IITA Research for the Humid Forest Zone
1993 – 1998

edited by
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Humid Forest Program,
International Institute of Tropical Agriculture
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Paper prepared for the opening of the IITA Humid Forest Station, Mbalmayo, Cameroon, December 1992

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ACRONYMS

AFNETA	Alley Farming Network for Tropical Africa
AIDAB	Australian International Development Assistance Bureau
CGIAR	Consultative Group on International Agricultural Research
CNRCIP	Cameroon National Root Crop Improvement Program
COMBS	Collaborative Group on Maize-based Systems Research
CORTIS	Collaborative Group for Root and Tuber Improvement Systems Research
COSCA	Collaborative Study of Cassava in Africa
HFS	Humid Forest Station
HFZ	Humid Forest Zone
IARCS	International Agricultural Research Centers
ICRAF	International Centre for Research in Agroforestry
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IITA	International Institute of Tropical Agriculture
IRA	Institut de recherche agronomique (Cameroun)
MHSWZ	Midaltitude and Highland Savannas and Woodlands
MPTs	Multipurpose Tree species
MSZ	Moist Savanna Zone
NARS	National Agricultural Research Stations
SODECAO	Société de Développement du Cacao

CONTENTS

1. Introduction and Background

1.1 IITA and the Humid Forest Zone

Within the new ecoregional focus of the CGIAR system, IITA has taken the responsibility to work in three zones (fig. 1), the Humid Forest Zone (HFZ), the Moist Savanna Zone (MSZ) and (for crop improvement and plant health research) the Midaltitude and Highland Savannas and Woodlands (MHSWZ).

The HFZ is defined in the IITA Medium Term Plan for 1994 - 1998 as that area of Africa at an altitude less than 800m and in which the length of the growing period is more than 270 days with a daily mean temperature during the growing period greater than 20°C. The area covers significant parts of Zaire, Congo, Gabon, Equatorial Guinea, Central African Republic, Cameroon, Nigeria, Ghana, Côte d'Ivoire, Liberia, Sierra Leone, and Guinée (fig. 1). IITA will continue to work with the National Agricultural Research Systems (NARS) of these countries to fulfill its commitment to research for sustainable agricultural development in these zones.

1.2 The IITA Humid Forest Station

In 1990, IITA took an important step towards this goal by signing an agreement with the Government of the Republic of Cameroon to establish a Humid Forest Research Station (HFS) on 1000ha of Government land near Mbalmayo. This paper has been drafted to mark the official opening of the HFS on 30 November 1992. It provides an outline of IITA's strategy for the first five years of research at the HFS and sets that strategy within the context of IITA's work in the HFZ as a whole. Thus, whilst the paper concentrates on the technology development studies to be carried out at the HFS and on nearby farms, reference is also made to characterization and technology evaluation research to be conducted throughout the zone.

1.3. Developing a collaborative research agenda

In the following sections there is first, a brief description of the HFS and the HFZ and the major constraints to agricultural production in this area. On this basis, the research priorities which IITA has assumed for the zone are outlined and a brief account is given of the approach which has been adopted in tackling the priorities. Section 5 describes some of the research projects which are proposed for the first five years of operation of the HFS.

One aspect which should be emphasized is that the HFS is intended as a center for research collaboration for the African HFZ and not just as an IITA research station. The most important purpose of this paper is therefore to invite response from our colleagues in NARS, CG and other international research institutions, and in particular to promote the development of collaborative research projects.

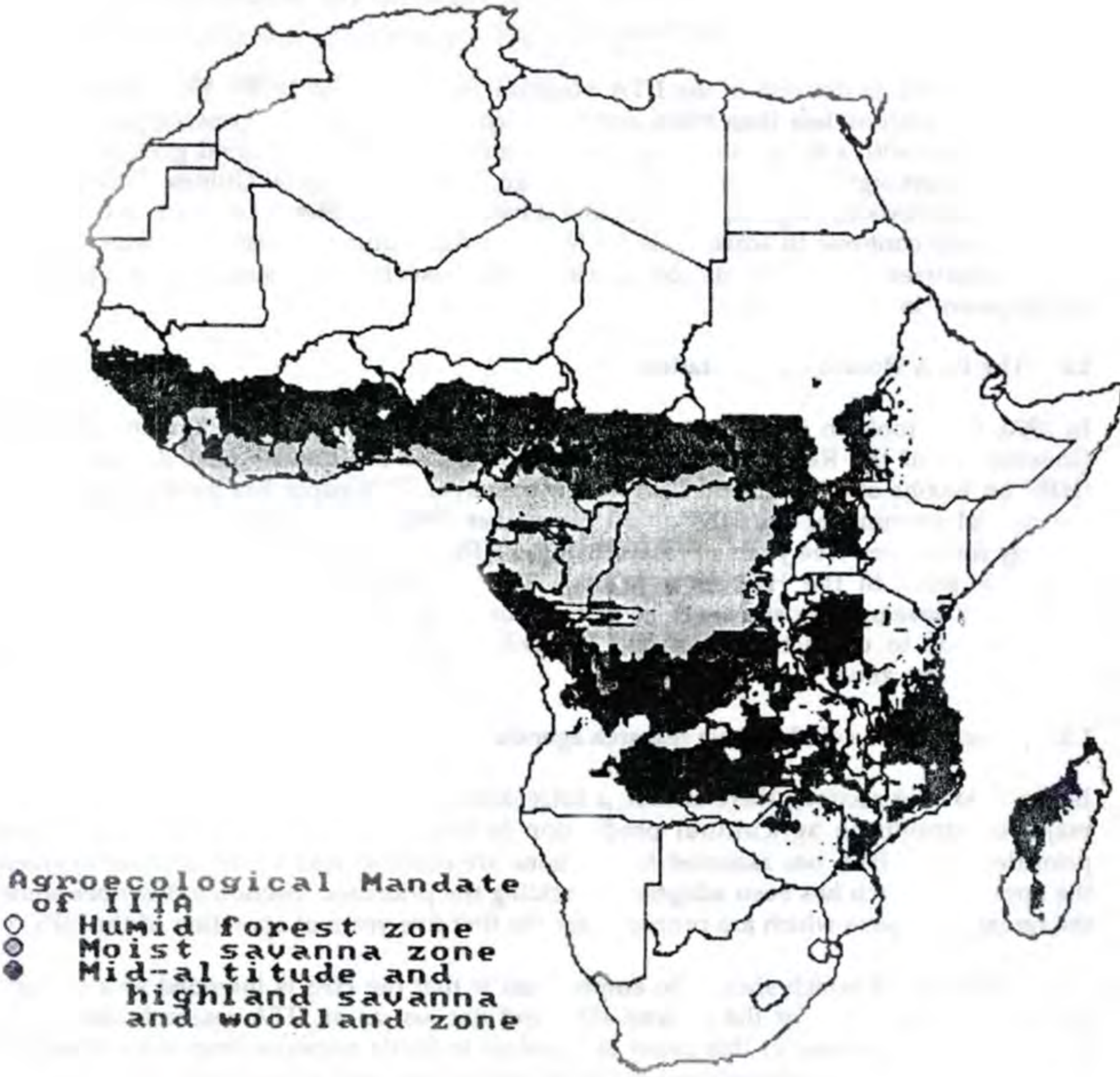

Figure 1. The distribution of the three agroecological zones of IITA's ecoregional mandate.

2. The IITA Humid Forest Station

2.1 Origins and development

The HFS Cameroon is being developed at three sites - Nkolbisson, Yaoundé, where an analytical laboratory and an office building have been completed at the IRA site; Minkoameyos, 5km from Yaoundé, where IITA has a 78ha experimental site; and Mbalmayo Farm, approximately 40km south of Yaoundé, where field experiments are conducted on a 1000ha concession in the Mbalmayo Forestry Reserve. A farm building has been completed at Mbalmayo, road access through the Forestry Reserve to the site has been improved, and a weather station has been installed. The site is ideal for close collaboration with the Cameroon scientific research system; the Forestry Department is active in the surrounding Forest Reserve; laboratories and offices have been set up on the IRA site at Nkolbisson near Yaoundé.

