THE WASTED LANDS

ICRAF

THE PROGRAMME OF WORK OF

THE INTERNATIONAL COUNCIL FOR RESEARCH IN AGROFORESTRY

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CHAPTER I
WHAT IS ICRAF?

BACKGROUND

Much of the land in the developing world is mismanaged, underutilized, or unused. The forests of the tropical zones, in which the bulk of the developing countries is situated, are overexploited in some regions, underexploited in others, and unmanaged in almost all. Although trees are the dominant vegetation on more than half of the tropical land area, forest products contribute little to the social and economic welfare of the people who should be considered fortunate to possess these resources. On the contrary, the practices that are now being followed in many areas rapidly destroy the forest and land resource base on which the livelihood of a considerable proportion of the world's population depends.

The situation is not much different in other types of ecosystem. In Africa, seventy-two per cent of the land surface is permanent pasture or waste. Yet, on these lands there seems to be an almost inevitable process of further ecological degradation, which, if continued, would prevent them from contributing significantly to the economic development of that continent.

In Asia, the vegetation of mountain ecosystems that are vital to the health of national economies is being rapidly cleared, and very little effort is being made to reclothe the catchments. As a result, there are frequent and devastating floods when the monsoons arrive, and severe and pernicious droughts when they depart.

In Latin America, little systematic work is being undertaken to rehabilitate the soils of the extensive savannas, and to improve the quality of their vegetation. Here again, a significantly large area of land is being virtually neglected.

Everywhere, the practice of shifting agriculture is on the increase, the period of natural fallow is being reduced, valuable forests are being destroyed, and soils are rapidly becoming degraded.

This list of the ills of tropical land-use is by no means exhaustive. It is provided merely to illustrate the gravity of the problem, and perhaps more important, to emphasize the enormous waste of land resources which occurs in the developing world either through mismanagement or because of sheer neglect. These
wasted lands are the primary concern of the International Council for Research in Agroforestry (ICRAF).

Agroforestry has been defined as a sustainable land management system which increases the overall yield of the land, combines the production of crops (including tree crops) and forest plants and/or animals simultaneously or sequentially, on the same unit of land, and applies management practices that are compatible with the cultural practices of the local population.

The practice of agroforestry is by no means new, nor is it confined to particular geographic or climatic regions. However, recognition of the importance of agroforestry has increased dramatically in recent years, especially as regards its potential for optimizing land-use in the developing countries of the tropics. Its primary aims are the production of food and the conservation and rehabilitation of the soil resources needed for future food production. As recent natural calamities such as the Sahel drought or the Asian monsoon floods have shown, the food production potential in many developing countries is marginal. In the coming years, growing populations combined with increasing pressures on finite areas of inherently fertile agricultural soils, might make the food supply situation even more precarious. Indeed, FAO has estimated that the food requirements of the developing countries would almost double in the period between 1970 and 1990. There will not only be more people on the land to feed but there will also be an increasing demand for food for the growing urban populations.

In many countries a great deal of food is now being produced at the cost of undermining the existing soil resources. It appears, therefore, that in a number of regions of the developing world there is a great possibility that the food producing resources are being impoverished and depleted at the same time as the demands upon them are increasing. Although enormous energy inputs in mechanization, fertilizers and biocides have resulted in greatly increased production on decreased acreages in the industrialized countries, it seems that, at least in the immediate future, such inputs will not be available on a large scale to the developing countries. Sustained, increased food production will therefore require in many areas the continued use of marginal lands and the development of improved varieties and more efficient farming systems.

In July 1975 the International Development Research Centre (IDRC) established a project for the identification of new research initiatives in tropical forestry which might significantly improve tropical land management. It was hoped to identify major gaps in forestry research and training, to assess the interdependence
between forestry and agriculture in low-income tropical countries, and to propose research for the optimization of land-use that might within a reasonably short time, yield results of significant economic and social impact on developing countries comparable to those achieved by the "green revolution" in agriculture.

The IDRC Project Report Trees, Food and People - Land Management in the Tropics identified 23 tropical forestry problem areas of major importance. However, the study led to the inescapable conclusion that first priority should be given to agroforestry. Despite the growing awareness of the need for "hard facts" on which agroforestry systems may be effectively based, very little research is being undertaken. When research is conducted it is often haphazard, unplanned and unco-ordinated. Those problems that are specific to agriculture on the one hand, and to forestry on the other, seem to be better served by on-going research than are the problems encountered when these production systems are combined. The IDRC Project Report therefore recommended the establishment of an internationally financed organisation, now known as the International Council for Research in Agroforestry which would support, plan and co-ordinate on a world-wide basis, research in combined land-management systems of agriculture and forestry.

This initiative was generally well received by international and bilateral agencies, and at a meeting of potential donors and other interested agencies in November 1976, a Steering Committee was appointed to consider the establishment of the proposed Council in further detail.

The Steering Committee met in Amsterdam early in April and again in June, 1977. It decided to proceed with the establishment of ICRAF along the lines proposed in the IDRC Report. It approved a draft charter for ICRAF and elected a Board of Trustees. It appointed IDRC as the Executive Agency for ICRAF until such time as the Council became a full juridical personality. It decided that the permanent headquarters of ICRAF should be in a developing country, the selection of which would be left to the Board of Trustees, including the Director-General. And it accepted the kind offer of the Government of The Netherlands to provide temporary headquarters facilities for ICRAF at the Royal Tropical Institute, Amsterdam, pending completion of arrangements for the Council's location. ICRAF maintained a small office at the Institute from August 1977 to July 1978.
NATURE OF THE COUNCIL

ICRAF is an autonomous, non-profit, international institute, the objective of which is to improve the social, economic and nutritional well-being of the peoples of developing countries by:-

(a) promoting agroforestry systems to achieve better land-use in developing countries without detriment to their environment;
(b) encouraging and supporting research and training in agroforestry systems;
(c) facilitating the collection and dissemination of information relevant to such systems; and
(d) assisting in the international co-ordination of agroforestry development.

The Council is governed by a Board of Trustees. The Board consists of equal representation from developing and developed countries.

The principal financial support for the Council is, and will be, derived from voluntary contributions provided by governments and by international public or private organisations and agencies. ICRAF's requirements will be based on estimates of expenditure as approved by the Board of Trustees.

The Council will require funds for two types of activities:-

(a) its "core" work (e.g. the collection and dissemination of hitherto unpublished agroforestry data and information; the publication of abstracts of agroforestry material; the conceptualisation and planning of a global network of field research projects in agroforestry; the publication of research results; the conducting of seminars in research techniques with special reference to agroforestry; and the training of different cadres of researchers in the "new" area of agroforestry); and
(b) its field activities (e.g. the identification, preparation and implementation of field research projects in agroforestry; and the monitoring and co-ordination of these research projects).

The Council is empowered to establish co-operative relationships with such governments, international, public or private organizations and agencies, and universities that are engaged in any activity relevant to agroforestry which it considers necessary for the realisation of its objectives.
The Council will be staffed by a small number of "core" personnel whose expertise would be supplemented from time to time by consultants. As far as possible, the research activities of the Council will be global in nature, and will be undertaken by citizens and/or national institutions of the countries in which the research is to be conducted. Where necessary, internationally recruited experts will complement the local research teams.

