6</td>
<td>1,393</td>
<td>111</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>5.9</td>
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<td>0.144</td>
<td>5.4</td>
<td>735</td>
<td>63</td>
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<td>1.28</td>
<td>0.184</td>
<td>8.1</td>
<td>675</td>
<td>126</td>
<td>2</td>
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<tr>
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<td>0.101</td>
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<td>4</td>
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<tr>
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<td>0.194</td>
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<td>945</td>
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<td>10</td>
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<tr>
<td>6</td>
<td>6.2</td>
<td>1.28</td>
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<td>720</td>
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Results and Discussion

The results (table 1) indicate that soil under Gliricidia fallow is better than soils where Gliricidia has not been grown in terms of pH, organic matter, available phosphorus, and cation exchange capacity. They also show that the level of soil fertility increases with the length of the fallow period. Also the protein content of G. septum leaves is relatively high, with values ranging from 20.65 to 27.39 per cent. The mean value of 23.6 per cent compares favorably with other woody legumes like Leucaena leucocephala (14.2 per cent) and Cassia spp. (12.6 per cent) (NAS, 1979).

IITA (1980) reported on the effects of planting maize and cowpeas between rows of Cajanus cajan, Gliricidia septum, Leucaena leucocephala and Tephrosia candida. The crops were intercropped in alleys 2.25, 3.75, and 6.75 m wide. The results indicated that G. septum at an alley width of 3.75 m resulted in a maize yield of 5,055 kg/ha and a cowpea yield of 586 kg/ha. These were the highest figures recorded among all the yield data. No information was obtained on the amount of nutrients supplied by the shrubs in this experiment. In view of its potential in aiding continuous arable cropping as evidenced by these observations, Gliricidia deserves greater research attention. Further work should emphasize:
• Its nodulating ability under different soil conditions;
• Its effects on the chemical and physical properties of the soil;
• The yield performance of early and late maize when intercropped with Gliricidia; and
• Its suitability as an in situ mulch and in alley cropping on contours.

The role of trees in the production and consumption systems of the rural populations of Senegal

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Abstract

In the Thies region of Senegal, the Serer practice a combination of agriculture, animal husbandry, and forestry. The species most valued in the southern part of this region for their multiple domestic and industrial uses are Borassus flabellifer (palmyra), Adansonia digitata, and Acacia albida, which are cultivated together with millet, sorghum, and groundouts, or in stands for livestock to browse.

Palmyra is used by Catholics and animists for wine-making and by Muslims for other products Although a system of agro-forestry may be said to exist among the Serer of western central Senegal, research needs to be conducted into ways of improving the system, notably by determining optimal spacing; the influence of trees on soil fertility and microclimate; ways of developing mineral fertilizers; and the profitability of tree-derived products.

Summary of discussion: Considerations for the future development of agro-forestry

In discussing the future of agro-forestry the supposed links between agro-forestry and poverty were mentioned. Contrary to what is often believed, those practicing agro-forestry are not necessarily resistant to modernization, nor are they limited to a life of bare subsistence. The case of the Kandy gardeners in Sri Lanka was cited as one example where a stable agro-forestry system can provide both subsistence needs and a substantial cash income. It is probably true that most of the people now practicing agro-forestry are in the lowest income brackets, but one can argue that for this reason alone there should be greater efforts to investigate the possibilities for improving yield. In many cases there simply may not be a feasible, sustainable alternative to agro-forestry.

The suggestion for "barefoot agro-foresters" to encourage agro-forestry practices was welcomed, but it was cautioned that they must have some training. In particular they would have to be familiar with the farming systems approach, even though their basic training might be only in agriculture or forestry.

A final comment was simply that there must be more exchange between the different regions within Africa. Each area has its own experience and its own crops, and much of this information could be of use in other areas. Given the tremendous lack of knowledge about agro-forestry, such an exchange could be considered essential for the understanding and development of agro-forestry.
Reports of the working groups

Working group on research needs
Working group on training and extension
Working group on systems management

Working group on research needs

Introduction

The widespread existence of stable and productive multistrata and multicrop associations in the humid tropics (including, in some cases, the incorporation of domestic animals) suggests these may be an optimal land-use system for the region. The fact that so far such traditional mixtures have received but scant research attention must be attributed in great part to the separation of the agencies which have responsibility for trees, food and other crops, and animals, respectively, and which have each demanded a share of land for their particular production activities.