The farm site is in a bend of the Nyong River, at 3°25'N and 11°28'E with an elevation of 640m (fig. 2). The rainfall is bimodal with a yearly average of 1530mm and with a dry period (<100mm monthly precipitation) from December to February and a short dry spell during July and August (fig. 3). The soil is an ultisol derived from a schist band. There is one large stream in the central region of the site and two others at the margin. Consequently, about 40% of the soils at the site are hydromorphically modified. A boundary survey of the 1000ha has been finalized, and cement markers placed at 100m intervals. This was followed by a topographic survey along trace lines cut at 100m intervals across the whole area.

A soil survey of the southern Cameroon has been completed with input from an Australian pedologist funded by the Australian International Development Assistance Bureau. A vegetation survey of the site has commenced in collaboration with personnel of the Cameroon National Herbarium, and the Universities of Ibadan and Ife, Nigeria.

The HFS at Mbalmayo is perceived as possessing a number of characteristics which constitute a particular advantage with respect to the conduct of research. Although the vegetation is largely secondary forest, it has been relatively undisturbed for a long time and represents a rich, diverse, and relatively intact natural resource base. The character of the site is thus substantially determined by biophysical rather than human factors, although varying degrees of human intervention and modification are apparent. The site has unique advantages for research in forestry and agroforestry. Farmers from neighboring villages still farm on the site and many agricultural plants are to be found growing there. Tree crops such as oil palm, cocoa, and rubber are also present in some areas, including wild fruit trees and adapted exotics such as *Persea americana*. Thus, although located within a reserve, the HFS forms a continuum with the real agricultural world of southern Cameroon. The site lends itself to the study of both upland and lowland agriculture with its varied topography and many areas of hydromorphic soils.

The Mbalmayo region is an area in the process of rapid agricultural and socioeconomic change. Lying 40km from Yaoundé, it is much affected by the expanding markets and changing demography of the capital city.

The site has the potential to act as a 'benchmark' for research in the HFZ. There is no comparable facility elsewhere in this ecological zone of Africa. Consequently, it is expected to attract a considerable degree of collaborative research.

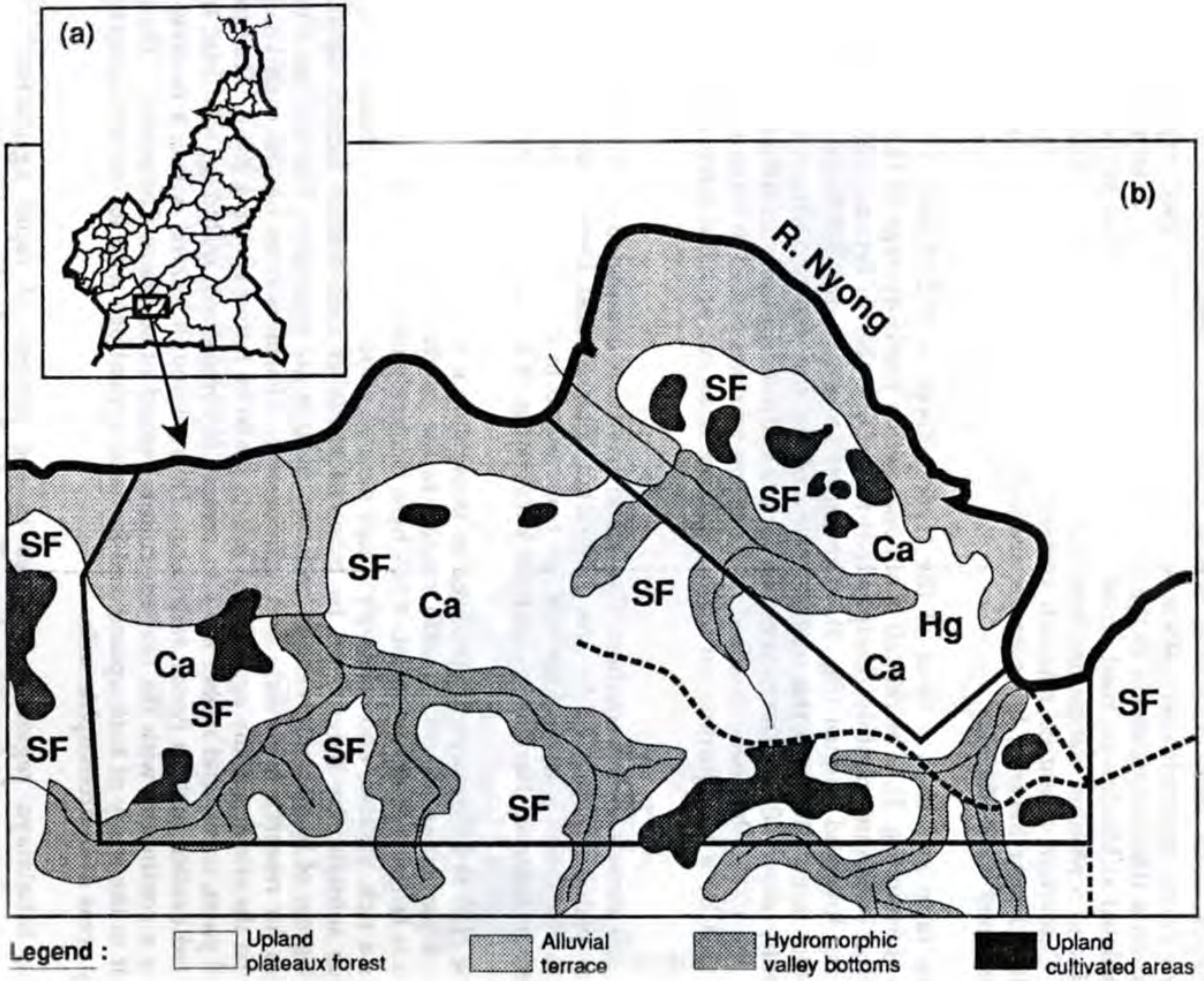

Figure 2. **Distribution of major soil–vegetation systems on the IITA farm in the Mbalmayo Forest Reserve. SF = Secondary Forest; Ca = Cocoa Plantations; Hg = Homestead Gardens with Fruit Trees.**

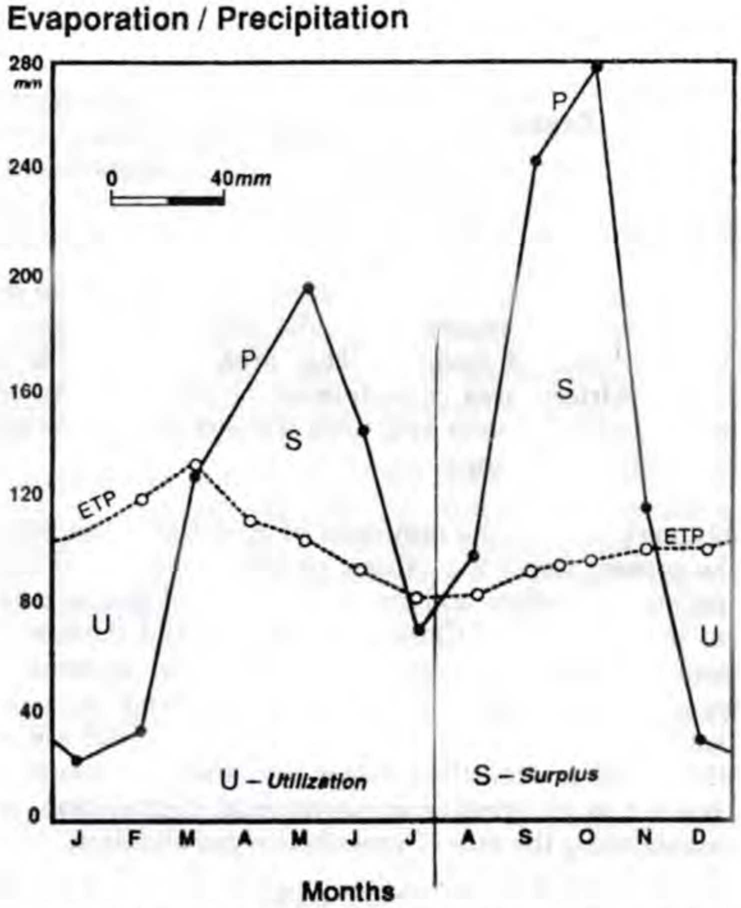

Figure 3. **Water balance diagram for Akonolinga, about 70km east of Mbalmayo. ETP = Potential Evapotranspiration; P = Precipitation; S = Period of water surplus; U = Period of total water utilization.**

2.2 Principles of site management

The land-use policy for the Mbalmayo Station will evolve as the results of the surveys are analyzed and greater familiarity develops with the site resources, but a number of principles will be followed;

- Resource conservation focus: the development of sustainable cropping systems is a major focus of IITA research. The same principle will apply in the development of the Mbalmayo site. Rejuvenation of soil by fallowing will be a feature of all cropping systems established at the station. The biological diversity of the site will be maintained by setting aside Conservation Areas representative of different ecological associations. It is hoped to obtain the collaboration of taxonomists and ecologists to characterize these communities.