THE ICRAF HEADQUARTERS

Nairobi, Kenya, has been selected as the permanent Headquarters of ICRAF. This city was chosen by ICRAF's Board of Trustees from among the many which offered to host the Council, for the following reasons:

(a) there exists in Nairobi a relatively large number of international agencies and research institutes, as well as several national and foreign scientific and developmental institutions. There is therefore already in Nairobi a reservoir of international scientists whose expertise may be easily tapped;

(b) because of the existence of these scientific organizations and agencies, Nairobi is frequently visited by scientists not normally resident in Kenya;

(c) Kenya possesses one of the most efficient telecommunication systems in the developing world;

(d) Nairobi is easily accessible by air from most parts of the world;

(e) because tourism is important to Kenya's economy, there has been established in that country an excellent "visitors' infrastructure"; in addition, the immigration facilities are among the least cumbersome in the developing countries;

(f) Kenya possesses what has been classified as the best "agroforestry library in one building in the Third World." This is located at the site of the now defunct East African Agriculture and Forestry Research Organization (EAAFRO), at Muguga, near Nairobi;

(g) Kenya has considerable experience in the practice of some agroforestry systems;

(h) the Headquarters of the United Nations Environmental Programme, the United Nations "agency" entrusted with the planning and co-ordination of the world's environmental programmes, is located in Nairobi;

(i) Nairobi's climate is equable and pleasant; there should therefore be little difficulty in attracting international staff of the requisite calibre to work there.
**THE RESEARCH PROGRAMME**

The initial programme of the International Council for Research in Agroforestry is as follows:-

(a) the investigation of agroforestry methods on which to base improved farming systems to replace shifting cultivation on tropical soils;

(b) the development of agroforestry pastoral and cropping systems for the prevention of desertification and the rehabilitation of arid and semi-arid ecosystems;

(c) the application of agroforestry systems to the maintenance and improvement of the quality of tropical pasture land; and

(d) the investigation of agroforestry systems for rehabilitating vegetative cover to ameliorate and upgrade degraded land in mountain ecosystems.

These four programmes will be supplemented and unified by "core activities" which apply, in varying degrees, to all the proposed programmes:

(a) the provision of documentation services;

(b) the collection, analysis and dissemination of data and the co-ordination of research on multi-purpose trees;

(c) the collection, analysis and dissemination of data and the co-ordination of research on fodder trees;

(d) soil studies;

(e) fuelwood production studies; and

(f) training and education.
CHAPTER II
CORE PROGRAMME ACTIVITIES
DOCUMENTATION SERVICES

One of the first priorities of ICRAF is the assembly, assessment and dissemination of the existing information concerning agroforestry systems. The development of a specialised documentation centre on agroforestry is urgent because the literature which is extant must be assembled and consolidated before research is undertaken, if the danger of unnecessary replication is to be avoided. Moreover, the existing literature is not now easily available to those researchers and policy-makers of the developing countries who require it. The information is difficult to obtain because it tends to be interdisciplinary, and is often recorded in reports of narrow distribution.

Another important element of ICRAF's information-gathering function is the employment of staff to collect hard data on promising agroforestry practices which have hitherto been unrecorded. Indeed, a global survey of those experiments and trials which have already been completed, and which are now being undertaken, has already been begun by ICRAF.

The ICRAF Documentation Centre will have its own indexing and abstracting capability, will possess a specialised documentation unit, and will be able to provide information regularly and on request to decisionmakers, scientists and technicians, other information centres, and the aid-sponsoring organizations. It will work in close co-operation with other relevant information services and will establish a working relationship with the existing library resources in Kenya.

With the generous assistance of the Royal Tropical Institute, Amsterdam, the nucleus of the Documentation Centre has been created from the collection of references and documents in the major European libraries. It is intended to produce the first ICRAF state of the art report early in 1979. This publication, in addition to describing the existing knowledge on agroforestry systems, will identify problem areas in which essential "hard-core" information is lacking, and will suggest possible lines of research.
MULTI-PURPOSE TREES

Traditionally, foresters have tended to regenerate trees merely for the production of wood. They have, in large measure, ignored the potentiality of many forest tree species for producing not only wood, but also fodder and food from their leaves, fruit and other cellulosic material. In addition, much systematic work has not been done on the selection of tree species which combine these desirable multi-product characteristics with the ability to improve the fertility, structure and texture of the soil.

Moreover, very little research has been conducted on the optimum rotations of these multi-purpose species, and on their management, in order that the optimum combined yields of fodder, food and wood might be obtained, while maintaining the fertility of the soil and ensuring that the ecosystem does not deteriorate through the practices that are followed.

The number of multi-purpose trees which might be used in agroforestry systems is almost infinite. Clear criteria for the selection of those species which have the greatest immediate potential must therefore be developed. In addition to assembling and assessing all the available information on these species, research is required to fill the very large gaps which are already known to exist in our knowledge. Reliable chemical analyses of the fodder, food, or other products of the trees is often not available, as is knowledge of their distribution, propagation characteristics, and life cycle.

ICRAF proposes to assemble, analyse and publish the existing data, and to stimulate and co-ordinate research in those areas where further investigation is considered necessary.

FODDER TREES

A high proportion of the trees and shrubs of the tropics provides food for domestic and wild animals. Leaves, shoots, tender twigs and stems, fruits and pods are all eaten to a varying extent by herbivorous animals. Much is not known however, about the effective utilization of browse as animal feed, and even less, on the establishment of browse tree groves.

Browse tends to have a high fibre content, and often tree fodder is out of the reach of grazing animals. On the other hand the nutritional value of browse is generally less subject to seasonal
variation than grass. Fortunately, trees may be grown to specified heights by, for example, removing apical buds. In addition, animals can be fed in a controlled manner by selectively cutting branches (pollarding) according to a planned programme. Hence, the utilization of fodder can be manipulated without the need for fencing. Some studies have indicated that where fodder is cut by hand to feed animals, the labour utilized is less than a quarter of that required to collect herbaceous fodder. Depending on the ecological conditions, tree fodder may therefore be used for day-to-day mixed feeding, for seasonal reserves or for drought feeding. A recent study in Nepal has identified over 50 species of fodder trees which are being harvested by the local farmers.

Reliable, comparable data on the chemical content of most tree fodder species are lacking. The collection of appropriate plant material and the required chemical analysis will therefore be an early core activity of ICRAF. Nutritional and digestability trials on promising species will also be promoted.

Studies will also be encouraged on the optimum time of harvesting tree fodder so as to optimise fodder yields and fodder quality. Species mixtures could also be planned on the information obtained from such studies.

It will also be necessary to conduct research on the optimum harvesting methods for tree fodder in order to minimize damage to trees, to maximize regeneration rates, and to create or maintain useful tree forms.

Analyses of the nutrient characteristics of the non-wood products of those tree species that are most abundant in the natural forests of the developing countries will also be pursued. It is possible that many of the species now deliberately eliminated as weeds by tropical foresters, because they do not produce wood that is considered at present to be of utilizable quality, may yield non-wood products of even greater benefit to mankind than wood.

**FUELWOOD PRODUCTION**

In 1975, when 2,431 million cubic metres of wood were harvested from the world’s forests, 1,182 million cubic metres (or nearly 49 per cent of the total volume removed) were utilized for fuelwood. 86 per cent of this fuelwood was removed and consumed in the developing countries and tropical regions of Africa, Central and South America, and Asia.
86.9 per cent of the wood harvested in Africa, 82.0 per cent of that in Central and South America, and 73.2 per cent of that which was felled in Asia and the Far East were utilized for fuelwood.