With increasing population pressures on land and shortage of both food and timber, such a separation is no longer justifiable. To date, foresters have taken a lead in promoting agro-forestry activities, but clearly a proper integration of agronomy, animal husbandry, and forestry must take place. The research approach implies a true interdisciplinary spirit and not competition between disciplines. Through the provision of information, funds, and technical assistance, international organizations that sponsor agro-forestry research can act as catalysts in promoting such integration. The concerned agencies must work together to determine the conditions optimal for mixed production (agro-forestry) as well as those for monocultures. They must begin with an identification of existing land-use systems, their needs and constraints—biological, economic, and social.

The experience that exists in the humid tropics should be collated; common tree, crop, and animal associations should be identified and their roles within the land-use system investigated. In regions where agro-forestry practices do not exist but appear desirable, there should be a search for the most advantageous integration of crops, animals, and forest species in an attempt to reach sustainability, optimal sustained production, and conservation of the environment.

To be successful, agro-forestry systems must be flexible, resilient, sustainable, economically attractive, and acceptable to local populations. The following outlines some of the key areas for research.

Existing and New Agro-forestry Systems

- Assessment of existing and new agro-forestry systems should be careful and systematic, based on standardized methods that define the constraints that can potentially be overcome by the application of an agro-forestry approach. This work is urgently needed, and the existing national and international agencies, such as ICRAF, FAO, UNU, IDRC, and IITA, should adjust their priorities accordingly;
- An attempt should be made to design, on the basis of existing information, optimum agro-forestry systems for implementation under a wide range of local conditions.

Species Composition

- The particular tree-food crop associations for agro-forestry (including, in some instances, animals) depend on the characteristics of the site. For example, on hilly terrain, hedge planting along the contours is a useful conservation practice. On large farms there is considerable flexibility in the distribution of trees, whereas on small farms trees may be feasible only as field boundaries. When
animals are part of the association, browse species must be provided. Thus, studies on farm size and the number and distribution of appropriate tree species are required;

- Opportunities should be taken wherever possible to: introduce crops of potential value in agro-forestry systems; maintain varietal selection programmes; and develop methods of propagation that will speed acceptance by farmers. At the same time care must be taken to avoid the introduction of species that are potential weed problems;
- There is a need to identify extension requirements in the field and to appoint appropriate staff who have the basic knowledge needed for the programme. They need to be provided with recommendations that are derived from available data and that are improved on a continuous basis;
- Research based on standard methods needs to be undertaken on the biological and environmental aspects of different species, including: tree-crop interactions (effects of shade and identification of shade-tolerant plants); optimal density and distribution; competition for water and nutrients and ways to obviate it; possible allelopathic and symbiotic effects; nutrient budgets and nutrient cycles (particularly offtake by crop harvests and grazing animals, immobilization in standing timber, returns to the soil from leaf litter and pruned branches, the available and total nutrient resources of different soils, recycling of animal and plant wastes to the soil, fertilization effects and their efficiency for both tree and herbaceous crops, and the contribution of nitrogen-fixing plants to the overall nitrogen budget); effects of soil characteristics, rainfall, and altitude (most promising systems for each set of conditions); pest studies (tree-crop associations that limit diseases, insects, rodents, etc.).

Economic Aspects

- There is a need to ascertain optimum yields from agro-forestry systems. The word optimum should be taken in a broad context, implying a cost-benefit analysis that includes social and other intangible benefits and costs in the short and long term. Economic comparisons of agro-forestry schemes with alternative land uses provide useful data, particularly for those responsible for land-use planning and management. The various risks such as crop failures, labour shortages (and the desirability to have labour-intensive or labour-extensive conditions), dependency on inputs from outside, and damage to watershed areas are some of the many variables that should be included in economic analyses. Marketing aspects, particularly those that favour the producers but with which they may be unfamiliar because of the commodities involved, are another research priority.

