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SOIL MANAGEMENT WITH SUSTAINABLE AGRICULTURE FOCUS IN CAMEROON

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SOIL MANAGEMENT CRSP

INTRODUCTION

Covering about 478,000 square kilometers, Cameroon extends from latitude 2° to 13° north. The country has a wide diversity of climate, ranging from the humid tropics near the coast, with annual rainfall up to 5000mm, to moist savannas in the central region with rainfall in the 900mm range, to the sahelian zone in the north, which has a nine to ten-month dry season and an annual rainfall of 500mm.

The bulk of agricultural research in Cameroon is presently undertaken by the Institute of Agriculture Research (IRA) for crops and forestry and the Institute of Zootechnical Research (IRZ) for animals and fisheries. Soil Science is listed as a priority within IRA and is organized as a National Soils Center (CNS) with stations located in various parts of the country. During the period of colonial research institutes, it is evident there was no effort to integrate nationals into the operational units. Although the British had recruited at least two nationals by 1962, the French made no attempt until 1966.

CLIMATE AND SOILS

Climatically, Cameroon can be divided into four (4) main agroecological zones, with subzones within affected by elevation

and topography. Soil formation and best adaptive crops are affected by temperature due to elevation that varies greatly within some of the main zones. The four main agroecological zones can be classified as follows:

1. Humid Tropics - with very heavy rainfall and a short dry season. The coastal regional and the mountain region of the west fall into zones where rainfall totals are up to 5000mm with as many as 250 rainy days per year. At higher elevation temperatures can remain too cool for maize and many days with very little sunlight and diverse rainfall.

2. Sub-humid Tropics - includes the forest zones of the south, and the southern reaches of the central savanna area. Rainfall in the zone is between 1500 to 2000mm per year.

3. Sudanese Zone - is marked by two dry seasons, rainy and dry, of about equal length. Although rainfall may attain 1600mm per year, evapotranspiration rates are higher than in the tropical sub-humid zone located to the south. The mean maximum temperature varies between 26°C and 28°C and the minimum between 16°C and 18°C.

4. Sahelian Zone - having a short rainy season and a long dry season. Total rainfall ranges from 500mm in the northern sector to 1000mm in the southern sector and is distributed over a three-

month period. Distribution is highly irregular. Temperatures may exceed 30°C and evapotranspiration rates are very high.

Soil associations in Cameroon are very complex because of differences in age, parent material, elevation, topography and climate. The soils of Cameroon have been mapped by FAO/United Nations Educational Scientific Cultural Organization (UNESCO) with surveys completed by French and Belgium assistance. The broad FAO classification (Figure 1) for the soils of Cameroon areas follows:

