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REPORT OF THE INTERNAL AND INTERPROGRAMME REVIEW OF THE IRA/ICRAF RESEARCH PROJECT IN THE HUMID LOWLANDS OF CAMEROON

13-19 June 1993

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EXECUTIVE SUMMARY

1. Introduction

Between June 13 and 19th, 1993, an internal and interprogramme ICRAF review was undertaken of the IRA/ICRAF Project based in Yaoundé, Cameroon. This was the first review of this project, established in 1987 following a Macro and Micro Diagnosis and Design Analysis in 1986.

The Review Team was given three objectives.

- Review the on-going station and on-farm activities in terms of quality and relevance.
- Identify future directions for the IRA/ICRAF collaborative research, including locations of the work.
- Identify strategic research issues which could form the basis of a joint programme between IITA/ICRAF at the Humid Forest Station.

Upon arrival in Yaoundé, the team found that the project staff had prepared a very thorough agenda, and provided a comprehensive set of documentation to support the review. The team's job was made a great deal easier by the excellent advanced preparation of Dr. Duguma and his colleagues. One document, a detailed and comprehensive report of the project background, experimental results, conclusions and proposed priorities for the future formed the centre piece for the review, and constitutes Appendix 1 of this report.

2. Review of past and on-going research

In this exercise, every experiment (both on-station and on-farm) was reviewed individually, both in the meeting room and the field. An experiment by experiment assessment is provided on pages 6-24 of this report. For each experiment, we provide (a) a brief description of the experiment, (b) the major conclusions drawn, (c) the review team's observations and (d) the review team's recommendations. For each experiment, the team refers the reader to the relevant pages of Appendix 1 for more detail.

This section was sub-divided into the four major areas of research addressed by the project to date, namely

Area 1 - Vigour/phenology species screening of MPTs
Area 2 - Management trials for hedgerow intercropping
Area 3 - Management trials for improved fallow
Area 4 - Management trials for the diversification of cocao production.

In the Area 1 - species screening, the team had several recommendations, but the three most important were.

(1) As a matter of urgency, in all species screening work (not only in Cameroon) standardization of assessment methods must be initiated

(2) Greater emphasis should be placed on indigenous trees and farmers knowledge of them

(3) In future species screening, trial design, species chosen for evaluation and assessment criteria should be targeted towards a specific technology.

In Area 2 - Management trials for Hedgerow Intercropping, the team noted that these early trials on hedgerow intercropping suffered quite serious design problems, and recommended that they be terminated and written up with caution. In another trial, which compared hedgerow intercropping with contrasting spatial arrangements of trees, again, the team noted some design problems, but recommended that the trial should continue with some modifications as biomass transfer from block planting appeared promising. Another trial investigated the potential of regression models using easily measured parameters to estimate biomass production of hedgerows. Models appeared to be species, species age and location specific and the team questioned their usefulness. An improved method of analysis was identified, and if this fails to produce more promising results, the team recommended that this work be discontinued. The last on-station trial (at Ebolowa) concerned the impact of the time of first pruning on subsequent biomass production of hedges. This trial was well designed and managed, and had produced useful results. The team noted that of the four species evaluated, ***Calliandra calothyrsus*** was showing outstanding performance. The team recommended that modified treatments should be imposed on this trial to compared hedgerow intercropping and improved rotational fallow systems with several appropriate control treatments.

Hedgerow intercropping was being evaluated with a large number of farmers near Yaoundé and Ebolowa in researcher controlled trials. In general, the team felt that given the projects resources, perhaps too many farmers were involved. The team did not observe any substantial responses to this technology thus far, but that in general, the hedges were well managed. The team had three major recommendations.

(1) At carefully selected sites, the Hedgerow Intercropping trial should be converted (which is easily done) into Improved Rotational Fallow trials in which the hedges are allowed to grow into trees for a two year fallow period. This had happened accidentally on two farms we visited, and farmers were pleased with the ease of fallow clearance and the response they got!

(2) Overall, the number of farms should be reduced.

(3) The team recommended greater researcher control in the early stages until farmers were familiar with what was required to make the technology work. With time, greater farmer responsibility can be allocated and adoption/non adoption and farmer management can be monitored.

ı **Area 3 - Management Trials for Improved Fallow**, two approaches were being aluated. In the first, the use of perennial shrubs, the team noted several design problems hich made the results hard to interpret. However, we felt that this approach had promise, ıd recommended that the work continue with fewer species and improved design. In the cond area, an Improved Rotational Fallow system was being evaluated, and showed great omise from both a biophysical and farmer adoption point of view. The team was very npressed with this work and fully endorsed its continuation and expansion.

ı **Area 4 - Management Trials for the Diversification of Cocao Production**, a new, large nd long term trial had just been initiated. Given the nature of this trial (no final result until 005), the resources required to run it and the very uncertain future of West African cocao, he team recommended that this trial be terminated now.

. Priorities for Future IRA/ICRAF Collaboration

Jsing 11 criteria, the review team assessed the relative priority of five broadly defined groforestry technologies for future research. There was substantial agreement amongst the eam, and the following order of priority was recommended.

(1) Improved Fallow Systems
(2) Indigenous fruit trees for Homegardens
(3) Live fences and associated fodder banks for livestock
(4) Hedgerow Intercropping
(5) Diversification of cocao production systems.

For the first three systems above, the team recommended research issues and strategies to be adopted. For hedgerow intercropping, the team recommended no new trials, but the continued monitoring of some existing trials. For the cocao production systems, the team recommended that all research in this field should be terminated.

4. Future Research Locations

The team recommended that IRA/ICRAF research should continue at both Yaoundé and Ebolowa, but in addition, noted the following:

at Yaoundé - (a) more and better quality land is required, (b) long term climatic data should be collected from a nearby location, (c) a weather station should be installed and (d) soils characterization data (already done) should be made available to the project.

at Ebolowa - (a) this station has been underutilized in spite of many attractive features related to land availability, soils conditions (low pH and high % Al saturation), accessability, housing and facilities, (b) IITA is also keen to use this location, (c) Caliandra appears outstanding at this location. Based on this, the team recommended expanded research at Ebolowa and the placement of an ICRAF Post-doctoral fellow full time at Ebolowa to be responsible for this research.

5. Strategic Research Collaboration with IITA at Mbalmayo

The team visited IITA laboratory facilities in Yaoundé and the research station at Mbalmayo. They were impressive facilities. The team also had discussion with IITA staff at Mbalmayo, - but were unable to meet with the senior scientist in charge. From IITA's side, the following fields of expertise will be available for collaboration, - Soil Chemistry, Soil Physics, Soil Biology, Weed Science, Crop Agronomy, and Social Science. Given ICRAF's own expertise in Cameroon, Forestry and Agroforestry, a well balanced team of expertise will be available for collaborative strategic research. Although the team was unable to hold specific discussions on collaboration with IITA staff, it was clear that those we met would be interested and willing collaborators.

The team discussed priorities for collaborative strategic research topics and recommended that the three top priorities for the IRA/ICRAF project, namely (1) Improved Fallows, (2) Indigenous Fruit Trees for Homegardens and (3) Live fencing/fodder banks, should also provide the agenda for strategic research, but placed the highest priority on improved fallows. The team also noted that ILCA (at Ibadan, Nigeria for 10 years) was also moving to Cameroon, and recommended close consultation and collaboration with them in the field of livestock research.

REPORT OF THE INTERNAL INTERPROGRAMME REVIEW OF THE IRA/ICRAF RESEARCH PROJECT IN THE HUMID LOWLANDS OF CAMEROON
13-19 June 1993

BACKGROUND TO THE REVIEW (see pages 1-12 of Appendix 1 for more detail)

The IRA/ICRAF agroforestry project was established in April 1987 based upon the conclusions arising out of a Macro (September 1986) and Micro (November 1986) Diagnosis and Design exercise. Based on this analysis, it was decided to place priority on the **cocoa/food crops/coffee production systems** which is found throughout the Southern Cameroon Plateau, and in the more sparsely populated transitional zone between the plateau and the Western Lowlands. It is the most important agricultural region in the humid lowlands of Cameroon, representing the bulk of smallholder producers and production. The Government of Cameroon is concerned that the economic zone around major cities becomes an effective supplier of foods to the growing urban population of the capital. Comparatively, little research has been done on food crop production for the Southern plateau.

The soils of these zones are predominantly low fertility Orthic Ferralsols. Rainfall on the plateau ranges from 1500-2000 mm, increasing to 3000 mm in the transitional zone where cocoa is more marginal.

Within the cocoa/food crops/coffee production system, three sub-systems were identified as follows:

1. **Food Crop Production Sub-system** in which traditional slash and burn agriculture is practised (fallow length 3-10 years) and food crops, dominated by maize, groundnut, cassava, plantain and cocoyam are grown. In this system, the D&D identified declining soil fertility, soil acidity and aluminium toxity, and labour shortages as principal constraints to production. The following agroforestry technologies were identified as having potential to mitigate these constraints.

   Hedgerow intercropping

- Improved fallows with multi-purpose trees
- Short fallow rotations with annual/perennial shrub mixtures
- Live stakes for yam and ngon (a small melon) production
- Practices which reduce soil exposure and hence soil erosion.

To date, the project has focused on the first three areas of investigation.

2. **Home Garden/Livestock Sub-system** in which a wide range of fruit, vegetable and food crops are grown in multi-strata systems close to the homestead. Goats, sheep, poultry and pigs are also associated with this system. The D&D identified labour shortages, destruction of crops by animals and lack of species diversity as the principal constraints in this sub-system. The following technologies were recommended as having potential to mitigate these constraints.

    - Live fencing
    - Associated fodder banks
    - Improved tree species diversity.

    To date, the project has not addressed the problems of this sub-system, -but the work of Dr. Ladipo in Nigeria and Cameroon is relevant.

3. **Cocoa Production Systems** in which cacao is grown in pure stands as a cash crop. In 1986, the D&D analysis identified poor farming tools, declining soil fertility, aluminium toxity, shortage of labour, poor quality shade trees, high incidence of disease and competition with food crops for resources as major constraints. However, within the last six years, a drastic decline in cocoa prices from 1000 CFA/kg about 10 years ago to 200 CFA/kg in 1993 has become the overriding constraint. Based on this recent event, a trial was initiated to examine the potential of diversification of cocoa production systems through intercropping with food crops and high value shade trees.

Based on the D&D and discussion with IRA colleagues, the project established three overall objectives.

- To develop agroforestry technologies aimed at ensuring improved and sustainable production of food and cash crops

- To assist in developing human resources in areas of agroforestry research

- To assist in the institutionalization of agroforestry research within the national agricultural research systems.