Social Aspects

- Methods of discerning social aspects of each locale are also a priority because agro-forestry, possibly more than other land-use techniques, assumes that desirable systems must be compatible with the prevailing local values and customs and that the local people should participate in making decisions that will affect them;
- Investigations need to centre on techniques of determining how acceptable a scheme is likely to be in a particular locale, and how community leaders or trend setters can be identified and provided with information on desirable changes; these investigations will provide a basis for successful extension campaigns;
- The possibilities for agro-forestry in relieving rival tensions and stemming the exodus of younger people from rural areas need to be examined.

Support Services

- Facilities such as seed banks, live collections of genetic materials, particularly indigenous species, should be promoted in association with appropriate international bodies;
- Appropriate tools and instruments that are useful to agro-forestry should be given priority.

Working group on training and extension
Training applicable to agro-forestry can be either formal (primary and secondary schools, technical certificate and diploma courses, and undergraduate and postgraduate degree programmes) or non-formal (in-service or short-term training).

**Formal Training**

In primary and secondary schools, the curricula already contain agriculture. Agro-forestry principles should be introduced so that agriculture and forestry are no longer compartmentalized. Emphasis should be placed on the environment and the role of trees, food crops, and livestock within it. Current teaching materials need to be revised so that they reflect this emphasis, and practical work—for example, encouraging pupils to plant trees in the school garden—should be included.

Technical training at agricultural, forestry, and animal sciences colleges or schools should introduce the concept of agro-forestry as an integrated form of land use.

Undergraduate training should include practical exposure to the multiple use of land so that students derive an integrated view of land management. Students of forestry, agriculture, and animal sciences should be brought together in at least one course on land management which embraces the various disciplines and includes the concept of agro-forestry. A specialized course on agro-forestry is not necessary, but agro-forestry should be highlighted in other courses wherever possible.

Postgraduate training, in addition to emphasizing research in agro-forestry, should incorporate courses on land management. Such courses should stress the role of agro-forestry and should be offered to students of agriculture, animal sciences, forestry, etc.

**Non-formal Training**

Non-formal training in agro-forestry should be encouraged for all people who are responsible for the related disciplines, especially the teachers of formal training courses. In-service training can provide professional staff with the opportunity to gain experience and new ideas, and it may be undertaken on a South-South basis, sometimes across continents.

Universities should play a key role in non-formal training, as they provide a favourable environment for it. Research institutes and government departments could also provide training. Centres which have informed staff, appropriate infrastructure, research and study facilities, and field experiments should be used for agro-forestry training. International agencies may provide financial assistance and help in the organization of such courses. ICRAF is planning to initiate a programme of in-service training, and the UN University has been training a limited number of scientists on an international basis since 1978.

**Priorities**

Priority should be given to the inclusion of agro-forestry in training at the technical and non-university levels, as technical personnel carry out the actual work in the field. The first step is to train, perhaps through non-formal courses, teachers of these personnel so that they can provide the right type of leadership. Funding for non-university level training should come from national governments and, where necessary, international agencies.

**Public Enlightenment**

Introducing agro-forestry to the people is necessary. Radio programmes, newspaper articles, posters, and displays at agricultural shows are possible avenues.

Each country should form an agro-forestry committee that would include people from a range of disciplines and interests in land use and include the ministry of information. This committee would put forward ideas to national information services or other appropriate channels.

Publicity material, as with the composition of the national agro-forestry committees, depends on each
country's circumstances. Universities should be enlisted to produce material, which may need translating into local languages, and could include posters, literature, films and filmstrips, and tapes for radio. The dissemination of such material could be done by various national agencies, including cooperative unions, adult education services, and the like.

Demonstration and experimental plots, sited in key locations and worked by field staff and selected local farmers, are essential. These should be financed by various national bodies and organized through the national agro-forestry committees.