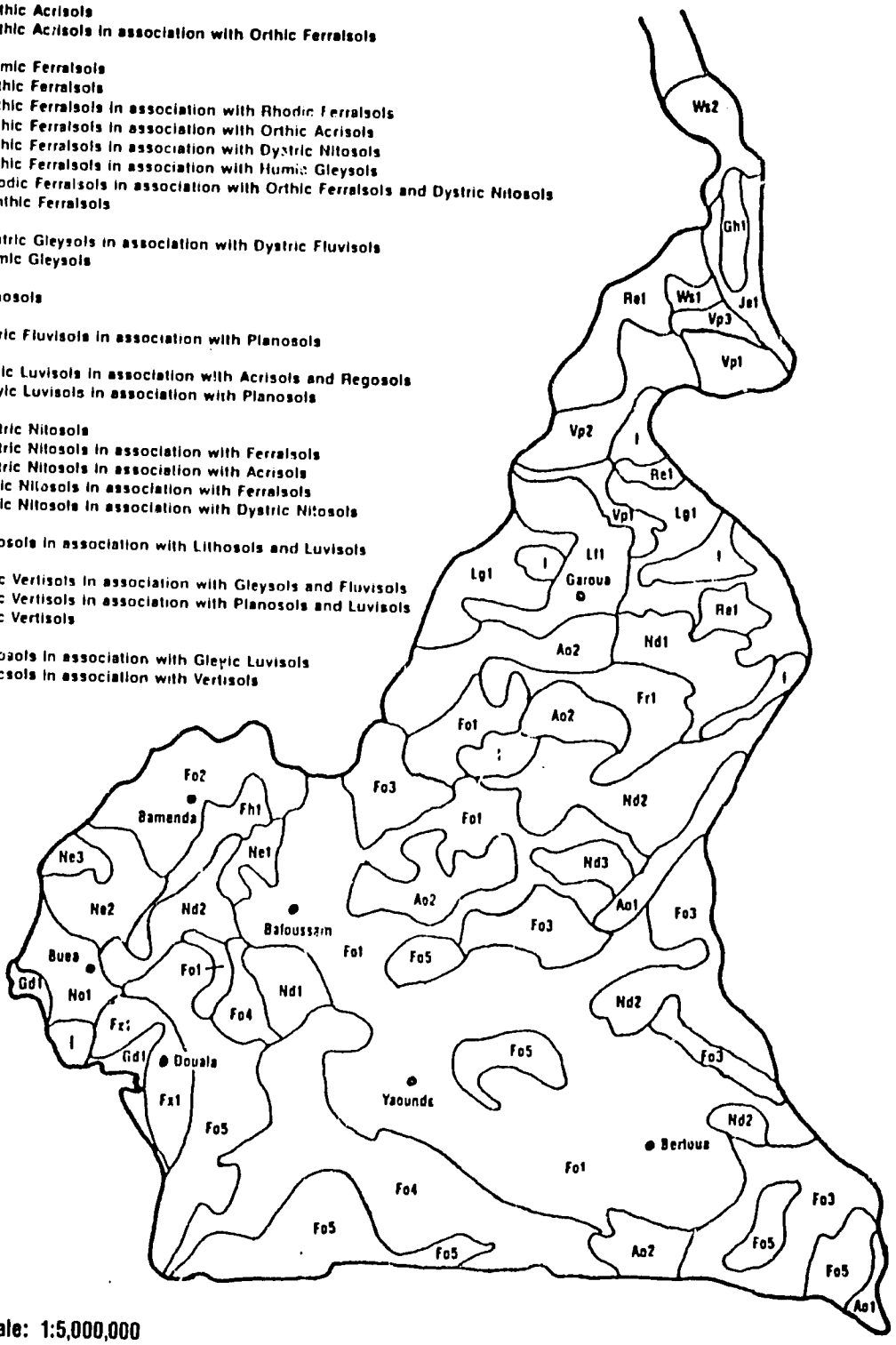
1. Acrisols - are very acid, highly weathered and leached soils. These are characterized by a low base saturation and have rather sandy surface horizons and clayey subsurface horizon. Most of the aerisols are found in central Cameroon.

2. Ferralsols - are highly weathered, red and yellowish red soils with a high content of iron and aluminum oxides. They are acid, generally very deep without much horizon differentiation, and clayey in texture. These soils are physically very good, but chemically they are poor and deficient in nutrients. Most of the Ferralsols in Cameroon are Orthix Ferralsols, which is the common type of Ferralsol. These soils cover most of the slightly undulating areas of the Central-South Province.

3. Fluvisols - are developed from recent alluvial deposits.

Legend

Ao1	Orthic Acrisols
Ao2	Orthic Acrisols in association with Orthic Ferralsols
Fh1	Humic Ferralsols
Fo1	Orthic Ferralsols
Fo2	Orthic Ferralsols in association with Rhodic Ferralsols
Fo3	Orthic Ferralsols in association with Orthic Acrisols
Fo4	Orthic Ferralsols in association with Dystric Nitosols
Fo5	Orthic Ferralsols in association with Humic Gleysols
Fr1	Rhodic Ferralsols in association with Orthic Ferralsols and Dystric Nitosols
Fx1	Xanthic Ferralsols
Gd1	Dystric Gleysols in association with Dystric Fluvisols
Gh1	Humic Gleysols
I	Lithosols
Je1	Eutric Fluvisols in association with Planosols
Lf1	Ferric Luvisols in association with Acrisols and Regosols
Lg1	Gleyic Luvisols in association with Planosols
Nd1	Dystric Nitosols
Nd2	Dystric Nitosols in association with Ferralsols
Nd3	Dystric Nitosols in association with Acrisols
Ne1	Eutric Nitosols in association with Ferralsols
Ne2	Eutric Nitosols in association with Dystric Nitosols
Re1	Regosols in association with Lithosols and Luvisols
Vp1	Pellic Vertisols in association with Gleysols and Fluvisols
Vp2	Pellic Vertisols in association with Planosols and Luvisols
Vp3	Pellic Vertisols
Ws1	Planosols in association with Gleyic Luvisols
Ws2	Planosols in association with Vertisols



Scale: 1:5,000,000

Source: FAO UNESCO
Soil Map of the World
Sheet VI Africa

Figure 1. Schematic Soil Map of Cameroon.