- Catchment integrity maintenance: cropping systems or experimental plots located at different positions on catchment areas may have important interactions. In particular, up-slope and up-stream activities may influence those lower down. In siting different types of agricultural activity at the Mbalmayo farm, consideration will be given to the potential influence on catchment processes.

- Land clearing policy: previous experimentation at IITA and elsewhere has clearly demonstrated the deleterious effect of heavy machinery on soil properties. Land clearing will be by hand. Trees and topographic features which conserve resources and aid in erosion control will be retained wherever possible.

3. Research Priorities for the HFZ

3.1. The Humid Forest Zone

The main concentration of the African tropical rainforest is in the Zaire basin. It is one of the few major remaining blocks of rainforest in the world and experiences, by global standards, a relatively slow rate of clearing. This area, however, is floristically poor compared with the Central African area of endemism centered in Cameroon and Gabon. The western area of Sierra Leone, Liberia and Côte d'Ivoire also show significant floristic distinctions from the Central African zone.

There is probably very little of the rainforest of Africa that has not been modified in some way by man. The present forest is a mosaic of different types of land-use, patches of secondary forest and fallow vegetation and small remnants of primary vegetation. Man's impact is most apparent in the forests of Cameroon, Nigeria, and those areas in West Africa where the margin shows evidence of progressive transition to savanna. Even in Central Zaire, significant areas of savanna and anthropogenic grassland have occupied previous agricultural land for several decades. In parts of the region that are undergoing rapid deforestation from timber cutting, intensified fallow use, and destruction of plantations, the removal of tree cover has led to progressive environmental degradation, with the increased frequency of burning accelerating the rate of greenhouse gas emission.

The dominant soils of the region (by the FAO legend) are ferralsols and acrisols (approximately equivalent to oxisols and ultisols in the U.S. Soil Taxonomy), i.e., acidic soils derived from low activity clays, commonly exhibiting aluminum toxicity and low phosphorus availability.

The zone includes many of the largest urban populations of sub-Saharan Africa. Other areas have low population levels and are relatively undeveloped in terms of infrastructure, with poor roads and a very uneven distribution of market outlets. In parts of the region, the rural economy has been largely dependent on plantation crops, such as cocoa, rubber, oil palm, and cola nut; there is currently a low demand for some of these products and world prices for all have declined; cocoa and other smallholder plantation holdings have degenerated in many places without being replaced by any economically viable alternative. In other areas, however, rice, cassava flour, and gari have provided opportunities for substantial expansion of cash cropping. Some parts of the zone have experienced a decline in per capita food production or even a decline in yield per unit area, while others have responded vigorously to market opportunities.

The traditional food production systems of the HFZ are those of shifting cultivation and fallow rotation. There are a great many variations of practice within these systems but fundamentally they depend on the alternation of short periods of cropping (one to four years) and fallow periods characterized by successional components of the natural vegetation. The fallow period serves to exclude weeds, reduce pests, and restore soil fertility. Traditional fallow periods usually exceeded ten years and often were as long as 30 to 50 years. In modern times, however, fallow periods have shortened and rarely exceed ten years, except in some parts of the Zaire basin. Recent studies in southeastern Nigeria have shown that most farmers have their fields in fallow for four years or less.

The HFZ is in the process of rapid change in terms of agricultural and other land-use practices. This provides the context for IITA's work in this area. Constraints and appropriate technologies vary across the zone because of the differences in factors such as climate, vegetation, soil resources, population density, demographic profile, infrastructure, and effective market demands.

3. 2 Constraints to agricultural production

The HFZ of Africa is faced with a dual problem of declining food production and increasing environmental degradation. The target for IITA research is thus the development of agricultural systems which are both sufficiently productive in terms of food but also sustainable with respect to the conservation of resources.

Present day agriculture in most of Africa has evolved from shifting cultivation in a relatively short period. Traditional shifting cultivation can be seen as a reversible disturbance of the natural equilibrium. Although fallows of as long as 20 years would not restore the original primary forest, this secondary regrowth was able to restore soil conditions and limit the effects of weeds and pests. Disruption of this system has led to a number of trends:

- replacement of the original shifting cultivation system by a recurrent cultivation system with short fallows;
- an increase in the relative importance of foodcrops as compared with tree crops;
- a decline in the "spontaneous" tree components such as oil-palm, timber trees, and perennial fallow species;
- continued clearing of forest for foodcrops production;
- dominance of *Chromolaena* as a fallow species in the early stages of intensified land use, later replaced by grassy savanna species;
- a decline of crops with high fertility requirements, such as yam and plantain, in favor of cassava;
- a serious increase in weed pressure; and
- associated changes in socieconomic circumstances, including a shortage of labor.

Thus, whilst the factors determining the current low levels of productivity and resource-use efficiency in the HFZ are complex and highly interactive, a number of major constraints can be identified which can be targeted within an interdisciplinary agricultural research program.

The ultisols and oxisols of the HFZ have a low inherent fertility. The low activity kaolinitic clays have a restricted cation-exchange capacity and low base saturation. The soils have a high level of acidity; the associated aluminum toxicity represents a major constraint to production. Phosphorus availability is low, with some soils showing a tendency for P-fixation. The soils also have a low structural stability and, in many cases, a compacted subsoil. In such soils, the organic matter is a key component of soil fertility, as a reservoir of nitrogen, phosphorus, and sulfur, as the main source of cation-exchange capacity, and as a major promoter of aggregate structural stability. Under conditions of continuous cultivation, the soil degrades rapidly, associated with a substantial decline in organic matter status. Nutrient limitations become apparent, acidity and aluminum toxicity are increased, and structural coherence is diminished, resulting in runoff and erosion. The soil fertility constraint poses an increasing and ever-present challenge as fallow periods shorten and as agriculture becomes more intensified.

Weeds are also a major constraint to food production, exacerbated by the shortening of fallow periods. The HFZ environment favors growth of ruderal species in cleared land, but these are suppressed by long-term fallow. Under shortened cycles, certain species, such as *Chromolaena odorata* ("Eupatorium") become established as the major fallow species of foodcrop fields. *Chromolaena* effectively hampers the re-establishment of perennials in fallow fields, thus further contributing to the decline in the tree component. In areas where population pressure is low, considerable secondary forest still remains with interspersed fallow fields in various stages of regrowth with *Chromolaena* as the dominant species. In other areas, the "evolution" of the system is in an advanced stage and the original forest vegetation has been entirely replaced by man-made savanna. With the shift to a savanna environment, *Chromolaena* tends to disappear and is succeeded by a predominantly grassy vegetation. Land infested with spear grass *(Imperata cylindrica)* is the final stage of this evolution in humid and sub-humid areas and reclamation of such land is extremely difficult.

Cassava is a major staple and, in many areas, a cash crop. Food preferences vary widely, including the consumption of leaves as well as of roots, and of bitter varieties as well as of sweet. Cassava has a spectrum of pest problems, e.g., cassava mosaic virus, cassava bacterial blight *Xanthomonas campestris*, cassava mealybug *Phenacoccus manihoti*, cassava green mite *Mononychellus tanajoa*, cassava anthracnose *Colletotrichum gloeosporioides*, and the variegated grasshopper *Zonocerus variegatus*, each of which can cause yield losses of 50% or more. The other major staples in this zone, plantain and banana, are threatened by the recent spread of black sigatoka disease *Mycosphaerella fijiensis*, and increasing pressure from the banana weevil *Cosmopolites sordidus*, and nematodes.