Motivation of farmers is vital and can be aided by governments through guaranteed purchases of certain products such as pulpwood.

**Working group on systems management**

Managing agro-forestry production means organizing three basic elements-labour, land, and capital. Each presents constraints as well as resources for management. In addressing the issue of how to combine these inputs, one should not lose sight of the time requirements-both for crop-tree decisions and for longer-term development interests.

Labour in agro-forestry systems is mainly provided by small farmers, and this is the most critical input in systems management. Labour is limited, and the farmers have priorities. They will usually prefer to give their efforts to activities with guaranteed food or other outputs. Agro-forestry requires additional labour input, especially in the establishment of trees; however, in some circumstances direct labour savings are possible. Farmers are frequently employed off the farm, and this fact should not be overlooked by agro-forestry planners. Agro-forestry systems that call for combinations that cut across the traditional division of labour of a particular culture or community, for example between men and women, are likely to be poorly accepted.

Agro-forestry may mean a re-organization of the sequence of labour inputs that conflicts with other activities. In short, labour cannot be defined simply as the number of workdays required. If farmers must forgo or make short-term production sacrifices, incentives are necessary.

In the African humid tropics, land is less of a constraint than is labour. Agro-forestry should mean both trees in the fields and crops in the forest. In other words, agro-forestry as a system has production goals and conservation goals, depending on needs and resources. In management decisions regarding land, the great majority of the constraints derive from ownership or tenure. A tenant or other user may wish to plant trees but be prohibited by the owner because tree planting may confer rights of use. Although land tenure in many countries is changing rapidly, it may be distinct from that which is officially described. Tenure seems, therefore, to have more important implications for agro-forestry than does land availability.

**Institutional Framework**

- Although an institutional framework for agro-forestry at national level is desirable, it may never be possible. What is possible is joint efforts of all land-use sectors. Coordination of services to farmer participants in agro-forestry programmes means a common understanding of the system by all the agencies involved. Such an understanding is lacking today and, because it enables systems management, it must be a priority;
- Institutional coordination must start with the policy-makers and extend to the field workers. Government may wish to designate a lead agency or focal points for agro-forestry to get programmes off the ground.

**Policy**

- A considerable effort should be made at the international level to clarify agro-forestry policy
proposals; at present, few, if any, agro-forestry policies per se exist. Clarification will substantially aid countries to develop their own policies;

- Policies must not be seen as just another means for foresters to achieve their tree-planting goals. To overcome this suspicion, foresters should meet with members of all land-use sectors and discuss their common interests at the planning and execution stages. Better representation of agriculturalists at agro-forestry meetings, either national or international, is a first step;

- Policy development and review must be based on clear objectives understood by all. The existing objectives are, in many countries, still only semidefined and need to be made clear-cut. Basic information on the merits of agro-forestry and its development potential in broad socio-economic terms must be put forward to policy-makers. Professionals involved in agro-forestry today must be more affirmative in taking their case to government decision-makers;

- Those interested in agro-forestry policy should consider as a first exercise a careful study of both agricultural and forestry policies to determine whether these will impede or promote agro-forestry.

Legal Instruments

- A careful review of the law and its relationship with agro-forestry is fertile ground for endeavour. Policy is implemented through legal instruments and the lack of agro-forestry policy implies a lack of legal instruments. Indeed, many of the constraints to agro-forestry management have their origins in the laws. In this respect, the laws that put constraints on the use and ownership of forest trees should be reconsidered. Legal constraints to agro-forestry may lie outside forestry and agricultural laws; they may be found in laws on credit availability, land tenure, land reform, business enterprises, and tribal and family customs. These laws should not be overlooked in a holistic approach to agro-forestry managements;

- The implications of changes in the laws should be examined carefully; how they would affect everyone from government staff to smallholder farmers should be anticipated as much as possible;

- Legislation should seek to promote the permanent associations of agriculture, forestry, and animal sciences for the general good of society. Many of the details of agro-forestry management could be dealt with in complementary regulations that are more flexible, easier to interpret, and simpler to modify than legislation.
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