Following a recent visit to Cameroon, the Deputy Director General of ICRAF recommended a thorough internal and interprogramme review of the project, focusing on the achievements made towards meeting the first of the above three objectives. The specific objectives of the review team were to:

1) Review the ongoing station and on-farm activities in terms of quality and relevance

2) Identify directions for the IRA/ICRAF collaborative research (applied/adaptive) including locations of the work

3) Based on the ongoing work to identify strategic issues which could form the basis of a joint programme between IITA/ICRAF at the Humid Forest Station (Mbalmayo).

REVIEW TEAM COMPOSITION

The principal members of the review team were:

From ICRAF - Dr. Bahiru Duguma, Agroforester, Programme 4 (Cameroon)
- Dr. Elias Ayuk, Socio-economist, Programme 1 (Burkina Faso)

- Dr. David Ladipo, Forester, Programme 2 (Nigeria)
- Dr. Meka Rao, Agronomist, Programme 3 (Kenya)
- Dr. Peter Cooper, Soil Scientist, Programme 4 (Kenya)
- Mr. Richard Coe, Biometrician, (Kenya)
- Mr. Matthias Mollet, Agronomist, Programme 4 (Cameroon)

From IRA, Cameroon

- Dr. Jean Tonye, National Coordinator
- Mr. Tiki Manga, Agroforester
- Mr. Jacques Kanmegne. Forester
- Mr. Luc Andre Bayomak, Agronomist

However, during the review period, the team met several other scientists who contributed towards the mission objectives. A list of all these people is provided in Appendix 2 with our sincere apologies if we have omitted anyone.

MATERIAL AVAILABLE TO REVIEW TEAM

In addition to the field visits, both on-station and on-farm, substantial written material was made available to team members as indicated below.

- A detailed, comprehensive and high quality report of project background, experimental results, human resource development and proposed priorities for the future. This report was prepared by Dr. Duguma in collaboration with Dr. Tonye and Messrs Manga, Kanmegne, Mollet and Bayomak. **This excellent document served as a centre piece for the review and constitutes Appendix 1 of this report.**

- The same authors provided a field layout guide for all experiments.

- Copies of the original D&D report were also available.

- Full print outs for each experiment from ICRAF's Research Activities Management System.

Blank Experimental Questionnaires/Check Lists forms which had to be completed for each experiment by the review team. An example of this form is presented as Appendix 3.

GENDA FOLLOWED BY REVIEW TEAM

ıy	Time	Activity
ınday, 13/6/93	22:00	Arrival of delegates from Nairobi
:onday, 14/6/93	08:00-08:30	Meet project staff and visit project facilities (ICRAF delegates)
	08:30-09:00	Courtesy call on Hon. Minister of the Ministry of Scientific and Technical Research (ICRAF delegates)
	09:00-10:00	IRA/ICRAF presentation Part I
	10:00-10:30	Coffee Break
	10:30-11:30	Discussion
	11:30-12:30	Visit IRA and IITA soil laboratories (ICRAF delegates)
	12:30-14:30	Lunch Break
	15:00-16:00	IRA/ICRAF presentation Part II A,B&C
	16:00-16:30	Coffee Break
	16:30-18:00	Discussion
Tuesday, 15/6/93	08:00-09:00	IRA/ICRAF presentation Part II D & E
	09:00-10:00	Discussion
	10:00-10:30	Coffee Break
	10:30-13:00	Visit on-station trials, Nkoleeb, Yaounde
	13:30-14:30	Lunch Break
	15:30-16:00	Presentation by ODA Forest Management and Regeneration Project
	16:00-17:00	Discussion
	19:00-20:00	Cocktail - American Club .
Wednesday, 16/6/93	08:00-13:00	Visit on-farm trials Yaounde
	13:00-15:00	Lunch Break
	15:30-16:30	IRA/ICRAF presentation Part III & IV
	16:30-17:00	Coffee Break
	17:00-18:00	Discussion
Thursday, 17/6/93	07:00-18:00	Visit on-station and on-farm, Ebolowa Visit IITA Humid Forest Station, Mbalmayo
Friday, 18/6/93	07:00-16:00	Working Group discussion of final report
	16:00-16:30	Coffee Break
	17:00-18:00	Working Group continues
	19:00-21:00	Reception at the Hon. Minister of Scientific and Technical Research home to brief him on the major conclusions of the Review Team
Saturday, 19/6/93		Delegates depart Yaounde.

ORGANIZATION OF REVIEW TEAM REPORT

The report is presented according to the three objectives of the mission, namely (a) a review of past and on-going research, (b) priorities for future IRA/ICRAF collaboration research and research locations, and (c) areas of potential collaboration with IITA on strategic research at Mbalmayo Humid Forest Station. In the interest of brevity and clarity, the team agreed to restrict its comments in the main body of the text to major observations, conclusions and recommendations and refer the reader to relevant appendices which provide substantially more detail.

REVIEW OF PAST AND ON-GOING RESEARCH

Both on-station and on-farm research undertaken by the project between 1987 and 1993 can be grouped into four areas of research, namely

(1) Vigour/phenology species screening of MPTs
(2) Management trials for hedgerow intercropping
(3) Management trials for improved fallow
(4) Management trials for diversification of cocao production.

We will structure our report in the same order.

Area 1 - Vigour/Phenology species screening of MPTs

EXPERIMENT 1. A comparative assessment of 10 MPTs adaptability to local conditions, initiated on-station at Yaoundé in 1987 and completed in 1990 (see pages 13-20 of Appendix 1)

Major Conclusions:

- Establishment of trees with maize intercropping depressed yields of all species below those established without intercropping

- *C. calothyrus*, *L. leucocephala*, *G. sepium*, *C. siamea* and *A. auriculiformis* all showed good biomass production and coppice re-growth and were recommended for specific screening for hedgerow intercropping on non-acid soils

- *A. manguim* and *C. javanica* appeared appropriate for evaluation as shade trees in cocao production systems

- For most promising species, such as *C. calothyrus*, multi-locational provenance trials should be established.

EXPERIMENT 2. **A comparative assessment of 10 MPTs adaptability to local conditions, initiated on-station at Sangmelina in 1988 and completed in 1991** (see pages 20-26 of Appendix 1)

Major Conclusions

- The growth of local species was very poor compared with that exotics. Further research on alternative local species is recommended

- *C. calothyrus* demonstrated excellent biomass production and coppice re-growth at this acid soil location and was recommended for specific evaluation in hedgerow intercropping

- *A. mangium, A. auriculiformis* and *P. falcataria* grew well on the acid soils, but coppice re-growth was poor. They were recommended for evaluation as shade trees in cocao and coffee production systems.

Review Team's Observations on Exp 1 and Exp 2

(1) Due to difficulties with seed availability, heavy emphasis was placed on exotic species and each species was represented by a single provenance from commercial sources.

(2) The arrangement of such experiments in split-splot design (Exp 1) was statistically inefficient.

(3) Partial sampling of some trees in each plot for coppice re-growth is a questionable approach due to above and below ground interference of remaining un-coppiced trees.

(4) The methodology used to adjust results of biomass production for tree mortality could well give large over-estimates in plots where mortality was high.

Review Team's Recommendations for Future Species Screening Research

(1) In all species screening work (not only in Cameroon), ICRAF should, as a matter of urgency, standardize on assessment methods.

(2) In further species screening, trial design, species chosen for evaluation and assessment criteria should be targeted towards a specific technology.

(3) Trial design should allow for non-tree factors (e.g. soil fertility changes, light interception etc) to be monitored.

(4) Future species screening work at Cameroon should be undertaken in close collaboration/consultation with staff in Project 2.2 to assist in implementation of (1) & (2) above.

(5) Greater emphasis should be placed on indigenous trees, and farmers knowledge of them.

EXPERIMENT 3. **An evaluation of 15 provenances (OFI) of C. calothyrsus initiated on-station at Yaoundé in 1993** (Not described in Appendix 1)

Since this trial has only just been initiated, there are no results to comment upon, however the team had several observations and recommendations.

:view Team's Observations on Exp. 3

(1) This trial could usefully be duplicated at Ebolowa, a far more acid soil location.

(2) The trial design and arrangement and spacing of the trees is not well related to the technology to which *C. calothyrsus* is most likely to be targeted, improved fallows.

(3) Additional measurements over and above those proposed could usefully be made in association with other projects.

- Phenology studies (Project 2.2)
- Root biomass and distribution studies at the end of the experiment (Project 3.1)
- Chemical analysis of *C. calothyrsus* and soil changes by the end of the experiment (Project 3.2)
- The use of maize as a test crop of soil fertility upon trial termination (Project 4.4)
- Collection and assessment of litter fall using litter traps (Project 4.4 and 3.2).

Review Team's Recommendations on Exp 3

The team thoroughly endorsed this initiative on provenance evaluation of *C. calothyrsus*, but had the following recommendations.

(1) Future provenance evaluation trials should be designed and monitored with specific technologies in mind.

(2) Greater interaction with other ICRAF projects should be sought to maximize the amount of information that can be usefully obtained.

(3) Exp. 3 specifically should be duplicated (with improved design) at Ebolowa, and possibly other locations.

Area 2 - Management Trials for Hedgerow Intercropping

Research in the field of hedgerow intercropping in Cameroon incorporated a slight modification to the more standard continuous cropping between hedges as widely evaluated elsewhere, and was in response to the traditional cropping sequence of slash and burn farmers in this bimodal rainfall environment. In season one, after the burn, farmers establish a wide range of food crops, and at the end of the season harvest the annual crops (maize, groundnut) and allow perennial crops (cassava, plantain) to grow on into future seasons as natural regeneration occurs. The modification incorporated into Experiment 4 and Experiment 5 below was to crop between the hedges in season one and allow a short hedgerow/natural regeneration period in season two. This cycle was repeated each year of the experiments.

EXPERIMENT 4. **Effect of seven hedge species amount of mulch application and fertilizer application on crop yield, initiated on-station at Yaoundé in 1987 and to be terminated in 1993** (see pages 26-32 of Appendix i)

Major Conclusions:

- With the application of mulch of *C. calothyrsus*, *L. leucocephala*, *G. sepium* and *A. auriculiformis*, crop yields were increased by between 17 and 48% over the control, both in the presence and absence of nitrogen fertilizer and should be further evaluated in HI systems (see Exp.5).

- With or without mulch application, 60 kg N ha^{-1} (applied as NPK 20-10-10) enhanced maize yields by between 22 and 25%.

- Maize yields in rows adjacent to the hedge were significantly lower than those in the middle for all species.