3A

These young soils do not show much horizon differentiation, but generally they have a good level of organic matter and fertility, particularly the Eutric Fluvisols. This soil covers small areas mostly in association with others.

4. Gleysols - are formed from unconsolidated materials exclusive of recent alluvial deposits, and they show hydromorphic properties. Most coastal soils covered with mangrove vegetation belong to this unit. The Gleysols of Cameroon are mostly Dystric Gleysols, and Humi Gleysols, which have a considerable amount of organic matter.

5. Lithosols - are soils which are shallow to very shallow over continuous coherent hard rock. They occur normally in areas with steep mountain slopes in the Cameroon highlands and the Adamaoua massif. Their agricultural value is low, although some of them, like those around Mount Cameroon, are associated with young volcanic soils which have a very good development potential.

6. Luvisols - are characterized by an accumulation of clay in the subsurface horizon. In Cameroon, these soils have rather sandy texture, low organic matter contents, and are not very favorable for development.

7. Nitosols - are deep dark red ferrallitic soils developed mostly on old basic volcanic rocks. They are generally very

clayey, well structured, and relatively rich in organic matter with a fair to good fertility status. In Cameroon, these soils are among the most cultivated and utilized, and they are found notably in the western provinces and the Nagaoundre area.

8. Planosols - are soils of level areas with light-colored loamy surface horizons overlying a slowly permeable, dense, clayey surface horizon, showing hydromorphic properties and poor drainage. In Cameroon, these soils are found exclusively in the extreme North Province and are characterized by some sodium in the exchange complex.

9. Regosols - are soils from unconsolidated generally coarse-textured materials without much horizon differentiation. They occur particularly in the north, Mandara massif, around Maroua and northeast of Nagaoundre.

10. Vertisols - are dark-colored clayey soils with a swelling clay. In Cameroon, most of the vertisols are very dark colored Pellic Vertisols. They occur in the north of the Logone Plain, and in the Benoue Valley in association with Gleysols and Fluvisols.

SOIL SCIENCE IN CAMEROON

Soil Science appears to be concentrated in two institutions

in Cameroon IRA and the Central University of Dschang (CUD). Both institutions operate under the same Ministry. CUD is under a long-term USAID development contracted with the University of Florida. This university offers a three-year degree (TA, technical agronomist) and five-year degree (IA, engineer agronomist). The TA degree program has been judged by some U. S. University less than equal to a B. S. and IA degree less than a M. S. degree. They plan to work to a two-year technical program and a four year B. S. program. The Soil Science curriculum was initiated by Belgium and three (3) professors still head up the department. The department has a laboratory that completes various plant and soil analyses for income purposes and to support some senior thesis projects.

The Soil Science research in IRA began in 1974 under a FAO project to install a laboratory at Ekona, about 75km northwest of Douala, to carry out characterization analyses in support of soil classification. FAO has not been operating in Cameroon to support this facility since 1983. The French Government, through ORSTOM, supported classification activities from 1983 to 1987. There has not been outside donor support for institutional development since 1987 although there were/are various activities collaboratively with IBSRAM, IBSNAT, EEC block grant and the University of Munich. Traditionally, soils research in the Cameroons has followed the French pattern with practically all of the work centered on soil genesis, survey and inventory. There

is a fairly substantial gap between this concept and that of U. S. universities, which considers soil science to include not only survey and pedology but also soil management inclusion of soil fertility, chemistry, biology, physics, conservations and use. In the French system soil fertility and management are included in agronomy.