The rural areas of most of the developing countries are almost totally dependent on non-commercial organic fuels for cooking, heating, agricultural processing and industry. Domestic energy requirements are estimated to vary from about 1.25 million kilocalories per caput in the warm lowland tropics to over 6 million kilocalories in cold upland areas. The equivalent annual requirement for fuelwood ranges from 0.5 cubic metres to over 2 cubic metres.

Most fuelwood which is used does not enter the market, but is collected as needed within walking distance of the consumer. As fuelwood has a high ratio of weight to calorific value, it is seldom profitable to transport it long distances even for urban markets. The demand for fuelwood, therefore, places the heaviest pressures on ligneous vegetation closest to centres of population.

Where fuelwood is in short supply, food production may be adversely affected as animal dung and crop residues which could be utilized as soil nutrients and organic matter are often burned for cooking and heating. Moreover, as rural labour is increasingly diverted to fuel collecting activities, agricultural production is often neglected.

While changing economic and technological conditions may eventually make other types of fuel available to rural families in developing countries, local supplies of wood and other organic materials will continue to meet the bulk of their energy requirements in the foreseeable future. Except where site productivity and market proximity are particularly favourable, fuelwood production as a cash crop is unlikely to be a profitable use of land or labour. Where trees serve more than one function, however, their suitability as wood fuel would invariably be an important factor. For instance, trees to form windbreaks, shade trees, fodder trees and trees required for controlled fallows could all be selected with fuelwood production in mind.

The most efficient fuelwood species may be quite different from the best timber or pole species, and the silvicultural strategies for optimizing production may differ also. For integration into small farming systems, fuelwood species should ideally be multi-purpose, of high calorific value and easy to establish and manage. These biotic, utilisation and management aspects of the subject entail
investigation and research. Research is also required on optimal harvesting methods for the small farmer who wishes a sustained firewood supply. ICRAF’s fuelwood focus will be on these problems.

**SOIL STUDIES**

Implicit in the very definition of ICRAF is the use of trees to support arable agriculture in the most direct way. Since agriculture is essentially the management of soils for food production, the effect of trees on soil fertility is basic to all agroforestry programmes. The mechanism responsible for soil fertility restoration under bush fallow is very complex. Not surprisingly, therefore, the studies which have been carried out in tropical areas appear to give conflicting results. This is mainly due to a lack of standardization of sampling procedures and analytical methods. A related problem is that inferences have often been drawn from samples taken from different locations at different stages of regeneration and not from continually monitored sample fields.

Research on soil changes normally involves three distinct types of evidence: (i) evidence from crop yields, (ii) evidence of direct observation of the soil, and (iii) evidence from fertilizer trials. For obvious reasons, the monitoring of soil changes during the fallow period must be limited to direct observation; however, the apparent simplicity of this method is obviated by the practical difficulties caused by soil heterogeneity in the tropics. While fairly simple standardized methods exist for the determination of the humic content of soils, available nitrogen, available phosphorous, nutrient cations and soil pH, the interpretation of results is not always easy. The quantitative determination of soil structure, porosity, texture and water retention capacity are even more difficult to standardize and interpret. The development of an optimal package of soil evaluation characteristics particularly suited to the problem of natural fertility restoration will therefore be given early priority in the project network.

It is proposed to arrange intensive workshops which will be attended by the research institutions involved and by experienced international experts in order to develop the methodologies.

**TRAINING AND EDUCATION**

There would be little need for technical assistance if the developing countries possessed an adequate number of trained personnel able to transfer and adapt existing technology and
knowledge to their specific requirements, to identify both the crucial problem areas and the strengths of their national systems in the developmental process, to formulate plans and policies for the solution of the problems and the harnessing of the strengths, and to implement these plans and policies efficiently and effectively.

There is, in general, a shortage of trained manpower in almost all sectors in the developing countries. This shortage is particularly acute in the field of agroforestry, because, as the discipline is relatively new, the subject is not formally taught at any level in the training institutions of the world.

Indeed, agriculturists and foresters often consider themselves not only to be in competition for land, but also to represent interests which are in antipathy. As a result, in both national and international organizations, there is often overt strife between these two important land-using groups. As a consequence, much land is badly utilized.

Training and education are therefore specially important aspects of ICRAF’s programmes. The training of researchers both through practical on-the-job research experience and by normal institutional courses is imperative and will be an integral part of each research project. In addition, the training of existing agriculture and forestry extension officers in agroforestry alternatives of land-use is important. Short-term regional training courses for instructors in technical schools and universities will also be organized at the appropriate time to stimulate the introduction of agroforestry concepts into the curricula of these institutions.

Moreover, it is hoped that through the information which is being collected from published data, from the field visits of ICRAF consultants and staff, and from the research to be undertaken in various regions of the world in ICRAF sponsored projects, a fund of knowledge will be gained, sufficient to develop and formulate a body of agroforestry principles.
CHAPTER III
FIELD PROGRAMME ACTIVITIES
SHIFTING CULTIVATION

THE SCOPE OF THE PROBLEM

The term shifting cultivation embraces a large variety of traditional forms of agriculture. In general the systems so described are characterized by the felling and burning of woody vegetation, followed by one to several years of cultivation, and then by a period of forest or brush fallow. After fallow, the cycle is repeated.

Shifting cultivation is a form of land-use well adapted to the environment under certain socio-economic conditions. The nutrients released upon clearing and burning the forest are intensively utilized for food production, and the soil structure, organic matter and nutrient status are restored during the natural fallow.

Traditionally, shifting cultivation involved communities with strong historical, social and economic roots in the forests. The custom and knowledge of the development of both crops and trees which these communities possessed, ensured a relatively stable balance within the ecological environment. Moreover, the relatively low intensity of the populations which the system supported almost always permitted the resuscitation of the soil before the cultivators returned to a fallow area. Today, shifting cultivation is carried out under a number of climatic and ecological conditions. The period of cultivation, the size of area, the duration of fallow, the methods of planting and the crops involved all differ widely from place to place. The major common characteristic appears to be a dependence on the slow natural processes to regenerate the soil.

It is estimated that about 36 million square kilometres of land, or about 30 percent of the world's exploitable soils, are at present under shifting cultivation. They produce the bulk of the food for more than 250 million people or about 8 percent of the world's population. Shifting cultivation is practised in most tropical countries in Africa, South America, Oceanic and Southeast Asia.

Throughout the world, the practice of shifting cultivation is changing rapidly. In most cases, the changes have been induced by demographic factors such as increased population growth rates and population migration. The introduction of cash crops into some
communities has also had a marked effect. In some instances, the policies of Government have led to a reduction of the area of land available for shifting agriculture. For example, the large scale reservation of land for forests, though desirable in most situations, has resulted in a decrease in the traditional fallow periods of most shifting cultivators.

It is true that in many countries viable new intensive farming systems have emerged and are still being evolved. However, there has been very little research, and consequently little innovation, on the rationalisation and improvement of the farming systems of shifting cultivators on the often inherently infertile soils of the forests on which they work. What has happened is that there has been a shortening of the fallow period of the cultivation cycle, which has inevitably led to soil degradation, often to the point of making the land incapable of supporting further crop production.