Yam is a high preference crop, but its cultivation is declining because of high labor cost, lack of planting materials, diseases (especially root rots), and the dependence of the crop on a relatively high level of soil fertility. Yam is also subject to a range of insect pests which include the yam tuber weevil *Heteroligus meles*, and leaf beetles *Criocerus livida* and *Lema armata*, and a variety of nematodes. The stored tubers are also subject to losses from beetles.

The dominance of root and tuber crops leads to diets rich in starch and calories but poor in protein. This points to a need to enhance the production of grain legumes to achieve better balanced food regimes.

Cassava is increasingly intercropped with maize in this zone because of the complementary growth habits and the consumer appeal of the latter crop. Conditions favor green maize production which meets food security needs early in the rainy season. Production of maize grown to maturity is limited by a series of constraints that would have to be overcome for maximum exploitation. The length of the growing cycle presents difficulty in the proper timing of harvest; stemborers *(Busseola, Sesamia* and *Eldana)* and constrain yields in late-sown crops; and storage without proper drying leads to heavy losses by storage insects and may result in aflatoxin contamination, posing a serious health hazard.

In recent years the market value of large-scale and small-scale plantation crops such as cocoa has declined, emphasizing the need for alternative income-generating activities in a region historically dependent on cash earnings from tree crops. In some areas, food crops for local urban consumption can meet this need in the short run; in other areas, such opportunities could open up in the medium or longer term, with major shifts in government policy. Nevertheless, there are still significant areas where the potential for cash earnings from food crops is likely to remain minimal, either because of limited markets or very poor market access coupled with low population density.

3.3 Agricultural potential and research priorities

Food crop productivity in the HFZ does not have the same potential as that of the moist or midaltitude savannas because of the biophysical limitations of the environment - low insolation and infertile soils. Among the food crops, the root and tuber crops (cassava, cocoyam, yam and sweet potato) together with plantain and banana have the highest adaptive possibilities. The best market opportunities for the region remain with perennial, particularly tree-based, production systems; oil palm, cocoa, rubber, timber, fruits and medicinal products.

There is nonetheless a need for the zone to attain self-reliance in food production, at least until the "breadbasket" zones are better developed. Zonal food production will certainly continue to be substantially associated with small-scale farming in the foreseeable future. Farming systems that are profitable and sustainable are thus likely to be based on a combination of perennial cash cropping and short-term food crop cycles in rotation with improved fallows. We hypothesize that sustainable production in this zone at an acceptable level of yield will require at least one or two years of fallow associated with one or two years of cropping. Leguminous trees or shrubs will be permanent components of both crop and fallow periods and small applications may be necessary of P-fertilizer and other amendments to control acidity. The cropping systems may have a multi-canopy structure with tall high-value tree crops (oil palm, fruit trees) integrated with leguminous mid-canopy trees and a multi-species lower canopy. The food-crop system will be based on the current cassava-maize-groundnut combination with other minor components, such as alternative legumes, plantain, sweet potato, yam and cocoyam. A key feature of the cropping system design is to have a flexible system which can be adapted to meet location-specific cultural and environmental needs.

The major target for research in the HFZ is thus to develop improved cropping systems for small-scale farmers, which will enable them to practice relatively continuous cultivation as the traditional practices of shifting cultivation disintegrate under the pressures described above. The inherent fragility of the soils and the high risk of weed and pest impact are the major constraints to be overcome. Viable resource management practices will therefore be the first priority in research. In the light of this priority, the research agenda described in the following sections includes strategic studies of soil processes, weed populations, and the adaptive properties of trees, as well as germplasm improvement and associated pest management research. Although this agenda is presented for purposes of clarity in a sectoral or disciplinary format, it should be emphasized that the research program has been planned, and will be implemented in an interdisciplinary and integrated manner (fig. 4).

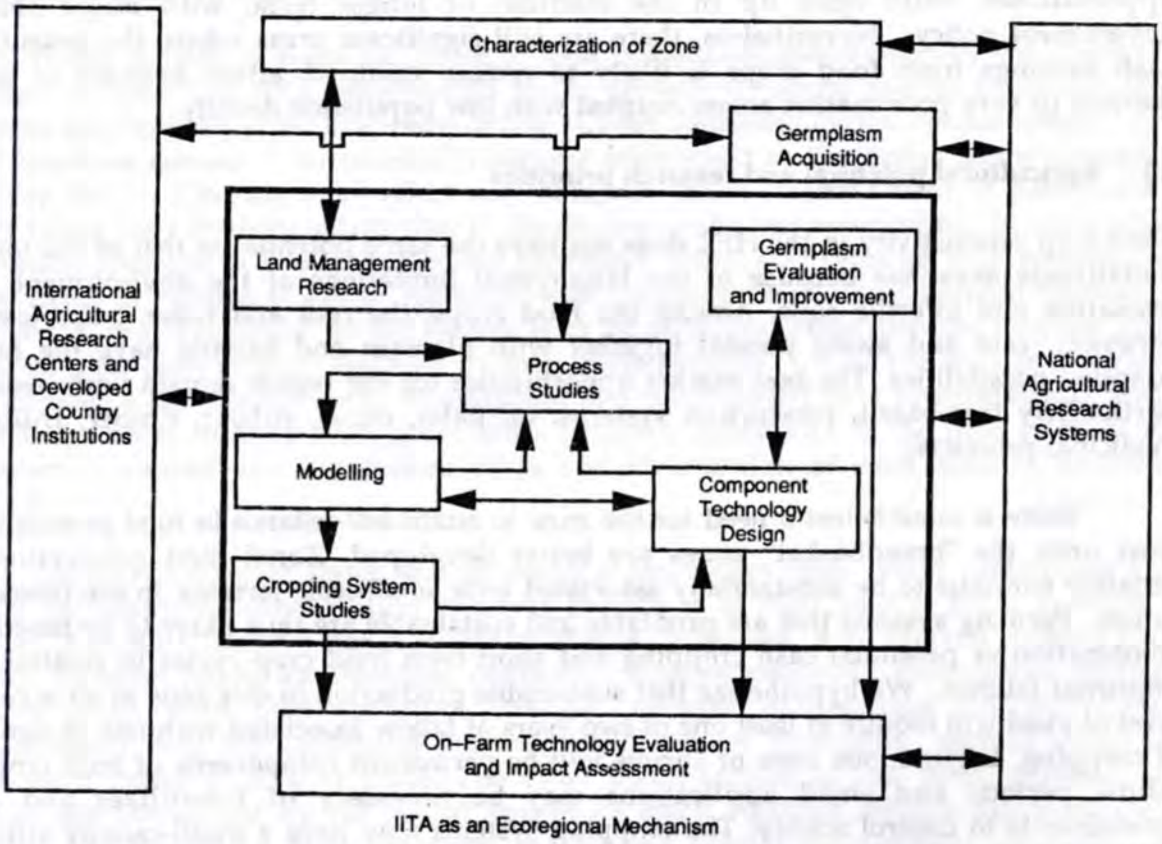

Figure 4. An integrated approach to agricultural research. The major on-station research activities at HFS are shown within the large box in the centre. These are shown interacting vertically with off-station characterization and technology evaluation research. The horizontal interactions emphasize the collaborative nature of the research agenda.

3.4 Research approach

The IITA research agenda for the HFZ is guided by a number of principles which have been articulated in the Strategic Plan (1989). In particular, these involve a focus on the development of technology which is both sustainable and adoptable and an operational approach which involves partnership with NARS.

The major challenge for agricultural research in the next decade is to arrest and reverse the decline in agricultural productivity. The role of cropping systems research is to develop component technology, analyze it for its potential contribution to farmers' productivity, and test it under station and farmers' conditions. New technology must be integrated in existing or new cropping systems in such a way that the improved systems are more productive, can be adopted by farmers, and are sustainable.