This historical development is very observable with respect to the human resource base in soil science. Depending on whose list you use, there are 18 researchers (mostly M. S.) in the IRA-CNS, mostly in pedology and classification, two with M. S. degrees in the discipline of soil fertility/chemistry and one studying for a Ph.D. in soil chemistry with TropSoils at Texas A&M University. There is not a total compliment of M.S./Ph.D. soil scientists in Cameroon that would fit into the 9-10 divisions of the Soil Science Society of America or the International Society of Soil Science classification.

The National Center for Soils (CNS) was created by order of the Prime Minister No. 59/CAB/PM of April 12, 1983, and is part of the Institute of Agronomy Research (IRA). It structures now comprise two (2) research centers at Nkolbisson and Ekona and the two stations at Maroua and Dschang. Major research sections are: 1) inventory and evaluation of soil resources; 2) conservation of soil and water resources; 3) utilization and exploitation of soil and water resources; 4) interdisciplinary inventory of natural

resources; and 5) laboratory operations. Supporting units include: 1) cartography; 2) data bank; and 3) documentation.

With respect to functional soil science laboratories in Cameroon, the CNS laboratory in Ekona and the CUD laboratory at Dschang are the most complete and functional in Cameroon. They were designed and equipped, with instruments, labware, methodology, to service soil characterization and classification programs. While they are capable of completing some analysis to support some soil fertility research programs, their analytical methods, quality and quantity, are far from adequate; and cost per sample is, by U. S. standard, excessively high. These laboratories are simply not properly equipped with the appropriate labware, equipment, instruments and methodologies to provide high volume capacity of analyses affordable to soil fertility programs. This has resulted in a number of happenings to Cameroon agriculture and the NCRE project. There is not a focused soil test correlation and calibration work to interpret soil test for the most economic quantity(ies) of fertilizer nutrients for the diverse soil-cropping systems. Lack of adequate foliar analysis capacity limits services to develop the competition advantage of Cameroon major cash export crops. Long delays in obtaining results from these laboratories and the high cost of analysis has resulted in the NCRE agronomy and TLU programs to minimumly utilize their services. They have shipped samples to IITA in Ibadan, Nigeria. The NCRE/IITA maize breeder

has sent samples off to an old colleague at the University of Minnesota, USA.

The Nkolbisson laboratory, while having some relatively new space, lacks for instrumentation to even be able to adequately support a soil characterization program and necessary labware to complete those analysis commonly employed in a soil testing program. There is still observable evidence of the OSTROM program at Nkolbisson via old soil samples equipment and chemicals that have been placed into storage.

The CNS laboratory at Dschang, developed by the French some years ago, was non-functional until the recent NCRE project purchase of some minor equipment and labware. This laboratory, while now being able to conduct some analysis to support field projects can not be classified as a functional laboratory. The CNS laboratory at Maroua was found to be completely non-functional with a few pieces of old equipment and glassware once used to support characterization analysis.

The soil analysis methods used in the laboratories originated from a FAO manual, modified for the Cameroon environment to fit the FAO, French and Belgium project requirements. The plant analysis methods to support the parastatal export cash crops are also thought to come from France. The concept and knowledge of soil testing methods, plant

analysis methods and their interpretations from calibration data for economic fertilizer recommendations and the gearing up for capacity to provide economics of volume is not presently adequate in Cameroon.

There are some non-institutionalized soils programs in Cameroon. GTZ has a runoff study at Nkolbisson. The EEC grant system is supporting a short term study on soil physics/conservation measuring the effects of mulch on rainfall infiltration and erosion abatement of soils that were exhaustively farmed and abandoned in the north provinces. There is also a GTZ project in the Northwest Province that is developing terraces to reduce runoff and soil erosion. There is not the critical mass of soil scientist to put together programs to address sustainable agriculture production, nutrient cycling in legume fallows, agroforestry and alley cropping systems; constraints of soil acidity, nutrient deficiencies and imbalances, physical problems, topography and water stress. Soil biology capability is inadequate to understand legume-nonlegume relationships for intercropping and alley cropping in both savanna and humid tropical environment.

INFRASTRUCTURE NEEDS

The issue of infrastructure development to bring along capability and competence in soil science to serve the emerging

food. fiber, fuel and building materials needs for Cameroon is complex. It is not within this proposal to solve all the deficiencies in soil science in Cameroon, but to build some physical needs, match human resource needs within IRA to service diverse and demanding number of programs from which long-term program strengthening can build upon. The final plan must build upon present infrastructure to develop as much overall research and service capacity as can reasonably expected to be affordable.