An increasing proportion of shifting cultivators have no legal or cultural ties to the land they cultivate, but are the product of economic and social circumstances which force them to clear land for food or cash crop production. Either because of a lack of knowledge of the requirements of shifting cultivation or because of a scarcity of land at his disposal the opportunistic farmer either cultivates the same plot until the soil is exhausted or limits his fallow to the shortest possible duration. Sometimes a short period of grazing follows cropping before the impoverished land is abandoned. After such severe degradation, the forest may be unable to re-establish itself.

Conservationists have long been aware of the damage that is caused, by uncontrolled shifting cultivation, to the forest soil and water resources of the tropics and have tried to stimulate concern and remedial action at both the national and international levels. The Food and Agriculture Organization has attempted to quantify the status and trends of land-use with respect to shifting cultivation, but a dearth of reliable data made the exercise difficult. However, the magnitude of the problem is obvious. Between 0.4 percent and 0.5 percent of the total land area of the tropics is being cleared annually by shifting cultivators, almost two-thirds of the land cleared being under upland high forest. On average, 14 percent of the total population of the countries studied by FAO is engaged in shifting cultivation, and the number thus engaged increases at approximately the same rate of increase of the overall population. Only about 15 percent of the timber cut is utilized, the wastage being estimated at $50 per hectare per annum.

The practice of shifting cultivation has destroyed many tens of
thousands of hectares of forests. Valuable timber resources have been depleted and the protective cover removed from vast watershed areas. Flooding and silting of lowlands resulted and river basins have been desiccated. Perhaps most serious is the loss of soil fertility in areas where food production is already a serious problem.

Agronomists have often argued that the intensification of agriculture on better suited soils would provide an alternative livelihood for peasants who practise shifting cultivation. While impressive advances have been made, especially in the field of cereal agronomy in the tropics, these permanent forms of agriculture have not expanded rapidly enough to reduce the proportion of the population depending on shifting agriculture. In other cases, attempts to transform shifting cultivation on the better soils to permanent forms of agriculture have failed to be adaptable to the socio-economic basis of the system.

Restrictive policies and legislation to confine cultivation to certain areas, usually by excluding shifting cultivators from defined forest areas have not been altogether successful. On the one hand, the enforcement of such policies is almost impossible and, on the other hand, even where they are enforced, their influence tends to be limited to narrowly defined forest reserves.

One highly successful method of controlling and harnessing shifting cultivation is the well known *taungya* system, whereby cultivators are permitted to clear an area of forest land and sow agricultural crops at the same time as commercially valuable tree plantations are established. The farmers produce several successive crops before agricultural yields diminish and the forester has an economical method of establishing a forest plantation.

*Taungya* however, has been used by governments as a system for minimizing the costs of forest plantation establishment. It depends, *as practised at present* on land shortage and unemployment. It does not generally involve farmers with a cultural background of shifting cultivation and it often requires centralized administration and supervision. This, not surprisingly, restricts any stimulus towards self-generated activities.

The forced resettlement of shifting cultivators has also been resorted to in several countries. As a generalization, such policies normally only temporarily relieve the pressure on fragile soils and
often involve the colonization of new areas of forest land where the alternative forms of sedentary agriculture do not always develop as anticipated, but where the protective values of the forest may nevertheless be overlooked.

Given the pressures on modern tropical societies, shifting cultivation must inevitably be superseded by new land-use patterns. Stable long-term management systems capable of higher production per unit area must be developed. Because of the ecological diversity of the areas now under shifting cultivation, and because of the variation in the socio-economic status of the societies which practise the system, there can be no one solution. In some cases, topography and soil types are such that permanent forest plantations or natural forests seem the only sensible land-use. At the other extreme, there are large areas of land now under shifting cultivation which could support known permanent forms of agriculture, given the necessary modern inputs. The introduction of fertilizers, improved crop varieties, suitable cultivation methods and pest and weed control programmes would, of course, be important components of this latter type of land-use.

There are large areas on which cultivation is practised, however, where the development of a long-term solution appears to be neither in the traditional forestry sector nor in the agriculture sector. Moreover, even in some of the areas in which it appears that permanent intensive agriculture might be the most useful type of land-use to pursue, the necessary inputs are generally not available or are too costly. Developing land-use systems for these residual areas is the mandate of ICRAF.

We may distinguish, on the basis of vegetation, shifting cultivation of the forests, of the bush savannas, and of the grassland areas. In virtually all cases the climatic requirements for the development of a forest ecosystem are present. Agroforestry systems are therefore a viable alternative. Agroforestry systems can not only replace some of the shifting cultivation that is practised, but can also form the basis of rehabilitating soils which have been degraded through uncontrolled shifting cultivation. In other words, it should be possible not only to intensify land-use but also to make more land available for food and wood production.

**THE ICRAF FOCUS**

The lowland high-rainfall tropical forest zones of the world have been chosen for the focus of the study of shifting cultivation and the development of alternative agroforestry land management systems. These zones represent the largest single pantropical ecological complex in which shifting cultivation is practised.
Two generalizations may be made about the agricultural potential of soils of the humid tropics. Land of medium to high cropping potential is confined to soils which are being, or have been recently, geologically rejuvenated either by sediment deposition or by volcanic activity. These soils are intensively utilized and well studied. The major problem on them is man-made erosion.

On the other hand, the zonal soils of old land surfaces have a moderately low to very low inherent fertility. These soils occupy the largest land area of the humid tropics and are normally covered with forest ecosystems which possess the highest biomass and gross primary production of all terrestrial ecosystems. This apparent contradiction is due to the fact that the nutrient level built up over time is maintained in the system by a cycle of uptake, deposition, uptake and deposition again.

When the tropical forest on these old soils is felled and burned, the cycle is broken and the humus and available nutrient content decrease significantly after only a few years. This process of soil degradation proceeds fastest where temperatures are highest and rainfall greatest. If the natural vegetation is restored before soil structure and organic matter decline below critical levels, the nutrient level can be rebuilt. Shifting cultivation is based on this principle.

Successful long-term sustained yield systems in the humid tropics will, therefore depend on the maintenance of soil nutrients and organic matter at a level suitable for the particular type of land-use. This level may inevitably be lower than that generally obtained under forests and may display cyclic variations; it cannot however be allowed to decrease continuously.

Typical and comparable soil catenas will be chosen in all three continental areas and a research programme with the following interrelated components carried out on carefully selected sites of each continent:

(a) description of the traditional shifting cultivation system and its effect on the soil;
(b) testing of tree fallows of controlled botanical composition;
(c) espacement trials of tree planting in conjunction with crop cultivation;
(d) multi-storey continuous cropping systems;
(e) regeneration of soils degraded by intensive leaching.
DESCRIPTION OF THE TRADITIONAL SHIFTING CULTIVATION AND ITS EFFECTS ON THE SOIL

The evolution of traditional shifting cultivation into rational agroforestry systems which take account of existing socio-economic conditions, will require, first, a knowledge of the current practices and their effects. The research to be undertaken would therefore entail:

(a) socio-economic descriptions of the shifting cultivator population including their local knowledge of crops, their attitude to the land and forest, their response to innovations, their relationship to the market economy, and the present division of labour within the society;

(b) descriptions of the agronomic practices employed, including methods of clearing and planting, the agricultural crop species planted, crop sequences, times of planting, spacing, methods of weed and pests control, harvesting and storage systems;

(c) descriptions of soil changes during the cropping period including changes in the physical conditions, nutrient status and the composition of fauna and flora; and

(d) descriptions of soil changes during the fallow period.