:XPERIMENT 5. **<u>The effect of 4 hedge species and fertilizer application on crop yield and soil characteristics, initiated on-station at Yaoundé in 1988 and to be terminated in 1993</u>** (see pages 33-38 of Appendix 1)

/Iajor Conclusions:

- Averaged across 4 seasons and fertilizer levels, three hedgerow species gave significantly higher maize yields than the no hedge control. (***C. calothyrsus*** 3.92 t/ha, ***L. leucocephala*** 3.71 t/ha, ***G. sepium*** 3.66 t/ha, control 2.92 t/ha).

- In contrast, in the one season when maize/groundnut intercropping was tried, all hedgerow species except ***C. calothyrsus*** depressed groundnut yields compared with the control.

- In all treatments, a significant maize yield response to 30 and 60 kg/ha N fertilizer (applied as NPK 20:10:10) was observed, but there was no difference between 30 & 60 kg/ha N.

- There was little interactive effect of mulch type and fertilizer response.

- *A. auriculiformis* died after 2 years.

Review Team's Observations on Exp 4 and 5

(1) In Exp 4, modification to treatments and inconsistent cropping practice made this experiment hard to interpret.

(2) In both Exp 4 and 5, single row hedge plots were used with probable implications for below ground species interference, and control plot validity.

(3) Sub-plot size for mulch and fertilizer treatments were too small, and coupled with (2) above may well have resulted in considerable nutrient transfer (from both mulches and fertilizer) from one treatment to another.

(4) In Exp 4, the practice of standardizing the amount of mulch applied across all species resulted in import of nutrients from outside "the system" for some of the species, and not for others.

Review Team's Recommendations on Exp 4 and 5

(1) Because of the inherent design faults of these two experiments, the team recommends that they be terminated this year and be written up, - but the team cautions against drawing too many substantive conclusions.

(2) On termination, the team felt it would be worth using the hedges of contrasting species for superimposed observational trials of relevance to improved fallow research. Factors which could be investigated are:

- Impact of cutting at ground level, after various periods of fallowing, on coppice re-growth

- Impact of fallow residue burning v. incorporation on species survival.

<u>EXPERIMENT 6</u>. <u>Evaluation of design and/or hedge arrangement efficiency initiated on-station at Yaoundé in 1989 and due for completion in 1994</u> (see pages 43-45 of Appendix 1)

This trial (using ***L. leucocephala***) examined the effect of green manure produced from four arrangements of trees, on the yield of maize. The treatments were:

T_1 = Standard hedgerow arrangement
T_2 = Trees as block at one end of field
T_3 = Trees as a block in the middle of the field
T_4 = Trees as two blocks at either end of field.

Major Conclusions:

- Biomass production of trees over two years was greatest in T_2 and T_4 where trees bordered on the edge of the plot.

- T_2, T_3, and T_4 all resulted in higher maize yields than the conventional hedgerow, but the yield advantage was not great.

Review Team's Observation on Exp 6

(1) T_2 and T_4 are likely to be importing nutrients from outside the experimental plots.

(2) The experiment had no "no tree" control.

(3) The site was very variable with regard to maize growth within plots. Very good growth was associated with rotting tree stumps.

(4) Although initial yield advantages of block planting were not great, block planting minimises the tree-crop interaction and provides greater flexibility in the timing of tree pruning.

Review Team's Recommendations on Exp 6

(1) The team felt that this "biomass transfer" approach has potential and that the trial, with some modification should continue beyond 1994.

(2) A "no tree" control should be created by removing trees from T_2. A "no tree + mulch" treatment should be created from T_4, using mulch imported from outside the experiment.

(3) The areas previously under trees in the modified T_2 and T_4 should be harvested separately from the area previously under crop until no differences are observed.

(4) T_1 and T_3 should remain the same.

(5) In plots with great variability in maize yield, selective sampling should be undertaken away from obvious sources of variability such as tree stumps.

EXPERIMENT 7. **The use of regression models for biomass prediction of 4 species in hedgerow intercropping systems, established on-station at Yaoundé and Ebolowa in 1990 and due to be completed in 1994** (see pages 45-47 of Appendix 1)

This trial was initiated to see if simple measurements such as branch number, plant height and mean stem diameter could be used to predict leaf biomass accurately, thus saving considerable time.

Major Conclusions

- Efficient models, accounting for up to 75% of the variability, can be developed, but better prediction was observed at Yaoundé than Ebolowa.
- The 'best fit' models appear to vary with hedge age, species and location.

Review Team's Observations on Exp 7

(1) Because of the apparent species, species age and location specificity of the models, the team queried their practicality and accuracy.

(2) Errors in estimating mean stem diameter had been made.

Review Team's Recommendations on Exp 7

(1) Errors in calculations should be corrected, and an improved method of analysis should be undertaken. ICRAF's biometrician has agreed to assist in this.

(2) If error correction and improved analysis does not produce more encouraging results, the team recommends that this trial be terminated.

EXPERIMENT 8. **The effect of first pruning time of four species on subsequent tree biomass production in hedgerow intercropping systems, initiated on-station at Ebolowa in 1990 and due for completion in 1994** (see pages 47-49 of Appendix 1)

Traditionally, the first pruning time of hedges is recommended at 12 months after establishment. Under poor growth conditions, such as found at Ebolowa, this can often lead to tree death. This trial investigated the impact of first pruning after 12, 18 and 24 months on biomass production.

Major Conclusions

- As would be expected, biomass production at time of first pruning increased with time to first pruning.

- Once regular pruning regimes were superimposed on all treatments in 1993, the above trend appears to continue with more biomass continuing to be produced by trees which were not pruned for the first 24 months.

- Throughout the experiment, *C. calothyrsus* dramatically outperformed *G. sepium, L. leucocephala* and *P. falcataria* at this acid soil location.

Review Team's Observation on Exp 8

(1) The trial was well designed and calliandra hedges were performing well, - but crop yields were not being monitored between the hedges.

(2) Death had occurred (to a minor extent) in some parts of the calliandra hedges and appeared to be associated with ant activity. However, it was not clear if

the ant invasion caused death or resulted from death caused by some other factor.

(3) There was "no tree" control plot included as initial experimental objectives did not require one.

(4) Only calliandra appeared adapted to these acid conditions.

Review Team's Recommendations for Exp 8

(1) Given the excellent performance of *C. calothyrsus* hedges and good trial design, the team recommended that this trial be continued, but with some modifications as indicated below.

(2) *G. sepium, L. leucocephala* and *P. falcataria* plots gave such poor performance, that they can readily be converted to appropriate but contrasting control treatments to be decided upon by the project team.

(3) In the *C. calothyrsus* plots, there is now little difference in hedgerows first pruned at 16 and 24 months. The team recommends that one of these treatments should be converted to a "rotational fallow" system which is currently being examined in Experiment 12 at Yaoundé.

EXPERIMENT 9. **On-farm evaluation of 4 MPT species and fertilizer use in Hedgerow Intercropping in Abondo Village, Yaoundé initiated in 1988** (see pages 50-52 of Appendix 1)

The Review Team did not visit any of these researcher controlled on-farm trials, but it was explained to us that a considerable number of social problems had occurred, and little scientific information of value had been gathered, although many lessons were learnt. The whole initiative is now being thoroughly reviewed by the project. If it is decided to try again in this village, the team had the following recommendations.

Review Team's Recommendations on Exp 9

(1) "Improved Rotational Fallow" should be tested instead of Hedgerow Intercropping.

(2) Restrict the number of species to one, probably *C. calothyrsus*

(3) Limit the initiative to 5 or 6 carefully selected farms.

(4) Initially strong researcher control with farmer participating in trial management is recommended. As technology starts to perform and the farmer becomes familiar with technology management, greater responsibility is allocated to him.

(5) Focus attention on biophysical monitoring in the early years, but increasingly seek farmers ideas/reactions as technology becomes established and functional.

<u>EXPERIMENT 10</u>. <u>On-farm evaluation of an integrated hedgerow intercropping/improved fallow system with 35 farmers around Yaoundé and Ebolowa, initiated in 1991</u> (see pages 52-54 of Appendix 1)

This researcher controlled on-farm trial was initiated to examine the potential of an improved short season fallow in a hedgerow intercropping system with Leucaena and Calliandra. The treatments are

T_1 = Hedge + second season natural fallow

T_2 = Hedge + second season *Cajanus cajan* fallow

T_3 = No Hedge + second season natural fallow

T_4 = No Hedge + second season *Cajanus cajan* fallow.

The test crops are maize and cassava. The cycle begins with the planting of maize and cassava in the first season. Following maize harvest, Cajanus is established in T_2 and T_4 and grows together with cassava and natural regenerating fallow for the second season. This cycle is repeated. The team visited several farmers both at Yaoundé and Ebolowa.

Review Team's Observations on Exp 10

(1) There were not yet clear yield advantages apparent at any of the farmers visited, although hedges were well established, and in most cases, well managed.

(2) At some farms, the second pruning of hedges appears to have been done late, and adjacent rows of maize had suffered.

(3) Establishment of Cajanus was very poor, possibly due to shading by cassava and the hedge.

(4) At two farms, farmers had temporarily abandoned the trial for between 18-24 months for health reasons and the hedges had naturally grown into a 18-24 month tree fallow. When farmers cleared this and incorporated the leafy biomass into the soil they reported that (1) it was much easier to clear than natural fallow, (ii) crop performance was much better than after natural fallow and (iii) the hedges continued to regenerate after fallow clearance. These observations greatly impressed the team with regard to the potential and adoptability of the improved rotational fallow system described in Exp. 12.

Review Team's Recommendations on Exp 10

(1) Given observations (4) above, the team recommended that at carefully selected number of farms at both Yaoundé and Ebolowa (approx. 5 at each location) the trial should be converted to an "improved rotational fallow trial" in which the hedges are allowed to grow unpruned for 12 and 24 months (old treatments T_1 and T_2). Old treatments T_3 and T_4 would become natural regenerated fallows of 12 and 24 months.

(2) Greater researcher control is required in the early stages as indicated in recommendation (4) for Exp 10.

(3) Given the greater researcher input required, the number of farms involved

should be reduced to the appropriate number.

(4) In the un-modified Exp 11, the team recommends that Cajanus be replaced with another annual legume which is shade tolerant, possibly ***Mucuna*** spp.

Area 3 - Management Trials for Improved Fallows

Two types of improved fallows have been investigated. Firstly, a modification of hedgerow intercropping which allows a 2 year fallow period in which the hedges grow into trees and are then cleared and the land re-cropped. This is referred to as "Improved Rotational Fallow'. The second approach has been to evaluate the effect of 1,2 and 3 year fallows of selected shrub species on crop yield compared to natural fallows.