Sustainability is generally expressed as a complex and somewhat abstract concept incorporating issues of ecological stability and resilience (e.g., conservation of resources and reduction of impact on the environment), economic viability, and the quality of life and human welfare. The requirements of scientific research and agricultural development, however, necessitate moving away from this holistic concept to give sustainability a more specific and rigorous character that is susceptible to measurement. The reconciliation of these two levels of conceptualization lies at the heart of developing an operational approach to sustainability. The interdisciplinary approach that IITA is adopting for its research at the HFS is designed to meet this requirement. In brief, this involves a synthesis of specific process-level assessments of resource-use efficiency and population trends with agroecosystem scale measurement and modeling of agronomic and economic performance (fig. 4).

The emphasis on sustainability has its problems, however. Sustainability is a concern for the medium and long term and as such it is rarely taken into account by farmers in their short-term management decisions: a sustainable technology will only be adopted voluntarily by farmers if it also provides short-term gains.

The conventional approach to agricultural development has been to propose fairly simple packages of improved technology, including high-yielding varieties, fertilizer, pesticides and sometimes mechanization, under the assumption that straightforward profit maximization is the driving force of farmers' management decisions. The success of such technology has been limited and many development projects based on them have been expensive failures. In addition, the rate of adoption of complex technologies, (such as alley cropping) with an improved resource management component, which are advocated because of their greater sustainability, has been disappointingly slow.

The causes of these failures are complex and poorly understood. IITA is giving high priority to investigating the basis of adoptability criteria as an essential component of its technology development program. The essential components of this approach are full characterization of environments and the participation of farmers in identifying research priorities. On this basis, recommendation domains may be more rigorously identified and technology development and evaluation more critically pursued.

IITA works with NARS in all its research activities. In the plans for the HFS, the development of a new model of partnership with colleagues from IRA is being planned. Funding is being sought to provide operational costs which will enable a team of IRA scientists to work side by side with those of IITA, ICRAF and other international organizations in the operations in Cameroon. This team will in turn be linked to regionwide collaborative groups, examples of which are CORTIS (Collaborative Group for Root and Tuber Crop Improvement and Systems Research) and AFNETA (Alley Farming Network for Tropical Africa). These groups are already established.

4. Agroecosystem Characterization

The characterization of current agricultural systems and their environments is an essential component of the IITA research strategy. When combined with participatory studies of farmers' decision-making processes, it provides the essential guideline for technology development research. By utilization of the Geographic Information System developed by the Agroecological Studies Unit at IITA Ibadan, these databases can be used to define recommendation domains for technology evaluation.

During the three year period preceding the opening of the HFS, IITA scientists have been conducting a number of characterization exercises in the HFZ of Cameroon, and elsewhere in Africa, with the above purposes in mind. These are, in the most part, on-going exercises in recognition that characterization research interacts in a continuous iteration with technology development and evaluation (fig 4). These projects are briefly described in the following sections. It is anticipated that a new phase of characterization research will develop in response to the expansion of HFS research activities.

4.1 Regional studies on agricultural production systems

A unique database on production systems in the HFZ is already being compiled by the Collaborative Study of Cassava in Africa (COSCA) which has been in operation in 14 countries in Africa since 1989. This study gives information on the current status and evolutionary trends of cropping systems incorporating cassava which will permit the mapping of the different systems in the surveyed areas.

COSCA commenced data collection in 1989 in six countries namely Côte d'Ivoire, Ghana, Nigeria, Tanzania, Uganda, and Zaire which together produce 70% of cassava in Africa. The data are being collected in approximately 300 villages selected in these countries in such a way as to fully represent the humid and the subhumid climate zones. The 300 villages include some in the dry climate zone, although that climate zone is not fully represented. Since the inception of COSCA, eight other countries have adopted COSCA type of surveys. These are Burundi, Cameroon, Kenya, Liberia, Malawi, Rwanda, Sierra Leone, and Zambia.

COSCA is conducted in four phases, Phase I is broad characterization of the physical, biological, and socioeconomic environment of cassava- producing zones by the rapid rural appraisal method. Data collected covered production, processing, marketing, consumption, and health issues on a broad basis. This was completed in 1990. Phase II is a detailed production survey at the field level. The investigators took information on cropping practice, inputs, and field size for all arable crops in addition to yield measurement, as well as proportions of total production marketed and processed for cassava. Data collection for Phase II was completed in 1991 and analysis has reached advanced stages. Phase III consists of a detailed postharvest survey at the household level in the 300 villages. Information being obtained from the rural households includes household characteristics, composition, and health conditions, food consumption (all items), food and non-food expenditure, cassava processing methods, characterization and product quality assessment, cassava marketing structure, conduct and performance. Phase III data collection has reached advanced stages in the six original countries. Phase IV consists of a detailed postharvest survey at the household level in the urban centres. Data collection for this phase is planned for 1993.

Validation surveys will be conducted to verify key elements in the system as identified by the COSCA study. Such surveys require a precise but simple methodology which will be designed on the basis of the COSCA experiences.

The delineation of "major cropping systems" should be based not just on current biophysical and socioeconomic parameters, but also on dynamic criteria, in particular on the intensification pathway the system is following, which has important implications for long-term productivity and sustainability.

The use or non-use of wetlands or valley bottoms should receive more attention in systems characterization. Valley bottoms may often represent an important resource, either for economic exploitation or as an ecologically valuable natural buffer. Current wetlands utilization may be related to population pressure and to the productivity and seasonality of the uplands.

A question which is increasingly being asked is about the relative importance of maize across ecological zones, from humid forest to Northern Guinea savanna, the uses to which maize is put, and the biological disorders prevalent in the different zones. One possible option would be a COSCA type of study on maize, but short of this, a focused survey could be considered on some key issues relating to maize production, in particular on the importance of the stemborer problem across zones.

4.2 Identification of production constraints and opportunities in current farming systems

The identification of problems and opportunities in current farming systems is part of the overall characterization process. Production systems may differ as regards their major problems. The COSCA study will provide a ranking of the major problems in each system.

Pending the outcome of the COSCA study, some preliminary hypotheses on major problems can be made. Many localized surveys which have been conducted in the region during the past decade suggest that weeds are a major problem in most areas where a recurrent system of cultivation is practiced. Since recurrent cultivation with occupational and fallow periods of comparable length now appears to be the dominant practice in the humid zone, it seems likely that this constraint is on the increase.

Detailed field level studies were conducted recently to quantify the effects of biological, physical, and management factors on crop yield in a cassava-based system in southwestern Nigeria. This confirmed the overriding role of weed pressure as a yield-depressing factor. Studies, concentrating specifically on the weed problem in inland valleys, were also conducted in Ohosu and Bida (Nigeria) and Makeni (Sierra Leone). Similar studies should be considered at carefully chosen sites in order to quantify the major factors, including weeds, constraining yield at the field level.

The field diagnostic techniques used so far, however, are too detailed and complicated for general use and a leaner diagnostic method should be developed on the basis of the comprehensive studies. The resulting "operational method" can then be used in collaboration with NARS to quantify factors affecting yields and yield differences in selected sites.

The data generated by field diagnostic studies will also be valuable in the development of models for crops and cropping systems. On one hand, information is obtained on the major factors which need to be incorporated in models in order to make them realistic. On the other hand, model calculations with climatic and soils data as variable inputs are a convenient way of transforming these variables in a biologically meaningful manner into "potential yield". This may in turn be used as a single variable in statistical analysis to explain yield differences.

4.3 Characterization of resources and resource management in current farming systems

During 1991 and 1992, a survey was conducted in 20 villages in the HFZ of Cameroon to characterize the resource base of current farming practices.

The survey used a geographic grid coded for native vegetation and soils as a sampling frame. Through village level interviews, important tree species and bush plants were identified, such as indicator trees, trees and bush used for firewood, staking, and medicinal purposes. The survey also made an inventory of field types, and categorized plant associations, planting schedules, and fallow times for the different field types. Data on market access, fertilizer use, and animal husbandry practices was also collected. On this basis, types of fields and fallow management practices can be correlated with population density, market access, and socioeconomic variables. A key goal of the study is the identification of native trees and bush for use in studies of improved fallow, and an understanding of their place in indigenous farming systems.