TESTING OF TREE FALLOWS OF CONTROLLED BOTANICAL COMPOSITION

Because of the known ameliorating effects of the natural forest on the soil it has generally been assumed that tree plantations would also restore fertility. The evidence indicates that this is not necessarily the case. There is therefore a need to select tree species and to evolve patterns of establishment which do restore soils. Presumably, rotations could be considerably shorter than natural fallow periods if the species were selected primarily for soil building rather than for wood or pulp production. The synergistic effects of a number of forest species might also be explored.

Multi-purpose species would initially be tested in small species elimination trials. The prime purpose of these trials would be the selection of species and/or provenances with suitable survival and growth rates for each site.

The elimination trials would be followed by replicated soil regeneration trials of selected species. In these trials the soil changes over time would be monitored and the yield (wood, fodder,
nuts, etc) of the trees evaluated. Some trials would be established early with species, the survival and growth characteristics of which are already known. Planting would be done at the end of the normal crop production phase of the shifting cultivation cycle.

TREE PLANTING ESPACEMENT TRIALS IN CONJUNCTION WITH CROP CULTIVATION

In the Taungya method of establishing forest plantations, initial tree espacements are normally based on purely silvicultural criteria. Preliminary evidence indicates that where tree crops are planted with agricultural crops, silvicultural tending costs are significantly decreased. The presence of the agricultural crop obviates the need for the early closing of the canopy in order to reduce soil exposure and weed competition. However, wide espacements often lead to an increased rate in the decline of soil fertility. Therefore, if the system is to optimise and sustain the combined productivity of both the forest and food crop, the trees chosen must either be pruned, be self-pruning, or inherently bear light branches. In addition, the forest and food species, collectively or separately must have soil ameliorating properties.

Two types of espacement trials are required, (a) espacement trials under typical Taungya plantation establishment conditions in which popularly planted species would be tested at various espacements, and soil changes, crop yields, tree increment and timber quality carefully monitored; and (b) espacement trials of soil fertility regeneration species selected for optimal tree fallows, in which similar trials would be involved except that wider espacements would be tested and the multi-purpose yields of the trees evaluated. It is conceivable that these trials could lead to tree and crop combinations that could be continuously maintained.

MULTI-STOREY CONTINUOUS CROPPING SYSTEMS

Most of the success stories associated with the introduction of high-yielding cereal varieties in the tropics have occurred in areas with more or less inherently productive soils and where irrigation was available or water was subject to control. In most areas of the humid tropics, however, the replacement of shifting cultivation by permanent or semi-permanent agriculture is limited by one or a combination of the following physical factors:

(a) frequent periods of moisture stress because of the poor water retention capacity of the soils;
(b) high soil temperatures;
(c) high rainfall intensities, leading to leaching and erosion;
(d) high night temperatures reducing net photosynthesis; and
(e) low or uneconomic response to fertilizers.

Under these conditions few viable alternatives to bush fallow have yet been evolved. Studies, at the International Institute of Tropical Agriculture (IITA), of farmers attempting to cope with the diminishing productivity of land and labour indicate the components which may be necessary in a continuous cropping system:

(a) concentration of production on smaller areas to which are applied organic materials to improve the soil fertility;
(b) minimum tillage, combined with mulching to control weeds and improve soil fertility;
(c) intercropping to provide continuous plant cover; and
(d) multi-storey cropping (including tree and bush crops).

Agroforestry systems may be designed to improve these production strategies.

A multiple cropping system in which trees are a component is both perennial and multi-storey. Coconut palm (in India), rubber (in Indonesia) and oil palm (in West Africa) have, in certain circumstances, become the perennial component of viable continuous cropping systems.

In many areas, especially in places with high population densities, it is unrealistic to expect farmers to take land out of production for the establishment of even short-term fallows. Research is, therefore, urgently required to test mixtures of tree and crop species that might form profitable continuous cropping systems to increase the level of sustained productivity on land which has already passed out of the shifting cultivation phase.

Such farming systems would require that the agronomic packages being developed by agricultural research institutions, such as The International Centre of Tropical Agriculture (CIAT), and the International Institute of Tropical Agriculture (IITA) be designed with agroforestry in mind. The systems may also be fairly location specific with limited transferability of specific components.
Where the original forest vegetation has been removed by shifting cultivation, perennial weeds may invade the cultivated area, spreading rapidly. When the labour involved in controlling the weeds exceeds that of clearing more forest, the farmer may abandon the cultivated area. Often, the original forest cover is unable to re-establish itself and intensive leaching causes further soil degradation.

The spread of *Imperata* grassland is a typical example of a perennial weed which effectively denies the farmer the use of large areas of land in the tropics. Its control and eradication is a matter of great urgency in a number of developing countries. *Imperata cylindrica* also known as lalang grass, alang-alang, cogon grass, and spear grass, is a serious pest in many parts of South East Asia, Africa and South America, especially in cultivated upland areas. In 1970 it was estimated that in Indonesia alone 16 million hectares were covered with *Imperata* grass, with an annual increase of 150,000 hectares.

Experiments show that *Imperata* can be killed by various chemical and mechanical methods. However, these methods are very costly and the prevention of regrowth from the underground parts of the plant still presents a problem, as does the restoration of soil fertility.

Natural succession from *Imperata* vegetation to secondary forests sometimes takes place and the circumstances of the occurrence have been studied. It follows therefore that one approach to the rehabilitation of *Imperata* infested soils would be to employ methods that are based on the principles of natural succession. Indeed, trials have been carried out with *Gliricidia maculata*, *Moghania macrophylla* and *Leucaena leucocephala* which indicate that these species can be made to compete effectively with the weed. The challenge however is not only to reclaim these lands for food production, but also to develop long-term management systems which will prevent recolonization by *Imperata*.

The methodology evolved for the suppression and eradication of *Imperata* and for the improvement of the soil, could be applied to the solution of other similar weed problems in the tropics. Research is required on the selection of suitable woody species to be used in the artificial succession of the various weeds. Work is also necessary on low cost establishment and maintenance methods.
The species to be tested should:
— compete effectively with the weeds;
— yield some products that are harvestable within the first years (leaf fodder, nuts);
— have a short rotation;
— provide a marketable wood product; and
— build up soil fertility and structure.

Generally, because of the nature of this type of weed problem, the most suitable woody species would be those which close canopy quickly. They may therefore be unsuitable for mixed cropping systems. However, trials should be carried out to ascertain the minimum shading necessary to prevent recolonization by weeds, and the thinning regimes to be followed in the management of the plantations establishment. The cropping system eventually evolved might therefore involve either a rotation of a shade-producing tree fallow with a crop production cycle or a shade-producing tree plantation, which after thinning permits the growth of food crops or fodder or the practice of grazing. It may well be, also, that the most suitable trees for incorporation in the rotation alternative may not necessarily be the most effective for the initial suppression of perennial weeds, but may be useful in preventing the degradation of new areas of shifting cultivation.
AGROFORESTRY IN ARID ZONES

THE SCOPE OF THE PROBLEM

ICRAF intends to concentrate its arid zone programme on those tropical and sub-desert climatic zones which are represented in Africa, for example, by the Sudan and the Sahel Savannas. The zones extend in Africa in a narrow band across the continent south of the Sahara, including at least part of Senegal, Mauritania, Mali, Upper Volta, Niger, Nigeria, Chad, Sudan, Ethiopia and Somalia. In eastern and southern Africa, similar climatic zones are found in Madagascar, Kenya, Tanzania, Mozambique, Zambia, Zimbabwe, Namibia, Botswana and Angola. Homologous climatic areas are located in northwest India and Pakistan, in northern Australia and in eastern Brazil.