The following are recommendations based on field visits and understanding of available physical structure and personnel available to be able to conduct soil management research. The following infrastructural investments are recommended:

1. Nkolbisson - This should be the CNS central laboratory location that can serve the broadest number of research/service and training functions in the country. This should have the necessary labware, instrumentation, data processing, support facilities and space to be the national laboratory around which research/service/training programs can function. This will need to be put together in a step-wise need fashion. To start with, it should be able to serve soil fertility programs, i.e. soil and foliar analysis, characterization analysis and some support to soil biology programs. This does not imply the latest in state-of-the-art high-tech equipment used in many quality U. S. land-grant universities, but basic durable pH meters, colorimeters,

atomic absorption spectrophotometer, hand operated dispensers, digestion blocks, etc., that have proven to be very serviceable and require limited maintenance. This would require both structural modification of the present CNS facilities and importation of labware, equipment, etc. The details of which cannot be presented at this time.

2. Ekona - The Ekona lab appears to have received the most resources during the days of FAO programs for characterization and classification. To support a soil fertility field program, their immediate need is for labware to streamline their nutrient extractions procedures to increase soil analysis (soil testing) throughput capacity. This lab now charges $36 to $45 per sample for what is labeled as a routine analysis. This is the range of nine to ten times higher than cost per very similar analysis in the U. S. The Ekona laboratory has much of the basic instrumentation, but would benefit through purchase of lamps for their atomic absorption spectrophotometer unit to enable analysis of additional micronutrients, soil grinder to speed up soil preparation, etc.

3. Maroua - This laboratory is presently non-functional as far as being able to provide support to a soil fertility research and extension program to quantify most economical nutrient requirements for crops in the area. The laboratory was originally designed to support the soil classification program

but appears not to have been in service for quite some time. The NCRE project, active since 1983, has never been able to use it and shipped some samples for analysis to IITA in Ibadan, Nigeria.

This laboratory should be equipped as a satellite laboratory and be able to complete those analysis to be used in soil testing, or availability of plant nutrients to facilitate soil test correlation and calibration. In addition, capability to determine soil salinity might be necessary at this IRA center.

4. Dschang - There is an IRA laboratory with limited equipment at Dschang. Decisions on equipment and needs for this laboratory will need to wait until the decison is made as to whether this station will become part of CUD or remain a structure of IRA.

This should provide IRA-CNS a cost effective laboratory network to serve soil fertility research programs and generate the necessary soil test calibration data to support economic fertilizer recommendations. It is also recommended that the process of analytical quality control and coordination of national programs be charged to the center at Nkolbisson.

SUSTAINABLE AGRICULTURE PROGRAM FOCUS

Sustainable agriculture production is defined as: "The successful management of resources for agriculture to satisfy

changing human needs while maintaining and enhancing the natural resource base and avoiding environmental degradation." The benefits of developing sustainable agriculture include reduced tropical deforestation and desertification, increased soil productivity, and greater social stability. In short, sustainable agriculture will enhance the environment while providing food, fiber, fuel and shelter materials at affordable prices. The principle soil management constraints to sustainable agriculture production are: 1) soil acidity; 2) nutrient deficiencies and losses; 3) soil physical limitations; 4) topographic limitations; and 5) water stress. The following suggestions of some researchable problem addresses the constraints to sustainable agriculture production in Cameroon.

1. Soil Acidity - Farmers in the Northwest Province cultivate their soils into large mounds and plant on the mounds to compensate for loss of surface soils through erosion, thus, maximizing the benefit of the remaining topsoil. The farmers have observed poor crop growth when planted on shallow or subsurface soils because of acidity related problems.

There are two aspects to ameliorating soil acidity in Cameroon. Limestone deposits are not common in the Cameroon, found in small scattered pockets and is expensive and difficult to purchase. A cement factory by-product is being tested as a liming material. The quantity and quality of material appears to

be unknown. Without calcium-magnesium carbonate liming materials to correct for soil acidity problems this research thrust must investigate other options in soil-crop management. Use of legume fallow systems utilizing the biomass as the incorporated amendment offers a potential management alternative to ameliorate problems of soil acidity. The verification of the TropSoils ACID4 decision support systems for Cameroon soils could be used to conduct cost benefit analysis of soil acidity reduction.