This study was implemented to ask the following questions:

- What is the spectrum of resource availability for small-scale farmers in the HFZ?
- In what ways do farmers manage the resources available to them?
- What are the factors determining changes in resource availability?
- In what ways do farmers respond to changes in resource availability?
- What are the factors facilitating adoption of new technology by small-scale farmers?

The results of the survey will provide a baseline for guiding resource management research at the HFS and will later be extended to other parts of the HFZ.

The survey will also assist in charting the process of agricultural intensification. Conventional theory suggests that high population density is the main factor determining agricultural change in an area, and that in the HFZ a shortening of the fallow period is the best indicator of this intensification. Preliminary surveys in southeastern Nigeria indicate that a more complex model may be more appropriate.

Although increasing population undoubtedly increases the demands placed on the natural and human resource base of a region, it is less certain that the managers of agricultural systems react to such demands by passively or unthinkingly destroying their productive resource base. In addition to shortening the fallow period, farmers have employed other mechanisms to enable them to meet increasing demands. These include changing crops, cropping patterns or cropping systems; altering tenure arrangements; making input substitutions; making changes in soil and bush vegetation management; and outmigration. Because several mechanisms may be operating simultaneously, and because the effectiveness and feasibility of each mechanism can vary in different historical and environmental settings, there will be great complexity and wide variability of resource management practices. It is, therefore, necessary to identify the most important characteristics for delineating resource management systems.

On the basis of a pilot survey conducted in Nigeria, the following characteristics were identified as of importance.

- population density;
- fallow length;
- land entitlements;
- existence of crop - fallow field differential;
- existence of amendment - fallow field differentiation; and
- commercialization of bush products.

These are indicators of the degree of pressure bearing on the farming system and mechanisms for alleviating pressure. Refinement and testing of these variables as appropriate characteristics of resource management systems in the humid forest - acid soil zone will be undertaken by broadening the geographic range of study, and by conducting detailed topical studies at representative field sites. In addition, the refinement and substantiation of the characterization variables must mesh with climatic, soil, and biotic components being investigated within resource management research so that the final characterization gives a complete picture of resource management systems.

4.4 Anthropological studies at the village level

In the resource management survey work IITA is testing hypotheses related to the categorization of pressures on the resource base, responses by farmers, and other perturbations which shape resource management systems. A more intensive study was carried out during 1992 in a few villages in the Mbalmayo area that details the interaction of culture (farmers' perceptions and worldview), society (institutions), and history (events and developments internal and external to the community) in shaping resource management systems. Intensive studies of this kind explain differences among individual farmers, and analyze why certain changes take place. This type of analysis cannot be done by a broad-based survey which, by its very nature, can only suggest correlations. With both sources of information available, technology development can begin to be fitted into the structure and processes of the resource management system.

Resources include vegetation, soils and water, but also human constructs such as knowledge systems and social institutions. Natural constructs are manipulated by human agencies to create farming systems. Farming systems are in turn shaped by factors seen as external, but in fact often related to agriculture, such as warfare, epidemics, migration, and political upheaval. The following questions may be posed concerning potential for intervention in a farming system:

- What resources will the technology require (both natural resources and human resources such as land (tenure system), labor, and capital)?
- What type of knowledge does it entail?

- How will the knowledge be transmitted and the work carried out, e.g., individually, in groups, by men or women?

- How does it fit into the rhythms of life and the particular historical situation of the people, e.g., seasonal patterns of work, levels of migration?

Selection of the villages was made after discussions with officials of the department of agriculture, the sous-prefet and former agents of the Société de Développement de Cacao. They range from highly market-integrated (on the road from Mbalmayo to Yaoundé) to very isolated (on a very infrequently traveled, poor road, south of Mbalmayo). Other variables include size, history of incorporation, and access to non-agricultural income (see above description of villages). Additional sampling of villages will allow for a broad description of the Mbalmayo farming system. Village censuses and administrative records will determine population densities.

Quantitative data was collected from individual farmers, including size and history of fields, workforce available for different tasks, tools used, yearly purchases and expenses. Qualitative information from life histories was also collected to show how resource management strategies are formulated. On the village level, information was gathered about resources (e.g., fallow species) and access to resources (e.g., land tenure). Additional information obtained on markets, development activities, and alternative income-generating opportunities help define the parameters within which farmers work. These data will be used to create resource management profiles of different types of farmers and settings which can be utilized to determine technology options.

4.5 Characteristics of the Mbalmayo site

The choice of the HFS Cameroon as an ecoregional center for research on farming systems in the HFZ is based on the assumption that systems developed there will be transferable to a significant portion of the zone. As a good deal of the research will be conducted on the 1000ha Mbalmayo farm site, a complete biophysical characterization of this property is a necessary pre-requisite to the assessment of its representativeness. Ultimately, larger-scale studies of the entire zone itself will be necessary to answer the question "To what extent is the HFS representative of the HFZ?" The same question will also be applied to the experimental site at Minkoameyos. The underlying hypothesis is that a farming system developed on one or more soil types of the HFS farms will be technically transferable to other sites having the same range of soils and vegetation, since it is assumed that climatic variation in the region would not significantly influence transferability. Characterization studies are being conducted under five principal activities:

- Topographic survey,
- Vegetation survey,
- Soil survey,
- Microvariability studies (soil and vegetation) and
- Faunal inventory.

5. Technology Development

5.1 Integrated management of acid soils

This project is aimed at the development of improved management strategies for the highly weathered acid soils of the HFZ. Initial emphasis will be placed on defining constraints, but at a later stage, promising component technologies will be assessed in an integrated systems approach, along with components developed in other disciplines. An underlying principle is that a combination of inorganic and organic inputs is likely to achieve the most efficient management of acid soils and that a target key feature is maintaining a high level of organic matter in the soil. This leads to the hypothesis that a firm understanding of the relevant soil properties and processes of organic matter dynamics, nutrient cycling, and physical development will lead to the development of management systems appropriate to the region.

A brief reconnaissance survey of the forest zone of southern Cameroon has helped to identify the major soil profile classes of the region. Five classes have been named, and their areal extent determined. Mbalmayo is characteristic of one of these types and Minkoameyos of another. These soils will be further characterized in detail to determine specific constraints and potential for management.

Process-level studies of acidification, organic matter dynamics, nutrient cycling, aggregate stabilization and the role of key soil biota will be initiated in 1993 by a collaborative team combining soil expertise (chemistry, physics and biology) with that of agronomy and agroforestry. The experimental design will be generic rather than system specific in approach. For example, it is proposed to examine the effects of organic inputs on soil properties and processes by manipulation of the quantity and quality of organic materials from a range of tree and herbaceous plants rather than by comparison of different agronomic systems. Process studies will, however, be linked to cropping system studies (section 5.8) by modeling and by measurement of key variables within the systems.

It is also proposed to extend soil characterization and soil process studies to selected on-farm sites. The intensive village studies of resources and resource-management practices (sections 4.3 and 4.4) provide the basis for selecting farming practices and field types for investigation of the influence of farmers' activities on soil fertility. In their turn, these on-farm studies will set realistic boundary conditions for the recommendations for soil management that will be derived from the process-level strategic research at the HFS.

5.2 Food crop improvement for the HFZ

The following food crops have been identified as prevalent in the HFZ: cassava, plantain, cocoyam, maize, rice, yam, groundnut, and sweet potato. Cassava, plantain and groundnut have been selected as the priority crops for the region, although the others will, of course, be included in research on cropping systems. It is also proposed to examine the potential for incorporation of cowpea. The following were identified as the research issues pertaining to each of the crops.

5.2.1 Cassava: The HFZ is arguably the most important environment for cassava production in sub-Saharan Africa. Cassava is normally grown in association with other crops, according to locality. The intense genotype x environment interaction in cassava demands that genotypes are developed in their target environments. IITA's high rainfall substation at Onne is not representative of the bulk of the HFZ because of the high phosphorus content of its acid soils in contrast with the Mbalmayo station with acid soils of low phosphorus content. About 700 elite breeding lines of cassava developed by the Cameroon National Root Crop Improvement Program (CNRCIP) in collaboration with IITA have been transferred from Njombe, where they were originally bred, to the IITA farm at Mbalmayo. Three selections from these (8061, 8017, and 8034) are already being grown by farmers in the HFZ. About 120 accessions of local cassava cultivars collected by CNRCIP are presently being maintained at Mujuka.