The climate is characterized by a mean annual rainfall ranging from 250mm to 1,100mm, with potential evapotranspiration of 1,400mm to 2,200mm and a dry season of six months or more. The mean annual humid period, during which rainfall exceeds potential evapotranspiration, ranges from almost nil to about 140 days, and the season during which annual plants can be grown from 55 to 200 days. During the growing season the night temperatures tend to remain high.

Studies of these zones show a history of degradation of vegetation and soils, and a reduced productivity of both natural and "managed" ecosystems with adverse effects on the standard of living of the indigenous populations. The arid environment is characterized not only by climatic extremes but also by uncertainly. As rainfall decreases, the predictability of the rainfall also decreases.

Desertification of the arid zones is caused primarily by man. Traditionally, the populations coped with the extreme environment by practising forms of land-use that were extensive, by being extremely mobile, and by being part of a social system that was based on economic inter-dependence. Rapidly growing populations, reinforced by rising expectations in living standards and the introduction of inappropriate technologies without adequate social control, have resulted in increased livestock numbers, the removal of protective trees and shrubs for fuel and timber, and the cultivation of soils that are ill-suited to arable agriculture.

At present the arid zones are utilized mainly for the production of livestock. The system, which is practised primarily by nomadic
peoples, is extensive, the natural vegetation being the fundamental resource that is utilized. Overgrazing and trampling have, in many cases, destroyed the perennial vegetation (both woody and herbaceous) and have led to soil compaction, and to erosion. Moreover, the dependence on annual pasture leads to marked fluctuations in carrying capacity between drier and wetter seasons. Optimum stocking rates are, as a result, almost impossible to maintain. Sustained production, consistent with the conservation of pasture resources, is therefore both a technical and a social problem; technical in that native vegetation should be both rehabilitated and upgraded for long-term yields, and social in that the management systems to be evolved must take into account the traditions as well as the aspirations of the local population.

Although the area under rain-fed crops in dry lands is much smaller than that used by pastoralists, the population supported by farming is far greater. The proportion of the land used for farming is also increasing. As a general rule, arid and semi-arid areas with an annual average rainfall exceeding 350mm are, depending on soil conditions, suitable for the production of annual agricultural crops. However, the principal characteristics of the agriculture of the area are that yields per unit area are low and soil fertility is restored by fallows. The drier the area the lower the yield and the longer the fallow period that is required.

Subsistence crops, mainly graminaceous or leguminous grains such as millet, sorghum, maize and cow-pea are often grown under more marginal conditions than cash crops, e.g. ground nuts and cotton. It is therefore in the more arid parts that tree-based cash crops are most required.

Many intensive dryland farming practices, while increasing yields in the short-term, have made the soils more vulnerable to erosion. Because of the low moisture holding capacity of the soils and the leaching of nutrients, abandoned farmlands often do not recover quickly and sometimes not at all. This is a serious form of desertification since the limited areas of maximum agricultural potential are degraded to a state often beyond that caused by overgrazing. In areas where there is a close linkage between dryland cultivation and animal-based systems, through the grazing of stubble, use of manures, etc., the collapse of the crop-based systems tends to lead to failure of the pastoral.

The only available energy source for the rural and much of the urban populations of the arid zones is organic, principally wood and charcoal. Since the tree density is not high, vast areas of arid lands are deforested by the increasing fuel needs of the expanding
Because of the overgrazing of young plants, and also because of climatic and edaphic factors, natural regeneration rates are very low. Consequently, in many cases, trees and shrubs completely disappear from vast tracts of land. While consumption levels in these areas are difficult to estimate, 0.6 m$^3$ of wood per caput per annum is the generally accepted figure. Natural savanna vegetation rarely produces more than 1 to 1.5 m$^3$ per hectare per annum, hence the natural annual yields from one hectare can barely meet the requirements of two persons. Not surprisingly, in some countries removals have exceeded increments for over 10 years.

From the foresters' point of view, the arid zones present only marginal conditions for tree growth. Reforestation for timber production is therefore often uneconomic due to the high cost of establishment and the low productivity. Species must therefore be selected with other important features in mind: fuel production, rehabilitating soil structure and fertility, preventing wind and water erosion, providing fodder for animals, improving the microclimate, and providing harvestable cash crops (such as nuts or gums).

In the past quarter century, forestry research in the arid zones has been oriented to the problems of fuel supply, windbreaks and dune stabilization, and considerable knowledge is available concerning the species and methods best suited to these intensive types of tree establishment. Exotic species of trees, for instance, are known to produce 5 to 20 m$^3$ per hectare per annum of fuelwood, about 10 times the natural wood yield of savanna vegetation. Much less is known however about the establishment of trees for providing animal fodder or for maintaining soil productivity and very little work has been done on the management of indigenous trees producing human food or annually harvestable cash crops.

**THE ICRAF FOCUS**

Four broad areas of agroforestry emphasis in supporting and improving the economy of arid zones have been identified:

- (a) intensive fuelwood production;
- (b) integration of tree with animal production;
- (c) integration of tree with crop production;
- (d) multi-purpose cash crops from trees.

Each of these broad areas requires two types of research; research on management (farming) systems and research on the selection and silviculture of suitable tree species. The management problems tend to be more localized in nature and more dictated by
the particular developmental strategies of the social and political units involved. In order to narrow ICRAF's focus to those areas of research which appear to possess a high likelihood of application in the near future, and which do not compete with other international efforts, it is intended that the primary focus be the integration of agroforestry with crop production. Since unsuitable crop production systems present a threat to the best available land, and since an increasing proportion of the population of arid areas will depend on crop production for their livelihood, the long-term effects of this focus will be greatest. Also, since the basis of agroforestry in conjunction with crop production will be multi-purpose species, the technological advances made in this area of concentration will at least be partly applicable to those management systems that are evolved in other agroforestry areas.

Research on trees for the maintenance and rehabilitation of soil fertility will therefore be given the highest priority, followed by research on fodder trees and non-wood cash crops. The adoption of new species for intensive fuel production will stem from these activities.

TREES FOR THE MAINTENANCE AND REHABILITATION OF SOIL FERTILITY

The arid zone tree that has received the greatest attention is *Acacia albida*. This tree has a long tap root which does not compete with surface crops for nutrients or moisture, but which acts as a nutrient pump bringing nutrients back to the upper soil root zone of most agricultural crops and grasses.

As it is a legume, it is also capable of fixing atmospheric nitrogen. It sheds its leaves at the beginning of the rains when they decompose rapidly to release plant nutrients at the time they are most needed. It thus, at the same time, avoids the shading of agricultural crops planted beneath it. During the dry season the large crown of the tree shades the soil and animals, and provides a windbreak which decreases desiccation. The branches may be lopped for emergency cattle fodder and large amounts of nutritive seed pods are produced annually. The wood may be used as fuel.

Research in India indicates that Prosopis *cineraria* has at least some of the same properties.

At least one research site would be chosen in each of three major typical arid agricultural zones (from the point of view of rainfall and soil). Parallel research would be carried out in each of
these areas along the following lines:

(a) Elimination trials for indigenous and exotic xerophytic multi-purpose species

The purpose of these trials would be to test species outside their natural ecological zones (e.g. Acacia Senegal, Prosopis juliflora), and to determine the suitability for artificial regeneration of species not yet evaluated (e.g. Cadaba sp. and Boscia sp.). At the same time these trials would be used as a basis of preliminary screening of the effect of the species on soil quality, their tree form, their fodder productivity, the nutritive value and the palatability of the fodder, and their production of non-wood harvestable products (vegetable, seeds, gums, etc).