EXPERIMENT 11. The effect of a mixture of Leucaena and Gliricidia two year improved rotational fallow on crop yield and livestock production, established on-station at Yaoundé in 1988 and due for completion in 1996 (see pages 38-43 of Appendix 1)

This trial evaluated four treatments.

T_1 = Continuous cropping with no hedges
T_2 = Continuous cropping with hedges
T_3 = Two years grazed hedge fallow followed by two years cropping between hedges
T_4 = The reverse of T_3.

Major Conclusions:

- Continuous cropping with hedges (T_2) consistently outyielded continuous cropping without hedges (T_1). Over 4 seasons, T_2 yielded 14.87 t/ha of maize grain compared with 11.11 t/ha from T_1.

- In the first season of 1992, when T_1,T_2 and T_3 impact on maize yield could be compared, T_1 yielded 3.54 t/ha, T_2 yielded 4.79 t/ha and T_3 yielded 6.28 t/ha.

- During the fallow phase, the system represented by T_3 and T_4 can generate income by providing fodder/grazing for livestock.

- In areas where land is not a major constraint, and farmers can have part of their land as fallow and part being cropped, T_3 and T_4 show great potential.

Review Team's Observations on Exp 11

(1) The trial was well designed and managed.

(2) For various unavoidable reasons, the livestock management in this trial was erratic and only limited data was obtained. In addition, the team felt that liveweight gain of animals "free grazing" on natural vegetation should have been used as a control.

(3) Combined with their observations in farmers fields (see Exp 11) the team felt the Improved Rotational Fallow system has great potential.

Review Team's Recommendations for Exp 11

(1) The trial should continue, but the team recommends excluding the livestock component.

(2) The team recommends that similar research should be initiated at Ebolowa.

(3) The team recommends that additional measurements be made in this trial in conjunction with other ICRAF projects. (a) Weed dynamics (Project 3.4) (b) soil nutrient budgets and dynamics (Project 3.2).

(4) Each treatment consists of 1 hedge of Leucaena and 1 of Gliricidia. In all treatments, the team recommends that maize yield associated with each species be measured separately within each plot, but recognises that between species interference is inevitable.

<u>EXPERIMENT 12</u> **<u>The effect of fallow shrubs and fallow length on crop yield on soil fertility, initiated on-station at Yaoundé in 1989 and terminated in 1992</u>** (see pages 54-56 of Appendix 1)

This trial examined the effects on crop of 6 shrubs in pure stands (1) ***Cajanus cajan*** (2) ***Crotalaria anagyroides***, (3) ***Desmodium discolour***, (4) ***D. distortum***, (5) ***Mucuna utilis***, (6) ***Pureria phasioloides***, and a mixture of 1+2+3+4 and natural fallow for 1, 2 and 3 year fallow period.

Major Conclusions:

- In one and two year fallows, the shrubs gave a yield advantage over natural fallow, but after a three year fallow period, no significant difference was observed.
- *Cajanus cajan* appeared promising.
- Introduction of shrubs significantly improved soil organic carbon and total nitrogen in the 0-5 cm layer.
- Comparing erect species with spreading cover crops in the same trial caused i) invasion of cover crops into adjacent plots over time.

  ii) Desmodiums found their way into natural fallow treatment due to seed dispersal from pod shattering.

Review Team's Observations for Exp 12

(1) The design used did not allow the effect of length of fallow to be compared in the same season, thus some degree of fallow length times season of evaluation interaction is inevitable.

Review Team's Recommendations on Exp 12

(1) The team recommended continuation of research on shrub species for improved fallow (see Future Priorities section, page 24-26 of this report)

(2) The team recommends that particular attention be paid to plot size and phased entry designs in future trials.

EXPERIMENT 13 **The effect of fallow shrubs and fallow length on crop yield, initiated on-station at Ebolowa in 1990 and terminated 1992** (see pages 56-60 of Appendix 1)

This trial was designed to assess the effect of one and two seasons fallow (***Cajanus cajan, Desmodium distortum*** and natural fallow) followed by a comparison of one, two and three seasons cropping. However, soon after trial establishment, ***Mimosa invisa*** invaded all plots, so it was decided to replace ***D. distortum*** treatments (which showed poor growth) with ***M. invisa.***

Major Conclusions:

- There was no significant difference between the effect of shrub species and natural fallow on subsequent crop yields. This was probably due to the high level of infestation of natural fallow plots with *M. invisa*, itself a nitrogen fixer.

- By 1992, yields in all plots had declined to very low levels, and subsequent soil analysis indicated very low pH (4.0 in kcl) and high % aluminium saturation of the ECEC (>75%) as being the cause.

- It was concluded that this trial should be terminated.

Review Team's Recommendations for Exp. 13

(1) The team agreed that this trial should be terminated.

(2) The team re-iterated its recommendation for Exp 13.

EXPERIMENT 14 **The effect of *Cajanus cajan* residue management on maize and groundnut yield, initiated on-station at Yaoundé in 1990 and terminated in 1992** (see pages 61-65 of Appendix 1)

Burning vegetation after fallow clearance is the traditional practice in Cameroon, but inevitably results in gaseous loss of nitrogen and carbon. This trial was initiated to assess the relative impact of burning .v. mulching .v. incorporation of residue into the soil on maize and groundnut yield, and soil organic matter.

Major Conclusions:

- Maize yields were consistently the highest when residues were incorporated. In contrast, groundnut yields were consistently the highest when the residue was burnt. This result was attributed to greater N loss in burning, and groundnut's ability to fix nitrogen.

- The amount of decomposition of woody material (measured as loss in dry weight over 158 days) was higher, at 50%, than the leafy material, at 33%.

- Residue management affected the soil organic matter pools in the 0-5 cm depth interval, and high crop yields of both maize and groundnut appeared to be associated with the fine organic matter pool.

Review Team's Observations on Exp 14

(1) This trial, and its results are of direct relevance to the management of residues in improved fallow systems.

(2) There was no true zero control, as in the "residue removed" treatment, Cajanus root biomass was still present.

Review Team's Recommendations for Exp 14

(1) This trial need not be continued, but residue management research is an important topic for future research initiatives on improved fallows and should be addressed.

Area 4 - Management trials for diversification of cocao production

EXPERIMENT 15 **The effect of cocao spacing on companion food crops and subsequent establishment of shade trees, initiated on-station at Yaoundé in 1992 and scheduled to end in 2005** (see pages 66-67 of Appendix 1)

The experiment is in the early stages of establishment and no major conclusions are available, but the team had some observations and recommendations.

Review Team's Observations on Exp 15

(1) This is a large and long term experiment and has already proved to be expensive on time and cash resources required for land clearing and weeding.

(2) Currently, IRA is unable to contribute many resources towards this trial.

(3) The future of West African cocao is hard to predict, but a World Bank report (not seen by team) has apparently suggested no recovery in the near future.

(4) Research on diversification of cocao production systems, through wider spacing and intercropping with food crops and trees, could be more relevantly, cheaply and efficiently done through imposing thinning and intercropping treatments on existing cocao plantations, as this is what is likely to occur in practice.

Review Team's Recommendations for Exp 15

(1) Given the above observations, the review team recommends the termination of this trial immediately.

PRIORITIES FOR FUTURE IRA/ICRAF COLLABORATION

This was discussed at some length between the team and project staff, and centred around the relative priority which should be attached to five broadly defined technologies, namely:

- Hedgerow Intercropping
- Improved Fallows
- Home gardens
- Live fencing/fodder banks
- Diversification of Cocao Production Systems.

To assist in this discussion, eleven criteria were agreed upon by which each technology should be judged. They were (1) Potential demonstrated by results to date, (2) How much research remains to be done, (3) Probability of achieving positive results within 5 years (4) Relevance of technology to D&D conclusions, (5) The simplicity of possible interventions and management requirements in each technology, and hence (6) likelihood of adoption of technology (7) How many other institutions are working on the technology in the humid lowlands, (8) Likely level of impact on farmer welfare, (9) Environmental impact, (10) How many farm level constraints does technology address, (11) Congruence with ICRAF's medium term plan.

Each member of this working group assessed each technology by these criteria, and then the outcome was shared with the group. There was a high level of agreement between members, and the following order of priority was agreed upon.

(1) Improved Fallows
(2) Home Gardens
(3) Live fencing/fodder banks
(4) Hedgerow Intercropping
(5) Diversification of cocao production systems.

The working group then discussed the key research issues and approaches for each technology. The outcome of this is presented below.

Improved Fallows

The group agreed that research should continue on both tree fallows and shrub fallows, but that priority should be given to tree fallows. Research issues which need to be addressed were identified as follows.

Research needs	Tree Fallows	Shrub Fallows
a) Identification of target farmers	**	**
b) Time of establishment in farmers system	*	**
c) Species evaluation	**	**
d) Fallow length	**	**
e) Fallow regeneration	**	-
f) Fallow residue management	**	**
g) Compatibility with crop mixtures	**	-
h) soil type	**	**
i) Nutrient dynamics	**	**
j) Weed dynamics	**	**
k) Tree arrangement	**	-
l) Fallow products	**	-

Home Gardens

The group recognised the complexity of these systems, and the need to identify a precise area of intervention which had a good chance of rapid results and impact. It was felt that the potential for inclusion of a greater variety of indigenous fruit trees should be examined. However, before biophysical research is initiated it was recommended that a thorough review of existing information be made to include the following topics.

- the current status of home gardens, their species diversity and principal outputs

- current knowledge on indigenous fruit trees, their economic and nutritional value and production problems/opportunities

- the economic potential of local and international markets for indigenous fruits

- the potential and/or need to develop localized agro-industries to improve marketability of indigenous fruits.

Based on this, a few indigenous fruit trees should be identified for further research. Research needs are likely to include, domestication, propagation, tree management, shade tolerance, and post harvest issues such as storage potential, processing and marketing.

Fodder Bank/Live fences

Livestock (pigs, goats, sheep) are almost always free-ranging in association with the home and homegarden. They are recognised for their nutritional and income value, but farmers face two major constraints which often discourage livestock keeping. One is the damage they cause to high value crops, and the second is the high number of animals killed on village roads. Fodder supply per se does not appear to be a limiting factor, but the potential probably exists to improve fodder quality. The group felt that the potential for live fences and associated fodder banks was good, but strongly recommend consultation between ILCA (at Ibadan for 10 years, and moving to Cameroon), project staff and IRZ before research priorities are established.