2. Nutrient Deficiencies and Losses - Soils of the tropics, in addition to acidity constraints, are often low or deficient in one or more primary and secondary plant nutrients. Low crop yields attributable to poor plant nutrition and accelerating soil degradation are major contributors to rainforest destruction and land abandonment in the humid tropical zone, and the encroachment of barren lands in the savanna and semiarid areas in the northern regions of Cameroon.

Nitrogen is the primary nutrient universally required by the cereal crops, i.e. maize, rice, sorghum, pearl millet and cotton--the principal fiber crop. Maize, in many systems, is grown in mixtures with roots and legume crops, while sorghum and millet grown in dual or monocrop and flooded rice grown monocrop. Larger maize growers tend to grow maize as a monoculture as do the cotton growers. Nitrogen fertilizer is imported into Cameroon as single nutrient and mixed fertilizer and is very high

in price. The challenge is to develop legume based systems that could replace this need to purchase nitrogen fertilizer as an off-farm input.

Soils in Cameroon are reported to vary from very low in available phosphorus, with high phosphate fixation capacity, to being high in available phosphorus. The challenges are in calibrating soil test for most responsive phosphorus fertilizer inputs to and systems of legume fallows that would economically recycle phosphorus and other nutrients. There are other deficiencies reported; secondary nutrients magnesium and sulfur and the micronutrient zinc. This would require some specific research focused on the observed deficiencies or imbalances.

Depletion of soil nutrients and land abandonment because of low yields is a challenge in Cameroon. Systems to minimize off-farm purchase is a challenge to food crop production because of the need to reduce production cost because of internal and external production costs. Understanding nutrient needs for sustained production and rate of nutrient cycling systems offer opportunity for low-input sustainable systems.

The two primary nutrients, because of low inherited plant availability in the soils of Cameroon that if not added through use of addition of inorganic chemical fertilizer or recycled through biomass, is nitrogen and phosphorus. Other nutrient

deficiencies will occur upon supplying these two primary nutrients. Many soils are cultivated into degradation through depletion of the nitrogen supplying capacity of the organic matter and depletion of available phosphorus, which can be also concentrated in the organic fraction.

3. Soil Physical Constraints - Many of the soils in Cameroon do not have physical properties that limit or make especially difficult to cultivate. The exception being pockets of soil that are stoney, have rocks, eroded to subsoil and the vertisols. Many soils are relatively easy to physically cultivate. Some physical limitations have developed on hilly and upland soils because they are continuously cropped without application of proper soil conservation practices. Erosion to subsoils that are often acid and low in organic matter are also massive and hard. In old soils found in rainforest areas, this leads to low production, abandonment, and advancement to new areas. In some provinces, population pressure is limiting this advancement because there are no new areas.

In the northern savanna regions, continuous cropping and removing the total plant for animal feed, fuel and shelter material decreases organic matter, leaves the soil subject to wind and water erosion resulting in loss of the surface horizon containing the organic matter that tends to keep soil particles aggregated. This results in soil crusting, setting up in massive

form limiting water infiltration, poor plant growth leaving the area without vegetation for regeneration even if permitted to fallow.

4. Topographic Limitations - Landscape configurations in Cameroon impose special challenges in the development of appropriate soil management technologies for sustainable agriculture production. Much of Cameroon's most densely populated and intensively cultivated region is on landscape judged as hilly and steeplands. The perennial parastatal cash crops are generally cultured with a permanent ground cover. Food crops, coffee with intercropping, etc., are cultured through intensive and extensive land preparation. Many of these landscapes are cultivated by hand because of both economic and physical limitations for mechanization. Organic matter incorporation and weed control are major reasons for the physical cultivation, the process which leaves the soil very subject to erosion and degradation and loss of productivity. Cropping and farm-based systems research approached with soil management as the basis is needed to help offer labor saving low-input sustainable production technologies.

Topography of the northern savanna is very suitable for mechanization but this does not mean soil conservation practices should be ignored. Rainfalls are often intensive and even on relatively gentle undulating topography water runoff and soil

degradation by erosion is a deterrent to sustainable agriculture production. Specific research into potential utility of legumes as green manure and/or fallows as sources of nitrogen and nutrient cycling and soil protection to prevent soil physical degradation and loss by erosion should be undertaken.