(b) Multiplication and establishment of multi-purpose species

Advanced nursery and silvicultural techniques for arid areas are well developed (seed treatment, multiplication by cuttings, use of water conserving microcatchments, etc). The optimum methods for most of the multi-purpose species selected above will require careful elaboration, however. The ideal establishment method should not require the infrastructure and supervision of a Forest Service. Direct seeding establishment methods to eliminate the high cost of nurseries and replanting need some creative research attention.

(c) Management of multi-purpose species in arid land crop production systems

Where the value of a certain tree species in crop production systems is already well known (i.e. Acacia albida, Azadirachta indica), growth trials may be initiated immediately to ascertain, at various espacements, the growth rate (wood increment) and non-wood production of the plantations and their effect on soil structure, nutrient content and organic matter under various annual food crop production regimes. The purpose would be to arrive at a management strategy giving optimum tree spacing and optimum crop rotation. The beneficial effects of more than one tree species would be combined in some management systems. Espacement strategies would also take into account the necessity for leaving wide avenues for possible future mechanized cultivation.

FODDER TREES IN ARID LAND PASTORAL MANAGEMENT

The surface area covered by the arid regions of the world is so great that it is likely that plantations can be established on only a
small proportion of the zone, at least in the short and medium term. It is therefore necessary to supplement artificial regeneration schemes with measures that are designed to prevent the further destruction of existing resources and to regenerate those natural forests which have already been degraded.

However, the nomadic and semi-nomadic nature of the livestock industry of the zone is, in many instances, more restrictive to the practice of forestry than are the ecological factors. Consequently, physical and biological research must be accompanied by studies of the societies which inhabit this area if appropriate land management systems are to be evolved. While management of the natural vegetation must be based on sound ecological principles the policies and procedures by which they are enforced can only be effective if they are relevant to the existing culture of the livestock owners and to other forest users, and if they are adopted as a component of the wider resource policies of the particular country.

Accordingly, ICRAF proposes the following programme:

(a) socio-economic studies of the existing land-use patterns of selected nomadic and semi-nomadic livestock herders with particular reference to migration routes, ownership of animals, and the existing social structures which might be adapted to control stocking and range use;

(b) studies of the grazing and browsing behaviour of cattle in various seasons to ascertain the importance of ligneous species for cattle fodder and their palatability preferences;

(c) nutritional analysis of the fodder of ligneous species;

(d) research on the optimal pollarding methods for selected species, including their yields at various harvesting rates and the effect of different pollarding procedures on tree survival, vigour and form. The results of these trials will also be valuable in proposing management plans for forage tree plantations;

(e) trials on grazing and browsing rotation periods for optimum utilization of woody pastures under various rainfall and soil patterns. These trials should be carried out with the support, and involving the decisions, of the local people;

(f) studies of the ecology of the most desirable ligneous species (from the multi-purpose point of view) with a view to the development of methods of assisting regeneration. For example, the prevention of insect degradations of *Acacia* seeds, or the building of microcatchments around
selected species; and

g) the development of optimal planting strategies for
multi-purpose fuel plantation windbreaks around
villages and water resources. These may also be con-
sidered emergency fodder reserves in times of drought.

THE MANAGEMENT OF MULTI-PURPOSE TREE CASH CROPS

Many arid tree species produce important cash crops, such as
nuts, fruits, tannins, oils, saponins, natural pesticides, fibres and
gums, but the knowledge on which to base management decisions
for optimum productivity and maximum regeneration is lacking.
Among the many tree crops which require study are: *Acacia
scorpioides*, *Acacia Senegal*, *Balanites aegyptica*, *Borassus aethiopi-
urn*, *Hyphaene thebaica*.

Specific studies should also be conducted on honey-producing
species. As a general rule, larger honey crops are stored by bees
which must prepare for a long dearth period. It appears, therefore,
that the semi-arid zones of the world might possess a very high
honey production potential.

The studies should embrace:
(a) the present distribution and density of those species
which may produce cash crops;
(b) the potential demand for the various products of the
species examined;
(c) the natural regeneration of the species;
(d) optimum harvesting rates and times, and post harvest
treatment of products; and
(e) artificial establishment of plantations in conjunction
with crop agriculture-
AGROFORESTRY IN THE OPEN GRASS SAVANNAS

THE SCOPE OF THE PROBLEM

The infertile acid soil savanna lands of the lowland American tropics cover an area of approximately 300 million hectares. The tropical savanna climate of the zone is characterized by a unimodal rainfall pattern with strongly contrasting wet and dry seasons. The total annual rainfall is high (1,000-3000 mm) but differs from one part to another, as does the length of the dry season. The relative humidity of the air is also high, ranging from 80 per cent in the wet season to 50 to 60 per cent in the dry season. There is little variation in the annual mean air temperature (25 to 28°C) though it is slightly higher in the dry season. The daily variation between minimum and maximum air temperature, however, tends to be large (10°C). In addition to the Colombian Llanos, similar ecological conditions occur in the Gran Sabana of Venezuela, the Rupununi savannas of Guyana and the Campo Cerrado of Brazil.

The types of savanna vegetation found in these areas vary with rainfall and geomorphological characteristics. Generally, trees are found only in clumps and along water courses, the transition to forest being very abrupt. It is considered likely that dry forest or closed savanna woodland was once the climax vegetation in much of the area and that human action was important in the conversion to open grass savannas. Fire is often the main factor preventing the re-establishment of wooded areas.

The pedological characteristics of the savanna soils may also be considered to be a result of biotic activities. Soil pHs are generally less than five and sometimes below four. The predominant exchangeable cation is Al, the toxic effects of which severely restrict the growth of cultivated crops.

Even though the relief is generally level, extremely low soil strength in terms of cohesion and friction make these soils prone to serious erosion if the plant cover is disturbed. Seasonal inundation of the poorly drained soils make them susceptible to solifluction and reticular gully erosion. The better drained soils are prone to sheet erosion. In the dry season, wind erosion also prevents a serious risk.

The population of the savannas is low, but increasing, and the economy is based largely on cattle breeding. It is estimated that the
area concerned carries approximately seventy-five million head of cattle. These savannas have a low grazing capacity, much of the area being capable of supporting only one head for every eight to sixteen hectares. Stock farmers customarily practise rotational burning of the mature forage during the dry season to obtain tender forage for cattle feeding. Crop production tends to be limited to rice, corn, cassava and plantain for local consumption, with a small amount of cotton and groundnuts produced as cash crops where marketing is possible.

THE ICRAF FOCUS

The improvement of cattle production in these zones is one of the areas of focus for CIAT, which is emphasizing the nutrition of beef cattle through the development of legume-based pasture systems. The work is carried out principally in the Colombian Llanos at Carimagua. In the same area a Colombian ecodevelopment pilot project at Gaviatos is developing silvopastoral activities and the culture of indigenous palms for oil and fibre. In Venezuela, the Organization of American States (OAS) and the Venezuela Institute of Scientific Research (IVIC) are involved in several studies in the savannas including one on the establishment of polders to provide more plentiful forage.