Hedgerow Intercropping

The group agreed that no new research initiatives should be made in this field either on-station or in farmers fields. However, in the previous section on the review of on-going research, it was recommended that some HI trials should continue to be monitored. Project staff should refer to these specific recommendations.

Diversification of cocao production systems

The group agreed with the recommendation that research into this system should be terminated.

FUTURE RESEARCH LOCATIONS

Yaoundé (Nkoameyos Research Station)

The team recommends that research should continue at this station, but noted the following.

(1) Lack of suitable land, both in terms of area and quality, has in the past had a strong influence on trial design, plot size and within plot variability. The project does need access to more land of good quality. This was mentioned

to the Hon. Minister of Scientific and Technical Research. He has agreed to help.

(2) Long-term daily climatic data should be collected from a nearby site (5 km away) and a met. station should be installed at Nkoameyos.

(3) Full data on soils characterization of this station (already done) should be made available to the project.

<u>Ebolowa Research Station</u>

The team felt that this research station had been underutilized, and that research should be expanded. The station has many attractive qualities.

(1) The road between Yaoundé and Ebolowa is excellent (2 hrs)

(2) Ebolowa soils have much lower pH and show greater aluminium toxity than either Nkoameyos or Mbalmayo

(3) Land is not a constraint (120 ha available) and the terrain is more even than at Nkoameyos. The Hon. Minister informed us that as long as the Project covered land clearance costs (between $1000-$2000/ha), the project could have all the land it needed, and would be allowed full control of that land

(4) Good quality housing is available on-station

(5) A new laboratory has been built, but is not being used. The Hon. Minister informed us that the Project could have full access and control of this building

(6) Following recent soil analysis undertaken for the project by IITA, IITA staff have expressed a strong interest in working at Ebolowa, - thus creating the potential of good institutional collaboration at this site.

Based on this, the team also strongly recommends that ICRAF look into the potential

f recruiting a Post doctoral Scientist to be resident at Ebolowa and take responsibility 'or the day to day research operations.

STRATEGIC RESEARCH COLLABORATION WITH IITA AT MBALMAYO

The team visited both the Mbalmayo Humid Forest Station, and IITA laboratory facilities adjacent to IRA, Yaoundé. Our sincere thanks to all IITA staff for the courtesy with which they received us, and the willingness with which they discussed their current research. At Mbalmayo, Stan Claasen, the farm manager hosted us, and introduced us to other IITA staff currently working there, namely Dr. Stephan Hauser (Soil Physicist), Dr. Stephan Weise (Weed Scientist) and Dr. Jacqueline Henrot (Soil biologist, based at Onne). Unfortunately, the senior scientist at Mbalmayo, - Dr. Gavin Gillman (Soil Chemist) was unable to meet with us. In addition, we were unable to meet with two post-doctoral fellows, Dr. Endow (Social Scientist) and Dr. Neil Menzies (Soil Chemist).

The team was not able to have specific discussions with IITA staff on issues of collaboration, but clearly, the scientists we met were keen to work with ICRAF. The facilities available were outstanding, and the expertise of IITA scientists (Soil Chemistry, Soil Physics, Soil Biology, Weed Science, Social Science and a crop agronomist to be appointed) is very relevant to agroforestry research needs. Given Dr. Duguma's Agroforestry and Dr. Ladipo's Forestry, a perfect team could be formed.

The team felt that two specific areas of research, identified as priority (1) and (2) for the IRA/ICRAF collaborative research, namely Improved Fallows and the Potential of Indigenous Fruit Trees in Homegardens should form the focal point for collaboration in strategic research at Mbalmayo, and also possibly at Ebolowa. In addition, if an ILCA scientist is also posted to Yaoundé, collaboration on aspects of livestock feeding systems may form a third possible area of strategic research collaboration.

Of these three potential areas of strategic research collaboration, the team recommended that highest priority be given to Improved Fallows both because of their huge potential, and the relevance of the expertise of IITA scientists to many of the research issues

identified (see page 26 of this report)

ACKNOWLEDGEMENTS FROM THE REVIEW TEAM

We greatly enjoyed and were invigorated by the time we spent in Cameroon. We learnt a great deal and hope that we were also able to contribute to the future of agroforestry research. Our sincere thanks go to the Honourable Minister of Scientific and Technical Research, Dr. Ayuk Takem for the gracious manner in which he both received us and our briefing in his house. We would also like to thank all IRA, IRZ, IITA and ODA colleagues for the time they gave us and for the freedom with which they made information available. Finally, we would ask ICRAF and IRA staff to re-iterate our thanks to all the farmers who welcomed us at their homes and on their farms.

APPENDIX 1

MINISTRY OF SCIENTIFIC AND TECHNICAL RESEARCH

MINREST

INSTITUTE OF AGRONOMIC RESEARCH

IRA

IRA/ICRAF COLLABORATIVE AGROFORESTRY PROJECT

REGIONAL WORKSHOP ON AGROFORESTRY RESEARCH IN THE HUMID LOWLANDS OF CAMEROON

14-19 JUNE 1993

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INSTITUTE OF AGRONOMIC RESEARCH
IRA

INTERNATIONAL CENTRE FOR RESEARCH IN AGROFORESTRY
ICRAF

INTRODUCTION

The IRA/ICRAF Collaborative Agroforestry Project came to existence in March 1987. This was the year when ICRAF celebrated its 10th anniversary and also moved to its then the new building at Gigiri in Nairobi. In his statements reported in ICRAF's Annual Report of the same year, the formal Director General, Dr B. Lundgren said:

> "A historically significant event took place in March when Dr Bahiru Duguma became the first ICRAF scientist posted outside Kenya to a joint project of the Institut de la Recherche Agronomique and ICRAF in Cameroon."

What was actually historically significant was the fact that it was the first collaborative agroforestry research initiated by ICRAF. At about the same time, a plan was already in motion to create the other networks in various ecological zones of Africa.

According to the strategy of the Collaborative Division at that time, the network for the humid lowland of West Africa (HULWA) was to begin, first, with a regional station in Cameroon and gradually expand to countries in the region (often referred to as centrifugal approach) while, for the other networks, country specific activities were to begin in all potential member countries at the same time with regional activities gradually expanding at the zonal stations referred to as zonifugal approach.

While the zonifugal approach was implemented according to plan, the centrifugal approach is still on paper with actual collaborative activities still limited to Cameroon and on a very modest level to Ghana. Due to this historical accident, the younger networks were able to cover wider geographical regions and command significant level of necessary human and material resources. This in turn provided an excellent opportunity for these network to undertake rigorous internal evaluation of on-going activities and identifying and planning future research needs through their annual regional planning meetings while the IRA/ICRAF continued to relay on its internal meager resources and ICRAF's annual planning meetings for similar purpose.

According to ICRAF (1993) and TAC (1993), ICRAF is likely to gradually devolve itself from direct involvement in area of applied research in country specific programmes in favour of increased contribution to strategic research under ecoregional mechanism.

It is this historical fact and the centres's new approach in its plan for the future that culminated to organizing the present workshop.

The primary objectives of the workshop are therefore:

1. To review the on-going field research in terms of quality and relevance;

2. Based on the achievements and constraints experienced to-date, identify strategic issues which could form basis for negotiation with partners such as IITA in the planned ecoregional efforts and

3. Identify direction for the IRA/ICRAF collaborative research (applied/adoptive) including locations of the work.

To set a stage for the workshop to achieve its stated objectives, this paper presents the summaries of activities carried out, achievements and constraints encountered from the inception of the project to-date and conclude by suggesting possible solutions for consideration.

These are presented in four parts. Part I deals with activities undertaken and outputs of the planning phase. Part II covers similar topics on field activities, while in Part III, activities and achievements in areas of Human Resource Development are reported. Research priorities categorized according to programmes and technologies are proposed under Part IV.

PART I. DIAGNOSTIC AND DESIGN PHASE

1. Background

The joint IRA/ICRAF "Macro D & D" mission was carried out on September 6-16, 1986. Based on information collected during the field visit and secondary data from available literature, a "Tentative Blueprint for Agroforestry Research in the Humid Lowlands of Cameroon was compiled in October 1986. The document was then validated through "Micro Diagnosis and Design" exercise, conducted on 6-14 November of the same year. The locations selected for the exercise were Lékié, a highly populated Division (<100 persons/km²) and Dja et Lobo (6 persons/km²). It was the findings reported and recommendations made in Micro D & D document, prepared after the exercise, that was used as a basis in setting priorities for research and determining activities to be undertaken by the project. Summaries of these findings and recommendations are presented below.

2. The Humid Lowlands of Cameroon

Large proportion (about 3/4th) of the population of Cameroon lives in forest zone. Most part of this zone lies within the lowland humid tropics.

The humid lowlands are the regions below 100 m altitude with an annual precipitation of over 1500 mm, a growing period of 265-270 days and covered by rainforest vegetation.

The humid lowlands of Cameroon (fig 1) are comprised of two geographic regions:
Fig 1

. Western and coastal lowland, which is predominantly flat area (below 100 meters) of sedimentary soils, that front the Gulf of Guinea.

. Southern plateau is the region east of the western and coastal lowland, consists of the southern plateau extending to Gabon, Equatorial Guinea and the Congo to the south and the Central African Republic to the east. The elevation of the plateau ranges from 600-900 meters.

Two types of equatorial climate prevail in the humid lowlands of Cameroon: "Guinean" and "Cameroonian" (Fig 2).

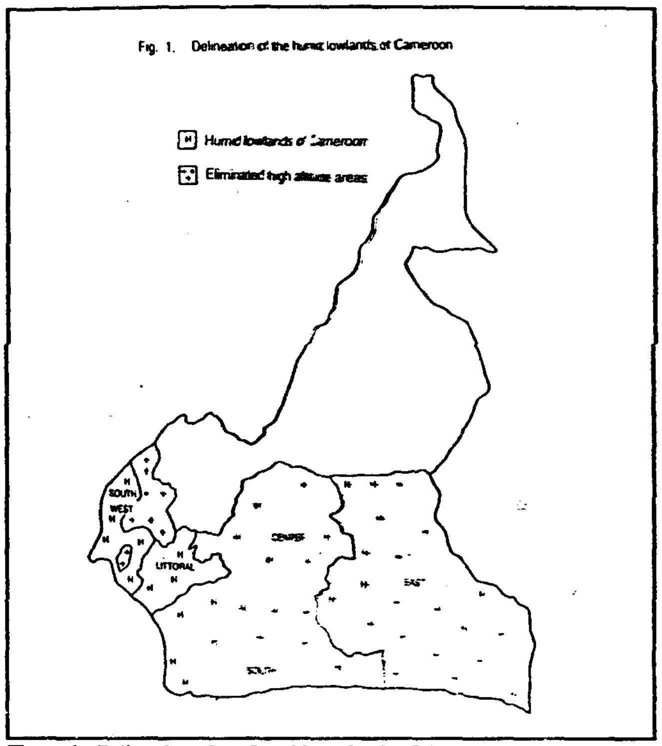


Figure 1. Delineation of the Humid Lowlands of Cameroon

The Guinean type is characterized by a bimodal rainfall pattern with annual average of up to 2000 mm in the southern part. The heaviest rains occur in August and September with moderately heavy rainfall in April and May. The driest season is December to January while the second short dry season is June-July when monthly rainfall drops to 76-152 mm.