The major constraints to stable cassava production in the HFZ are hypothesized as:

- disease: cassava mosaic virus, cassava bacterial blight, cassava anthracnose disease, root rots;
- pests: cassava green mite, cassava mealybug,
- poor performance in relation to acidic Aluminum-toxic, low phosphorus soils;
- low yield potential of traditional cultivars;
- lack of planting material of improved cultivars; and
- lack of appropriate postharvest systems.

On this basis cassava breeding at HFS will concentrate on the following factors:

- high yield potential;
- pest resistance;
- plant architecture suitable for the predominant cropping systems;
- high dry matter content of the storage roots;
- good cooking quality and low HCN potential;
- leaf size and quality suitable for use as vegetable; and
- good in-ground storability of the storage roots.

An important feature will be to consider all these factors within the adaptive context of the high rainfall, Aluminum-toxic, acid, low P soil environment.

5.2.2 Plantain: Plantain are an important component of cropping systems in the HFZ of sub-Saharan Africa. In this region, plantain have traditionally suffered from banana weevils and nematodes, and are subject to a rapid decline in yield which is currently being investigated at IITA's Onne substation. The most damaging constraint of recent time has been black sigatoka disease. The success at Onne in hybridizing susceptible plantain with resistant banana and the selection of resistant cooking banana lines has been a welcome break-through. Eighteen Musa lines including eight F1 hybrids, cooking banana, plantain, and dessert banana, have been sent to the Mbalmayo station for evaluation. The testing trial of hybrids at Mbalmayo is part of a larger multilocational evaluation. The resource and crop management studies at the HFS will contribute to the understanding of yield decline but the main focus of this research will remain at Onne.

5.2.3 Groundnut and cowpea: Due to the fact that plants with different growth habits are better suited to particular cropping systems, it is agreed that work on these crops should concentrate on the collection of varietal types. It was further noted that, although cowpea is not a crop of choice in the HFZ at present, there may be a role as a cover crop planted in late season and going through the dry season (see section 5.4). IRA, Cameroon and possibly ICRISAT will collaborate on this work.

5.3 Selection and screening of multipurpose tree species (MPTs)

The HFZ is a highly favorable environment for the growth of trees. Traditional farming systems use trees to improve the soil during the fallow period and retain trees of food or cash-crop value during the crop period.

MPT selection and screening, conducted by an ICRAF scientist, will be the initial focus of agroforestry studies at the HFS. The objectives will include the identification of adequate MPTs for the smallholder system in southern Cameroon, based on cocoa and foodcrop production, as a target for agroforestry in this area which is characterized by acid ultisols of low fertility level. The selection is planned to be based on a range of biological, environmental, and management considerations appropriate for soil nutrient improvement combined with multiple use potential (e.g., food, fruit, fodder, fuel and cash crop production). Utilization in a variety of agroforestry systems, including improved fallows, mixed cropping and fodder banks will be investigated, in close collaboration with ICRAF.

Development of the germplasm collection will involve:

- Exploration for seed and other propagules of species that meet technological and site specifications;

- Studies to determine germination characteristics and specific storage requirements of MPT seed; this is necessary to ensure the availability of seedlings for evaluation and general screening for use in agroforestry systems;

- Studies to provide alternative means of propagation particularly where MPT seed is edible or where seeds are recalcitrant and to provide rooted/grafted adult materials to enhance future genetic improvement based on already centralized germplasm;

- MPT evaluation to identify promising MPTs for use in selected agroforestry systems; this will be initially conducted at the HFS but will later be extended to other test sites in southern Cameroon to determine the effects of climate and soil factors. Parameters to be considered in this exercise will include: survival capacity; root development, form and distribution; pest and disease response (nursery and field; biomass productivity, green manure quality; forage quality; and decomposition characteristics.

The screening program will be followed by early management trials for alley cropping and other agroforestry systems to determine the the effects of different planting patterns including intra- and inter-row spacings, hedge width, alley width, etc. The objective will be to determine the potential productivity of promising MPTs under different tree management regimes for specific agroforestry systems. Treatment factors for trees will include planting density, arrangements, fertilizer use, lopping frequency, etc. For crop species, they will include planting density and fallow periods, including mulch and fertilizer application, if necessary. Assessment in this aspect of work will include tree growth rate, biomass productivity, and quality and crop yield, together with the effects of tree species on soil fertility and other environmental factors.

5.4 Selection and screening of herbaceous legumes

A key component of any sustainable food production system is the maintenance of soil fertility. The role of legumes in this regard is well documented. Added to this role is the potential of these legumes to suppress weeds and reduce the weed seed population in soils. The basic challenge is the development of suitable legume - crop combinations that will provide food, maintain soil fertility, and suppress weeds. The use of cowpea for these purposes is a particular challenge which builds on IITA expertise and resources.

The research approach will include:

- Identification and collection of legumes indigenous to the region;
- Screening of the above as well as exotic species for adaptability to the various agroecosystems in the region and for the following characteristics, considered desirable in the system: ease of establishment; ability to grow and spread rapidly thereby smothering weeds and checking erosion; high dry-matter yield; drought and shade tolerance; non-climbing growth habit; ability to return nitrogen to the soil either through nodulation or high litter fall.
- Selection for use in the various cropping systems as appropriate.
- Field testing in the various cropping systems

Germplasm to be tested will include herbaceous legumes which have shown promise at Ibadan (*Psophocarpus, Centrosema, Pseudovigna, Crotalaria*), plus additional indigenous and exotic species and grain legumes (groundnut and cowpea) which will provide a good balance between yield and dry-matter production.

The concept has only recently been advanced of using cowpea as a ground cover/mulching/weed suppression component of farming systems in the transition zone and HFZ environments. The idea is the identification, hybridization, and selection of genotypes that can, under typical farmer conditions (e.g., intercropped with cassava), provide early season control by smothering weeds, mature in less than 90 days so as not to have a detrimental competition effect on the tuber crop, produce a small amount of grain (200 - 400 kg/ha) at maturity, and leave behind a significant amount of organic matter and residual fixed atmospheric nitrogen. It is also anticipated that such a genotype would help reduce soil erosion. More traditional weed control crops in cassava, such as melon, lack many of these attributes: no nitrogen is fixed, residual organic matter is only modest, and the yield of melon is low. Cowpea grain also has significant market value and therefore comparing the economic return of growing cowpea as a cover crop with that of melon and other alternatives may be warranted. The specific approach for cowpea will address the following targets:

- Screening of semi-prostrate and prostrate, photo-sensitive and photo-insensitive cowpea at the HFS with the goal of identifying varieties suitable for growth in the forest environment.

- Testing the performance of selected cowpea varieties under sole-crop and intercrop systems at various planting dates, with the goal of identifying varieties suited to intercropping with cassava and to correlate suitability under sole-crop and intercrop systems.

- Establishing a hybridization program using the most promising varieties for ground cover, N fixation and weed control to further enhance cowpea contributions to sustainable forest ecology farming systems. Any weaknesses for insect or disease resistance will be improved using an appropriate breeding strategy. All trials will be conducted without insecticide use.

5.5 Weed management research

Weeds have been hypothesized as posing the most critical constraint to cropping systems in the HFZ. There is therefore a need for weed management that cuts across the spectrum of crops and cropping systems and environments of this region.

The problem of *Chromolaena odorata* deserves special attention. This plant often dominates short-term fallows but is also perceived as having a beneficial effect on soil fertility. It persists into the cropping period and competes vigorously with crops for all environmental resources, leading to reduced crop yields. As a fallow species it has been estimated as returning up to 4 t/ha of nutrient-rich litter to soil annually. It is also important in checking the growth and spread of *Imperata*, the more noxious perennial weed. Thus, research into the control of *Chromolaena* must be geared towards assessing both its beneficial and its detrimental qualities.