ICRAF's research on these savannas will be focussed on those land-use zones that are suitable for "natural savanna grazing" in combination with improved pastures and agriculture.

Research on the optimum types of windbreaks to be established wherever the soil is to be worked for pasture improvement or agriculture and on the establishment of groves of shade trees on naturally protected parts of savannas with a view to reducing the heat load of stock, extending the palatability of herbaceous fodder (natural or improved) longer into the dry season, providing tree fodder when herbaceous fodder is in low supply or of poor quality, and improving the surface soil nutrient status, will be undertaken. Such trees would have to be fire resistant and, at least in some cases, tolerant of seasonal inundation. Wood fuel producing species would greatly reduce the pressure on the remaining natural forests of the foothills and water courses. The successful establishment of such groves will require careful selection of the species and the close participation of the local population.

Close co-operation with the present research initiatives in the Latin American savannas will be necessary in order to ensure that agroforestry is considered among the systems that are being
developed. Because of the commitment to this zone already made by CIAT and the experience they have gained in working with existing economic and social systems, it is intended that this programme be carried out in collaboration with them. Subject to such collaboration, the following research will be undertaken:

(a) elimination trials of multi-purpose fodder species for growth on representative savanna soils;
(b) the introduction of selected fire-resistant fodder trees;
(c) the development of live fencing strategies to assist the rotational management of improved pastures;
(d) the testing of species suitable for the stabilization of polder dykes;
(e) growth trials for monitoring the effect of selected shade tree groves on soil fertility and herbaceous fodder quality;
(f) management of controlled savanna burning to prevent destruction of beneficial trees.

AGROFORESTRY IN TROPICAL UPLAND ECOSYSTEMS

THE SCOPE OF THE PROBLEM

Tropical upland ecosystems are being subject to increasing land-use pressure through both the growth of local populations and migration from lowland areas. The improper land-use of upland areas not only affects the economic livelihood of those who live there, but also often reduces productivity in the more valuable lowlands of the same watersheds. Since the lowlands produce most of the staple foods of the tropics, a great deal of effort has been devoted to their management. However, until recently, very little attention has been paid to the fact that agricultural performance in these lands is highly influenced by the activities and the conditions prevailing in the upper parts of the drainage basins. Erosion in the uplands can result in lowland crop losses through droughts, flood impeded drainage, and the silting of irrigation dams and canals. Industrial development in the lowlands can also be seriously affected by the uncontrolled water courses with high sediment loads that invariably result from destructive land-use practices in the uplands.

Several important social and economic factors must be taken into account in developing upland agroforestry systems. Because of the difficulties in communication, mountain villages tend to be relatively closed and localized economies, very often with special
customs and land-use patterns. While the rapid growth of the population in these villages leads to pressures to expand the cultivable area by clearing the forests, trees are also removed for fuel, fodder and building material. Shifting cultivation is rarely practised by the highly populated communities that are found in typical upland areas. Indeed, a recent FAO study in Nepal underlined the awareness of the local population of the value of trees as suppliers of many of the resources required for daily living. While the Ministry of Forest was trying to reforest denuded government lands with timber species, the villagers' priorities were first fruit trees and/or fodder trees on private land; secondly, fodder trees and/or fuelwood species on communal land; and lastly, construction timber species on government land. It is evident, therefore, that successful reforestation will require an order of priorities conducive to the co-operation of the indigenous populations.

In the absence of alternative energy supplies, the fuel needs of the population of upland areas must continue to be met by wood or charcoal. Where fuel trees are no longer available, animal dung may be used as fuel, thus robbing food crops of valuable nutrients.

The major constraint to upland land-use is the difficult topography or terrain morphology. This topography often results in large variations in climate over short distances, difficult communication and differing degrees of steep slopes which erode easily. Erosion removes topsoil which is usually the only horizon containing available nutrients, and which therefore must be conserved for continuous land-use.

Farmers practising agriculture on difficult topography face several major problems in soil conservation:

(a) efficient erosion control measures often require implementation on a watershed basis which needs careful organisation and supervision;

(b) erosion control measures (e.g. bench terracing) often require labour and capital inputs beyond the means of the small farmer;

(c) maintenance of soil fertility under continuous annual cropping is prohibitively expensive where leaching factors are high and market prices low.

The best short and medium term solutions to the problems of erosion control and soil fertility in tropical uplands, therefore,
appear to be the growing of perennial crops.

A variety of systems which incorporate a perennial crop as the main element in erosion control can be developed depending on slope, soil type and socio-economic conditions. Mixed cropping systems of perennial and annual crops have the advantage that they provide a cash income during the period of gestation of the perennial crop. Where land is under less pressure, short rotations of perennial crops and annual crops as proposed in the shifting cultivation programme may be developed. These may be especially important where weed control is a problem.

The following characteristics are of particular importance in selecting trees as the perennial component of upland farming systems:

(a) soil holding capacity - the minimizing of erosion requires trees with appropriate rooting systems. The trees must also permit the growth of other layers of vegetation beneath them;

(b) fuel production - fuel consumption is often high in upland areas because of high populations and because heating as well as cooking may be necessary;

(c) fodder production - in high population upland areas it is often impractical to herd animals, and feed is therefore often transported and given to them in pens. Tree fodder requires considerably less hand labour to harvest than herbaceous fodder;

(d) food production - the more food (fruit, nuts, vegetables) that can be produced from perennial species, the less will be disturbance of the soil cover;

(e) cash crop production - because of the marginal economics of farming under upland conditions, growing marketable food crops is often not practised. Much land misuse, therefore, results from the cultivation of higher value annual cash crops. The introduction of tree cash crops (medicines, exudates, nuts) would therefore help conserve soils;

(f) soil quality improvement - soil structure and fertility must be improved and maintained by the addition of organic matter either by green manure or through the intercropping of perennial species.
THE ICRAF FOCUS

While similar problems exist in the mountainous highlands of Latin America and eastern Africa, the initial focus of the upland watershed agroforestry programme will be the Himalaya foothills of Asia. A co-ordinated network of projects would be implemented by appropriate national institutions in India, Pakistan, Bangladesh, Nepal and Burma. Regular workshops for the researchers involved would maintain a high level of interchange of information and standardization of methodologies.

Because the upland watershed ecosystem is not an ecological zone in a climatic sense, the development of widely applicable agroforestry systems may not be possible. The ICRAF research programme would therefore emphasize:

(a) the development, through pilot projects of a methodology for the management of agroforestry systems (with the participation of the local population) in small sub-watersheds. This would include the evaluation of perceived tree requirements, the organization of private and co-operative planting, the protection of trees from animals, their integration with annual crops, and the marketing of produce;

(b) the selection of a small number of highly recommended fodder species, and research on the optimal management of each species (establishment, maintenance, harvesting, etc.);

(c) the documentation of the performance of horticultural (fruit and nut) varieties under different rainfall, temperature and altitude regimes with a view to simplifying the selection of varieties for introduction to individual locations;

(d) the documentation of the performance of fuelwood species, under varying ecological conditions with a view to simplifying their selection for specific locations;

(e) the interchange of existing traditional and research knowledge of the use of trees in upland areas.
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Philippines

Jan G. Ohler
The Netherlands

2 posts vacant

MEMBERS OF THE EXECUTIVE COMMITTEE

John G. Bene, Chairman

M. Sambavisan Swaminathan, Vice-Chairman

Kenneth F. S. King, Director-General

Hans-Jurgen von Maydell

Jacques Diouf