The "Cameroonian" type prevails in the western lowland regions covering the Littoral and Southwest Provinces. The rainfall pattern is unimodal with no pronounced dry season. Average rainfall range from 2500-4000 m. Temperature ranges from 22° to 29°C and average humidity is 88 to 90 percent.

The soils are mostly Ferralitic, reddish to yellowish with no pronounced profile differentiation and generally with clayey texture. They are rich in aluminium and iron oxide, show good physical but poor chemical properties.

Orthic Ferralsols predominate in most part of the region apart from the Southwest where Nitosols are found, also in association with other Ferralsols: Hydromorphic soils are found in the valley bottoms.

Soil types around Yaounde include:

a. Highly weathered, Ferrallitic soils without formation of secondary minerals: (a) red series, (b) occer and (c) yellow series.

b. Highly weathered, Ferrallitic soils with formation of secondary minerals: (a) deep series (formation of secondary mineral between 100-150 cm); (b) moderate deep series (formation of secondary mineral between 50-100 cm and (3) hydromorphic soils

(IRA/IITA/IDRC, 1986).

The vegetation of the humid lowlands of Cameroon consists of the tropical rainforest to the South and West and mosaics of forest and grasslands to the North (Fig 3). The different types of rainforest that dominate the region are:

- Guineo-congolian wet evergreen lowland rainforest,
- Guineo-congolian moist evergreen lowland forest,
- Guineo-congolian semi-evergreen lowland forest ,
- Mosaic of the above three,
- Guineo-congolian lowland rainforest-secondary grassland mosaic,
- Swamp forest and,
- Mangrove.

Detailed description of and dominant tree species in each of the above rainforest vegetation types are reported in IRA/ICRAF, (1986).

Fig. 2. Climate of Cameroon

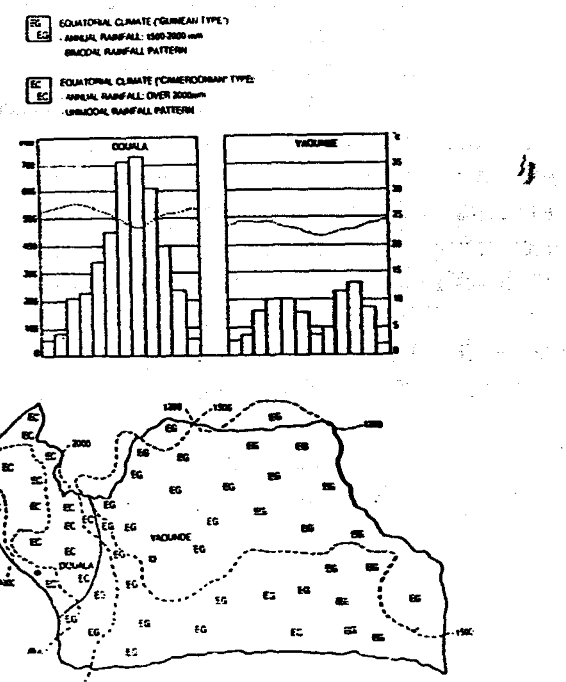
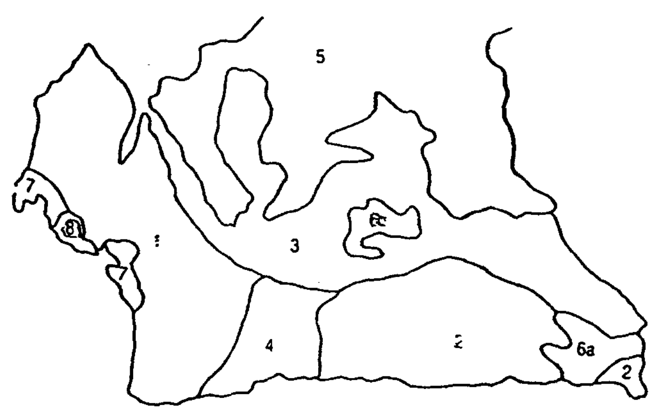


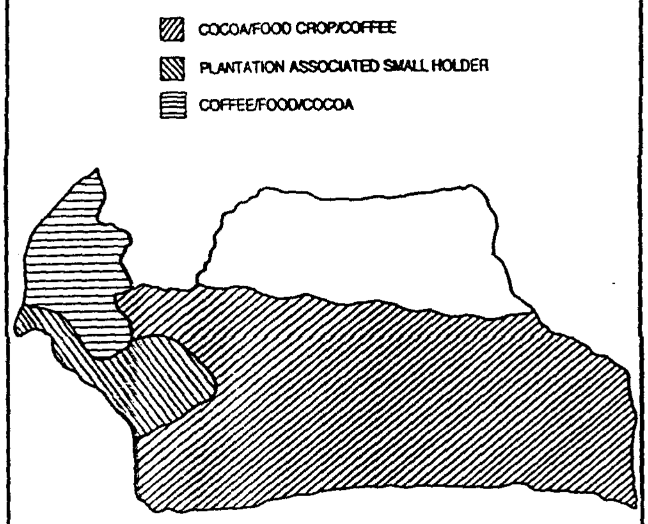
Fig. 3. Vegetation map of the humid lowlands of Cameroon.

1. Guineo-Congolian wet evergreen lowland forest.
2. Guineo-Congolian moist evergreen lowland forest.
3. Guineo-Congolian semi-evergreen lowland forest.
4. Mosaic of 1, 2 and 3.
5. Guineo-Congolian lowlands rainforest-secondary grassland mosaic.
6. Swamp forest: a (Upper-Nyong) and b (Sanaga)
7. Mangrove
8. Mountain vegetation (excluded from the study)



3. Land use systems description, associated constraints and recom-mended agroforestry technologies.

Fig. 4a. Major land use systems in the humid lowlands of Cameroon.



The principal variables used, in delineating the land use systems were: broad soil type (order), rainfall regime and cropping system. Large-scale plantation agriculture was excluded from the analysis. Although the smallholder sector throughout the zone can be characterized as food production system based on root crops with perennial cash crops, for the purpose of agroforestry research, however, three significant systems were identified within the sector (Fig 4a).

a. The coffee/food crops/cocoa system: found in the low altitude (0-200 m), high rainfall zone (> 3000 mm) on higher-fertility Nitosols, principally in Southwest Province and Moungo Department of Littoral Province. The principal food crops are cocoyam, plantain and cassava, while the major cash crops include coffee, pineapple, oil palm, cocoa and surplus from food crops.

Use of inorganic fertilizer is common on coffee, pineapple and some food crops.

Due to the relatively rich soil type, and lower level of importance in terms of its total output as compared to the national production level, this system was not selected for the purpose of IRA/ICRAF Agroforestry Research Project.

b. The household farm production system of plantation workers: This is found in Littoral and part of Southwest Provinces within the high rainfall zone (over 3000 mm). The soils are infertile Xanthic Ferralsols. The major source of cash income is plantation work, purchase of food is common, land pressure is high because most land is occupied by commercial plantations. Again due to its peculiar characteristics referred to above, this system was not identified as a priority for agroforestry research of the IRA/ICRAF Project.

c. The cocoa/food crops/coffee: is found throughout the Southern Cameroon plateau, and in the sparsely populated transitional zone between the plateau and the Western lowlands.

The soils are predominantly low fertility Orthic Ferralsols. Rainfall on the plateau ranges from 1500-2000 mm, increasing to 3000 mm in the transitional zone where cocoa is more marginal.

It is the most important agricultural region in the humid lowlands of Cameroon, representing the bulk of smallholder producer and production. It is the concern of the Government of Cameroon that the economic zone around major cities becomes an effective supplier of foods to the growing urban population of the capital. Comparatively, little research has been done on food crop production for the Southern plateau.

For the purpose of the IRA/ICRAF Agroforestry Research Project, this system was deemed to have priority and accordingly selected as a target land use system for agroforestry research.

An indepth analysis of this system thus revealed three sub-systems, each with their peculiar properties and constraints. These sub-systems, their respective properties and constraints as well as proposed or recommended agroforestry technologies for each sub-systems are presented below.

1. Food crop production sub-system:

Properties: The sub-system is based on fallow practice with the fallow length as short as two to three years in highly populated areas like Lékié and as long as 10 years in sparsely populated areas like Dja et Lobo. Even for areas where land availability is not a major constraint, short fallow period of 3 to 4 years is often practised due to shortage or high cost of labour (Duguma, B., Tonye, J. and Depommier, D., 1990). Commonly grown food crops include seasonal crops such as groundnut, maize and some vegetables and long vegetative cycle crops such as cassava, plantain and cocoyam. Both categories of crops are grown in mixed cropping. The traditional cropping sequence starts with the clearing and burning of a patch of forest or fallow land in dry season. Clearing is the men's task. Usually after clearing, the first crop planted in between the felled trees is "Ngon" (cucumeropsis manii) which overgrows the stumps and accelerates their decomposition. About six months after sowing, the "Ngon" is harvested and the field is planted in a mixed cropping pattern with groundnuts, cassava, cocoyam, maize, plantain and different vegetables. After harvesting groundnuts and maize (vegetative period of 3 to 4 months), the root and tuber crops and the plantain (vegetative period of 10 to 24 months) remain in the field.

Due to the staggered maturity pattern, they are harvested plant-by-plant and day-by-day according to the household needs. There is no single harvest period for these crops and the soil has the function of storing the tubers and roots. Natural vegetation progressively invades the plot and the fallow period usually begins after two years. Often however, there is no clear demarcation when the harvesting ends completely and the fallow phase begins as, depending on availability of land, land clearing and cropping may start soon after the last crop is removed.

This practice, involving mixed cropping of crops of different maturity cycles, in not defined geometric arrangement and absence of obvious delineation between the end of the cropping phase and the beginning of the fallow phase, is the aspect that needs to be critically examined in developing any agroforestry technology for the region.

Due to the two cropping seasons, two plots are cultivated annually. As a result of the short dry period June-July, labour shortage becomes very critical as it is required to harvest the first season crop and prepare land and plant the second season plot.