5. Water Stress - Moisture stress, natural and imposed, may result from either excessive or inadequate amounts of water. The consequence of water stress is often a loss of crop yield. Many of the cultivated soils in Cameroon have acid/hard pans and other properties that restrict root growth into the subsoil. Loss of topsoil, in this environment, restricting rooting to a shallow depth will limit exploration to a smaller quantity of the available soil moisture subjecting the plant to potential moisture stress during short periods of dry weather even during the rainy season.

In semiarid and savanna regions, loss of water by runoff induced by surface compaction reduces infiltration and storage of moisture in the soil subjecting plants to stress between rainfall events. Soil management systems focusing on enhancing water harvesting offers opportunities for developing sustainable production on these soils.

Because of topographic location, some soils pass through periods of water saturation as a different form of stress induced

by excess water. Some of these soils, not best suited for rice, offer high sustainable production potential if a proper management system is developed.

Sustainable agriculture development will require the management, conservation and enhancement of soil resources of Cameroon because it is most critical to meeting food, fiber, fuel and shelter requirements of the population, as well as to preserving genetic diversity and attenuating climatic change.

The IITA-National Cereals Research and Extension Project has generated some new ecologically suitable genetic material that is presently on the shelf. The Fertilizer-Reform project, to privatize the fertilizer sector to reach more growers with fertilizer at affordable prices offers the input to contribute to sustainable agriculture production. Evaluations of both projects has identified the weakness in overall soil fertility and management programs to maximize outputs from these to donor projects. A soil management based sustainable agriculture production program is the missing link to insure a maximum return from the research investment in the on-the-shelf new genetic material and fill the agronomic gap in the Fertilizer-Reform programs.

TRAINING NEEDS

A definitive training program will require the evaluation of available technical human resources within Cameroon at the present time. The latest list of soil scientist in Cameroon indicates 18 but does not break down this list by discipline and degree. There is strong indication that major past training emphasis has been on pedology and classifications. Future training would attempt to reallocate personnel away for the strength of pedology and classification, but would build upon this strength.

Available information indicates, only about two or three M.S. candidates in the soil chemistry-fertility discipline, one M.S. in training, three with possible emphasis on soil management and one Ph.D. candidate in soil chemistry. More information to sort out strengths and weaknesses by discipline will be required. For IRA to develop a balanced program in soil management would require development of critical mass in the following disciplines:

Soil Fertility

Soil Physics

Soil and Water Conservation

Soil Chemistry

Soil Biology

Land Use Management

The soil laboratories would need overall managers in charge with minimum of M. S. in soil fertility and some specialized training. To develop this critical mass will require a phase in of five to seven years, based on availability of candidates and ability of IRA to absorb most of recurrent costs.

TIME PHASE PLAN OF ACTION

It is expected that to develop the critical human resource mass, research facilities, programs at the rate the IRA could absorb the recurrent costs, and develop the autonomy to be a strong collaborating institution would require six to ten years. This would require modest quantities of funds spread over time to insure high probability of host country absorption.

Phase I

This would involve installing the soil testing and plant analysis laboratory in Nkolbisson. Parallel to this development will be the organizing of TLU field fertility trials so they can be used to develop the soil test calibration data base. Graduate student research could focus in on the correlation of soil nutrient extractants most suitable for Cameroon soil systems. Human resource requirements and training plan could be formulated during this period.

Phase II

The small supportive soil testing laboratory for Maroua would be installed and put into operation. This should be under management of a soil fertility agronomist of IRA. Selection of legume materials and growth competitive studies started before moving into low-input sustainable systems research. Social economist and agronomists in the TLU's will be expected to have completed the necessary surveys to understand the major cropping systems and help identify some low soil management programs to be researched to address farmer needs.

Phase III

The various low-input sustainable production systems work could be started. This will be based on absorption capacity and utility of incorporating research into student thesis problem. The Ekona lab could be upgraded to include the soil testing system into their capacity.

Phase IV

Installations of some of the soil management, soil conserving, sustainable systems in farmer fields. This would be the time that TropSoils could start participating more as a

collaborating entity to add more depth, modeling and verification to the program.