The natural vegetation is an important resource for fallow which under intensified cropping may change to become dominated by weed species. This transition is poorly understood but is particularly significant as fallow periods shorten. In order to develop interventions that will minimize the effect of weeds on crop production, there is a need to study the processes involved. A virgin site such as exists at Mbalmayo offers a unique opportunity to study this transition. Specifically therefore the following questions need to be addressed in relation to intensification of cropping:

- What changes occur in the species composition with time?

- How and to what extent does immigration occur?

- How does the seedbank operate?

- How does the type of crop and cropping system influence this transition?

And, specifically referring to *Chromolaena*:

- To what extent does *Chromolaena* occur in the HFZ?

- What is the pattern of distribution in field crops, plantation crops, and in fallow systems?

- Is *Chromolaena* a problem in arable crops?

- What is the nature of *Chromolaena* - crop interaction?

- What effect does it have on soil physical and chemical properties?

- How beneficial is it relative to other fallow species?

- What management options (short of eradication) will minimize its harmful (competitive) effect in crops?

5.6 Pest management research

Pest management research will be initiated by a survey of pests and diseases in the cropping systems of the Mbalmayo area. A faunal inventory of the Mbalmayo farm will also be initiated, utilizing the different vegetational associations as the sampling frame.

Integrated pest management research will be developed within the framework of the cropping systems reseach proposed in section 5.8.

5.7 Land management research

Previous experimentation by IITA and other institutions have shown that heavy mechanized methods of land clearing have deleterious effects on soil properties and the sustainability of subsequent cropping systems. For this reason, the decision has been made to utilize only hand-clearing methods at the HFS (see section 2.2). Nonetheless a number of problems remain to be resolved:

- Labor requirement: The clearing of fallow vegetation is said by some farmers to be a major constraint in their activities because of lack of labor. On the other hand, the availability of chainsaws is enabling farmers to cut trees of significant size. Research is required on labor-saving methods of clearing which are as environmentally conservative as traditional methods.

- Hand-clearing results in a heterogeneous distribution of soil resources. The secondary forest environment is itself spatially heterogeneous with microvariability due to the presence of termite mounds, trees of different sizes, and clearings with or without cultivation. Hand-clearing does not destroy this heterogeneity in the way that mechanized intervention does, but indeed adds to it by producing areas with and without biomass debris, stumps, and occasional standing trees. The effect of this heterogeneous resource distribution on cropping system performance requires investigation.

- Burning of biomass following clearing has complex effects on the fertility and the seed bank of soil. At Mbalmayo preliminary studies have shown that some areas subjected to intensive burning may remain sterile for a significant period of time. These effects, which may be a product of chemical, physical, and biological factors, need detailed study at the process level.

- The process of devegetation can influence surrounding areas of the same catchment and the associated lowlands by run-off and subsurface flow. These environmental effects are influenced by the intensity of clearing, the slope of the area, the place on the catchment of the cleared area, and the size of the cleared patch relative to the total catchment area. Catchment and sub-catchment scale studies are needed to investigate these effects.

- Many, perhaps most, inland valleys in the HFZ remain uncleared and uncultivated. These zones may, however, be progressively opened in response to increasing degradation of the uplands and the availability of germplasm and other technology for improved wetland cultivation. There is very little information either on methods of clearing of inland valley vegetation or of the consequences of clearing with respect to inland valley resources and environment. These are likely to be profound. Uncleared valleys have a diverse microtopography, whereas cleared and cultivated valleys are characteristically flat-bottomed. This is a product of both "natural" and "engineered" influences, resulting in the redistribution of both alluvium and water courses. Mbalmayo offers an opportunity for detailed study of the effects of clearing and for the development of appropriate methods.

Initial studies (i.e., the first three of the above) will be confined to field-scale studies on microvariability in relation to different methods and intensities of clearing (including the effects of burning).

The monitoring of water flow, water table, and water quality (sediment load and nutrients) will be established in all on-site Inland Valleys (and possibly, by agreement with the Forestry Department, in any streams flowing accross the HFS boundary). Catchment scale studies will be established later, in collaboration with the Inland Valley Program.

5.8 Cropping system studies for testing incremental impact of component technologies

IITA proposes to establish long-term fallow management systems at its Mbalmayo station. The core of the experiments will be the establishment of traditional fallow systems with varying cropping cycles (one to five years) which will establish a baseline for comparison with other systems. The systems will be highly replicated, such as to permit incorporation of various "improved" technologies for comparative purposes as they become appropriate in the future. For instance, replication could be such that a treatment (e.g., the introduction of a new crop variety, or weed management practice, or improved fallow) can be introduced for one or more cropping cycles, whilst still maintaining the baseline system as long-term controls. The essential feature of this set-up is thus to substitute traditional fallow systems for the conventional clear-field monocrops used as the control environment in conventional agricultural experiments.

In addition, different systems will be compared over a period of time, e.g., with a different fallow or fallow cycle. The results of the characterization and germplasm evaluation work would provide the basis for designing such systems. The development of these experiments will also be guided by on-farm information derived from the on-farm work of the Humid Forest Program as described in Section 4. This comparison, in terms of sustainability, would lead to modeling and would enable improved systems to be developed.

These studies will generate question and hypotheses to be tested, such as: how sustainable are the cropping systems of the HFZ and how do these systems respond to the incorporation of new component technologies?

6. Transfer and Adoption of Improved Technology

6.1 On-farm evaluation of technology

In the original CG concept, the task of developing prototype technology was assigned to IARCs, while NARS were expected to adapt the prototypes to the specific conditions of their mandate areas and test them under farmers' conditions. This role model suggests that on-farm validation is entirely the domain of national institutes.

Experiences from two decades of research by IITA have shown, however, that there is an important role for the institute to play in on-farm technology evaluation, for the following reasons:

- Adoptable technology cannot be developed in the isolation of the research station, but needs an early exposure to real farmers' conditions.

- On-farm research needs a consistent and generally accepted methodology in order to make results valid and mutually comparable. NARs expect IARCs to contribute to the development of such methodology, and to training in its application.

IITA's involvement in on-farm research (OFR) thus has the dual objective of directly testing its innovations in farmers' fields and assisting NARS in conducting quality OFR. Three mechanisms will be used to attain the two objectives:

- The regional Collaborative Group for Root and Tuber Crops Improvement and Systems (CORTIS, see below) will be developed into a mechanism for mutual technical support, with emphasis on on-farm technology testing.

- A methodology for the choice of appropriate varieties and on-farm varietal testing will be developed in close collaboration with CORTIS scientists, also a methodology for the incorporation of legumes in farmers' systems in collaboration with both CORTIS and COMBS (Collaborative Group for Maize-Based Systems Research).

- Pilot on-farm studies with other improved technologies will be conducted in selected sites in collaboration with NARS as such technologies become available.

6.2 Regional Collaborative Groups

A regional Cassava-based Systems Group was first set up in 1987 and consolidated in 1991 with the Collaborative Group for Tuber Crop Improvement under the name of CORTIS (Collaborative Group for Root and Tuber Crop Improvement and Systems Research). Apart from regular meetings and the exchange of materials and expertise among group members, the Group has chosen two areas for medium-term collaborative research:

- the use of legumes in root and tuber-based systems for weed control and fertility improvement; and

- the development of design criteria and procedures for on-farm testing of improved varieties.

It is expected that the group will further develop into a mechanism for the adaptation and on-farm testing of new cropping systems technology. The Savanna Systems Research Group has initiated a similar regional group for maize-based systems research (COMBS) and has made progress in developing a research methodology for the choice and testing of legumes in maize-based systems. Both groups should ensure consistency of approach in the future and develop a joint proposal to obtain external funding for their activities. The collaborative work on legumes and on the choice and on-farm testing of improved varieties should be pooled into projects covering both groups' ecological zones.

6.3 Pilot on-farm studies

The legumes project is an example of prototype technology which can be studied and adapted across a range of systems and ecologies to address the widely occurring problems of fertility decline and weed pressure. Other constraints may be more restricted and would need to be addressed in a particular system. The COSCA study will allow the identification of major humid zone cropping systems and the constraints peculiar to different systems. Further detailed field-level studies to better define and quantify those will be conducted in representative locations. These studies will provide guidance to the development of appropriate innovations, which will then be tested in selected pilot locations in collaboration with NARS.