Before the advent of the fall in the price of cocoa on world market, food crop production was predominantly the domain of women family members. Except for land clearing, for which they are assisted by the men, most of the field operations for food crop production was carried out by women. Recently however, more and more, men family members are joining the women folks in food crop production abandoning the cocoa farms.

External high energy input is not common for the traditional crops. However, as more and more farmers are now growing crops such as tomato and lettuce for cash income, purchased input is gradually accepted, mainly for these limited crops and the farmers confirm that the investment is justified by the return they are getting from the enterprise (cost of a fruit of tomato can be as high as USD 0.80 during the dry season).

Production constraints: The principal constraints in the fallow based food crop production system are:

a. Declining soil fertility; the Orthic Ferralsols (Oxisols) which dominate the zone are highly weathered, characterized by low nutrient retention capacity and poor response to inorganic fertilizers, vulnerable to erosion and heavy leaching of nutrients when vegetation cover is removed and fragile physical structure.

b. High soil acidity; and/or aluminium toxicity.

c. Labour constraints: labour shortage is one of the major problems for agricultural production. This is true even in more densely populated zones near cities, where off-farm employment offers serious competition for farm labour. The system is exclusively based on use of hand labour and is labour-intensive. Lack of labour for clearing operations has led to a "premature" reduction in the length of fallow, and the lack of annual clearing of forest or bush leads not only to overcropping of the soils, but to limited area of production of the highly lucrative "ngon crop" (which is only planted where stumps and fallen trees from newly cleared high bush or forest, are available). Yam production in the zone has also declined, due to excessive high labour requirement including for staking.

Suggested Agroforestry technologies: The development strategy for the fallow-based food crop system are to intensify fallow management and where possible, to shift to more permanent and semi-permanent cropping systems through improved methods of soil management. The specific technologies recommended are:

- Planted fallows with soil improving leguminous and other trees-essentially in form of hedgerow intercropping or mixed cropping;
- Short fallow rotation improved fallow;
- Live staking for yam and ngon production;
- "Practice which reduce soil exposure"

"Introduce labour saving tools".

2. Homegarden/Smallstock sub-system

Properties: The homegarden sub-system also provide food to the rural households. Crops grown around the homestead include fruit trees such as citrus spp, papaya, mango, safou; vegetable crops such as amarnthus, okra, pepper, and in few cases, other food crops such as plantain and cassava. Smallstock such as goats, sheep, poultry and pigs are kept primarily for home consumption and ceremonies and also in few cases for cash income.

In highly populated area around major cities, the animals are either tethered or kept in enclosure and fed with household waste and/or cut and carry system during the cropping season while in low populated area and during the dry season, they are left free ranging.

Compared to other regions in the humid lowlands such as Eastern Nigeria, the homegardens in the humid lowlands of Cameroon are under developed and are not fully exploited. It lacks species diversity and the multi strata intensive exploitation, common in other similar environment is conspicuously absent.

Production constraints:

a. Labour shortage: like in other sectors, labour availability is a constraint to smalltock and homegarden intensification;

b. Destruction to crops by animals: This has forced the farmers either to limit the number of animals to the barest minimum or site their food crop farms far away from homestead leading to long walking distance to and from farms.

c. Lack of species diversity: Probably due to the problem indicated in "b" above, the homegarden is not intensively cropped and lacks species diversity.

Recommended Agroforestry Technologies:

. **Fodder Bank/Feedgarden:** At no time did the farmers indicate shortage of fodder as a constraint to smallstock production. However, other factors such as destruction of crops by animals and labour shortage were considered as indirect symptoms of lack of readily available high quality fodder. It was envisaged that, if efficient fodder bank is developed and managed near homestead, it could encourage the farmers to keep more number of animals in enclosure and be able to feed them without necessarily spending more time searching for fodder from natural source.

. **Live fence:** This was also considered important to address the indirect but fodder related problem. Restricting the animals in fenced area with the fence providing the service function of restricting the animals movement and product function of ensuring fodder availability, it was perceived that the farmers would be encouraged to keep more animals.

. **Multistorey intensive cultivation:** To enhance productivity per unit area, it was recommended to improve on species diversity through efficient utilization of vertical space.

3. Cocoa Production Sub-system

Properties: Cocoa is the most import tree crop and men's farming domain. The tree is planted either on a newly cleared plot along with food crops or after the food crop production cycle. The food crops are intercropped at tree establishment phase to exploit the initial high soil fertility and also provide shade for the cocoa seedlings. After harvesting the food crops, the plot then becomes a plantation of cocoa trees.

Shading is provided by trees selectively left after clearing. In rare cases, farmers transplant, from wild stock, diverse economically useful trees (timber, fruit and medicinal trees).

Planting of the trees and spraying pesticides/fungicides are considered to be men's task. It is the men that also control the income from the produce. Women and children help with the transport and planting of seedlings for establishment of new plantations, weeding and in harvest and post-harvest processing.

Production constraints: Essentially, most of the constraints affecting productivity of food crop production also affect the cocoa production. These include:

- Rudimentary and inefficient farming tools,
- Declining soil fertility,
- High soil acidity and/or aluminium toxicity and,
- Labour constraint.

Cocoa production is also affected by:

- Poor quality shade. Often too dense thus providing conducive environment for fungal attack and limiting the possibility of introducing intercropping with food crops once the canopy closes;
- High incidence of disease,
- Competition for land with food crops.

The above constraints were those identified as major causes responsible for low productivity in cocoa production sector. However, over the last six years, the emphasis seems to have shifted. The major problem currently facing the cocoa sector is not just productivity but the alarming rate by which the world market price of cocoa is falling. The price of cocoa beans fell from a record high of over 1000 CFA/kg about a decade ago to less than 200 CFA/kg at present. This not only discouraged the farmers from expanding cocoa farms but forced many of them to abandon the existing farms in favour of food crop farming. The food crop production which used to be the monopoly of the women family members is now competed for by all.

Recommended Agroforestry Technologies:

- Enrichment planting to improve the amount and quality of shade in cocoa plantation;

- Introduce legume cover crops for fertility maintenance and weed control;

Encourage multistorey management to enhance productivity per unit area.

4. Priority setting and programme of work

Although the importance of the various land use systems, their associated constraints and the need to address the problems were recognized, it was also noted that given the limited human and material resources available to the project, it was not possible to attempt addressing all the identified problems. it was thus decided that during the first phase (1987-1992), the IRA/ICRAF project focuses on tackling the problems associated with the food crop production sub-system while the cocoa research unit of IRA address the constraints associated with cocoa based cropping system. It was also agreed that if the second decision fails to materialize, the project takes up the responsibility during the second phase.

With this understanding, the project then set itself the following objectives:

1. To develop agroforestry technologies aimed at ensuring improved and "sustainable" production of food and cash crops.

2. Assist in developing human resources in areas of Agroforestry research.

3. Institutionalize agroforestry research within the national agricultural research system.

To achieve its stated objectives, the project adopted the following strategies:

1. Initiate and promote close inter-institutional collaboration and work closely with the nationals in developing agroforestry technologies.

2. Provide training opportunities to the nationals in form of:

    a. In service training;

    b. Organizing short-term training/workshops or sponsoring candidates to similar activities elsewhere;

    c. Sponsoring and supervising:

        . Vacation research scholars,
        . Research scholars,
        . Research fellows,

    d. On the job training;

    e. Providing consultancy service to other national institutions, organization and/or schools interested in agroforestry research;

)btain full commitment from host institute in assigning permanent scientific staff to
.ıe project and provide necessary infrastructure to the project.

' II. FIELD ACTIVITIES

ſRODUCTION

ing the decision taken at the end of the "D & D" exercise, field activities focused on ›ing of agroforestry technologies targeted towards improving soil fertility for improved ıstainable" food crop production.

.ree agroforestry interventions, identified as potential solution to achieve the set ves were:

Hedgerow intercropping,

Hedgerow intercropping with animal component and

Improved fallow or short fallow.

;tep towards developing these technologies, the following activities were planned:

Identify source and obtain seeds of multipurpose trees (MPTS) suspected and/or known to be suitable for the recommended technologies;

Conduct vigour/phenology trials to assess adaptability of the MPTS to the study region and identify species with suitable characteristics for the various interventions;

Conduct management trials with known or studied species elsewhere;

Conduct local MPT and farming system survey with a view to identifying suitable local multipurpose trees and location specific land use systems and constraints.

:matic presentation of the strategy adapted in implementing field research activities is rted in Fig 4b.

On-station activities were initiated initially in Yaounde, Centre Province (in 1987) and Sangmelima, South Province (in 1988). In August 1989, another station was opened at the IRA Nkoemvone research station in Ebolowa, also in South province. The Sangmelima station was closed in 1991 due to the high cost of maintenance and the request by the chief of the village who wanted to sell the land to private individual. On-farm activities are in progress in Yaounde and Ebolowa. The locations and environmental characteristics of these stations are presented in Fig 5 and Table 1. Statistics of all the field activities, initiated from 1987-1993 are summarized in Table 2. Below are summaries of objectives, methods, results and conclusions of some of the major on-station and on-farm research activities.

Fig. 4b. Schematic presentation of the strategy adapted to implement the IRA/ICRAF field research activities.

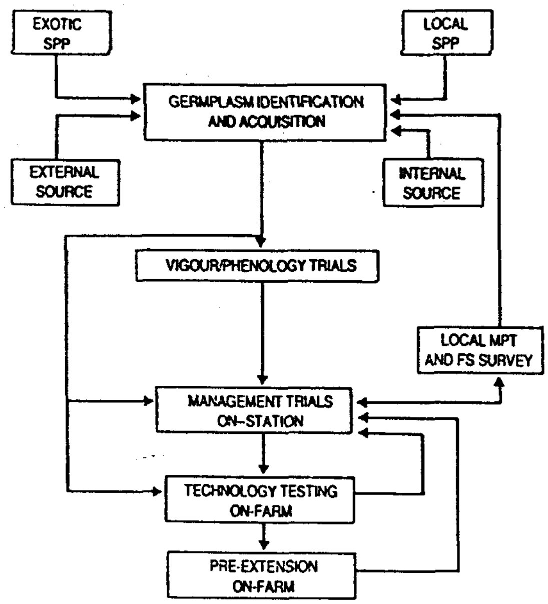
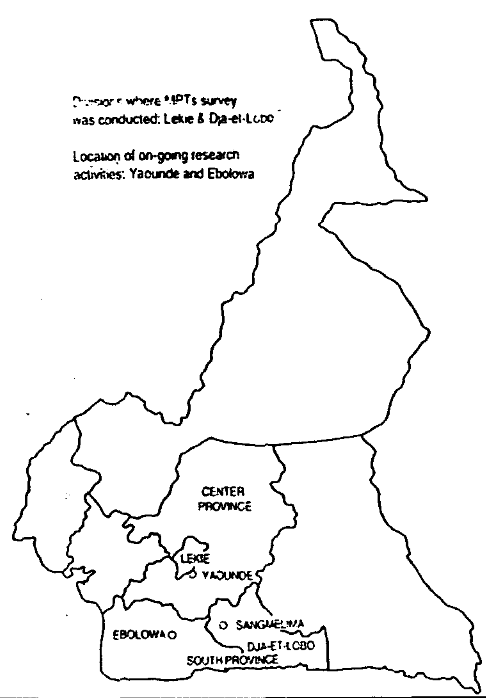


Fig 5 Showing IRA/ICRAF Research sites



2. VIGOUR/ PHENOLOGY TRIALS

Objectives: The specific objectives of the study were to assess the adaptability of selected exotic and local woody perennials to local conditions and to monitor the various growth characteristics of the species and their response to some typical agroforestry management practices.

EXPERIMENT 1.

Methods: The trial was initiated in August 1987 at IRA research station in Yaounde.

The experimental design was a split-plot in Completely Randomized Block with four replications. Main treatments were species in pure stand and species intercropped with maize. Split-plot treatments were the 10 species. The species included were: Acacia auriculiformis, Acacia mangium, Calliandra calothyrsus, Cassia javanica, Cassia siamea, Gliricidia sepium, Leucaena leucocephala, Sesbania grandiflora, Sesbania formosa and Paraserianthes falcataria.

The plot size was 5 m x 5 m with 25 trees per plot. Plant height and stem diameter at 50 cm above ground level were measured at three-month interval for the first two years and at six-month intervals thereafter. Twelve months after establishment, 50% of the trees were cut at 50 cm above ground level and biomass yield was determined. Measurements were taken from all living trees excluding the outer rows and mean values were used for analysis. Percentage re-sprouting of the harvested trees were determined.

Table 1. Environmental characteristics of Yaounde and Ebolowa where the IRA/ICRAF field experiments are located.

Parameters	Yaounde	Ebolowa
Longitude	11°25′ 11°27′E	11°6′ 11°10′E
Latitude	3°51′ 3°53′N	2°53′ 2°57′N
Altitude	700 m	615 m
Climate	Equatorial	Equatorial
Annual rainfall	1600 mm	1600 mm
Rainfall pattern	Bimodal	Bimodal
Temperature:		
Mean Minimum	19.2°C	19.7°C
Mean Maximum	26.6°C	29.1°C
Dry months:		
Long	Mid DEC-Mid MAR	Mid DEC-Mid MAR
Short	Mid JUN-Mid AUG	Mid JUN-Mid AUG
Vegetation	Degraded Tropical Rainforest	Tropical Rain Forest
Soil type:		
FAO	Ferric Acrisols	Ferric Acrisols
US	Rhodic Kandudutt	Rhodic Kandudutt

Table 2. Summary statistics of IRA/ICRAF Field Research activities from 1987 to 1993.

TYPE	SHORT TITLE	YEAR STARTED	YEAR ENDED	LOCATION	REMARKS
1. MPT SCREEN (OS)	VIG/PHENO *	1987	1990	YAOUNDE	PAPER ACCEPTED
2. MPT SCREEN (OS)	VIG/PHENO *	1988	1991	SANGMELIMA	PAPER REVIEWED
3. MPT SCREEN (OS)	PROV. TRIAL	1993	-	YAOUNDE	-
4. HR.INT.CROP (OS)	EFF. OF MULCH TYPE & LEVEL	1987	1993	YAOUNDE	PAPER IN PROGR.
5. HR.INT.CROP (OS)	EFF. OF MULCH TYPE & FERT.	1988	1993	YAOUNDE	PAPER IN PROGR.
6. HR.INT.CROP (OS)	DESIGN EFF.	1989	1994	YAOUNDE	-
7. HR.INT.CROP (OS)	BIOMASS ESTIM.	1990	1995	YAO & EBOLOWA	-
8. HR.INT.CROP (OS)	EFF. OF TIME OF 1st POLLARDING	1990	1994	EBOLOWA	-
9. HR.INT.CROP WITH ANIMALS (OS)	EFF. OF CROPPING GRAZING ROT. FAL.	1988	1986	YAOUNDE	-
10. HR.INT.CROP (OF)	EFF. MULCH TYPE FERT ON IMPROVED MAIZE VARIETY	1988	CONT.	YAOUNDE	CURRENTLY OVER 10 FARMERS INVOLVED
11. HR.INT.CROP (OF)	EFF OF INTEGRATED HR + IF ON CROP YIELD	1991	CONT.	YAO & EBOLOWA	A TOTAL OF OVER 35 FARMERS INVOLVED
12. I F (OS)	EFFECT OF FALLOW SHRUBS & FALLOW PERIOD	1989	1992	YAOUNDE	TERMINATED AND REPLACED
13. I F (OS)	EFF OF CROPPING AND FALLOW CYCLES	1990	1992	EBOLOWA	TERMINATED
14. I F (OF)	EFF OF FALLOW SHRUBS	1989	1991	YAOUNDE	PAPER TO BE WRITTEN
15. I F (OS)	EFF OF RESIDUE MANAGEMENT	1990	1992	YAOUNDE	-2 YRS RESULT AVAI. -NOT CROPPED IN 93 WILL CONTINUE IN 94
16. I F (OS)	FALLOW MANAGEMENT	1990	1992	YAOUNDE	BURNT BY STRIKING WORKERS
17. SCATTERED TREES ON FARMS	EFF OF COCOA SPACING	1992	2005	YAOUNDE	- IN ESTABLISHING PHASE

OS = ON-STATION   OF = ON-FARM   * = ACTIVE DATA COLLECTION COMPLETED

Other parameters measured were crown diameter at harvest, litter biomass yield at two years after planting and nutrient contents of above ground plant parts at one year after planting. Insect and/or fungal attack, flowering and fruiting dynamics were monitored through periodic visual observations.

Soil samples were taken before the trial was established to determine the initial soil properties. Three years after establishment, additional samples were taken from under those species considered promising and analyzed for pH, exchangeable acidity, exchangeable base and available P.

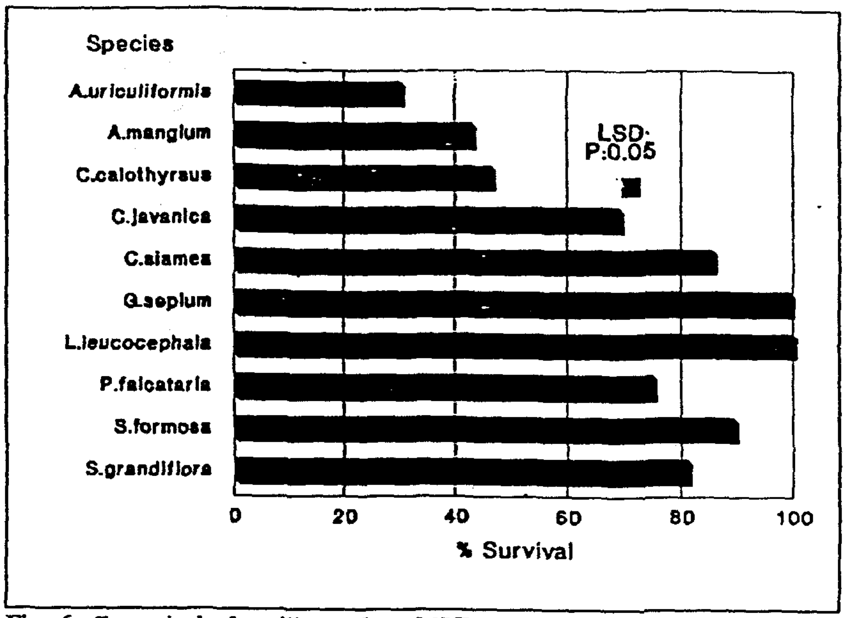


Fig. 6. % survival of seedlings of ten MPTs as affected by intercropping with maize at three months after planting

Results and discussion: Summaries of major parameters measured are reported in Tables 3 to 7 and Fig 6 to 8. Detailed results and discussions are reported in Duguma et al, 1991. Brief results and discussions on key major observations are highlighted below.

■ The two Sesbania species, although were among those with the highest percentage survival at the early stage (Fig 6), could not tolerate repeated pruning and after two years all the trees died. For all practical reasons, these species could be considered for short fallow or improved fallow technology but may not be suitable for hedgerow intercropping.

■ Intercropping with maize at establishment, significantly reduced the vigour of all the species although at varying degree.

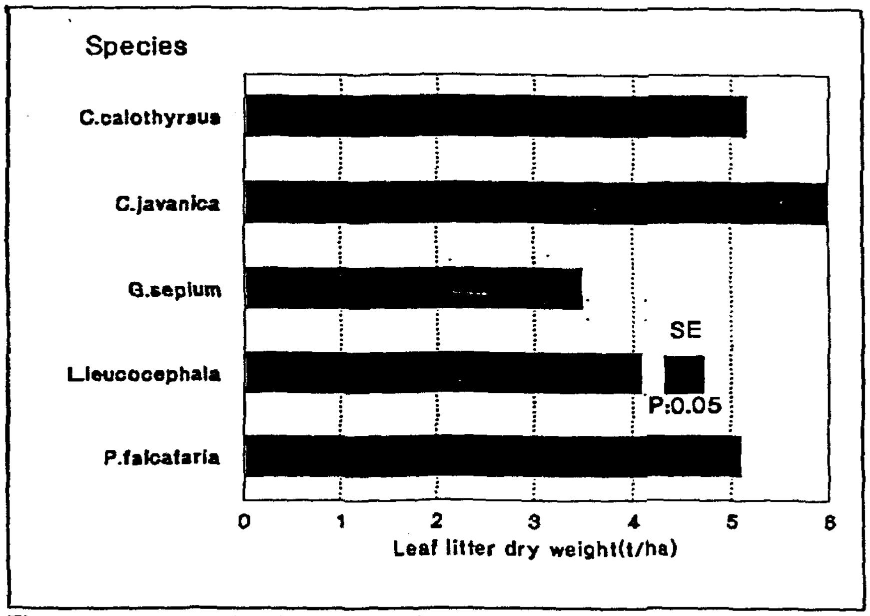


Fig. 7. Leaf litter yield of 5 MPTs during October to February

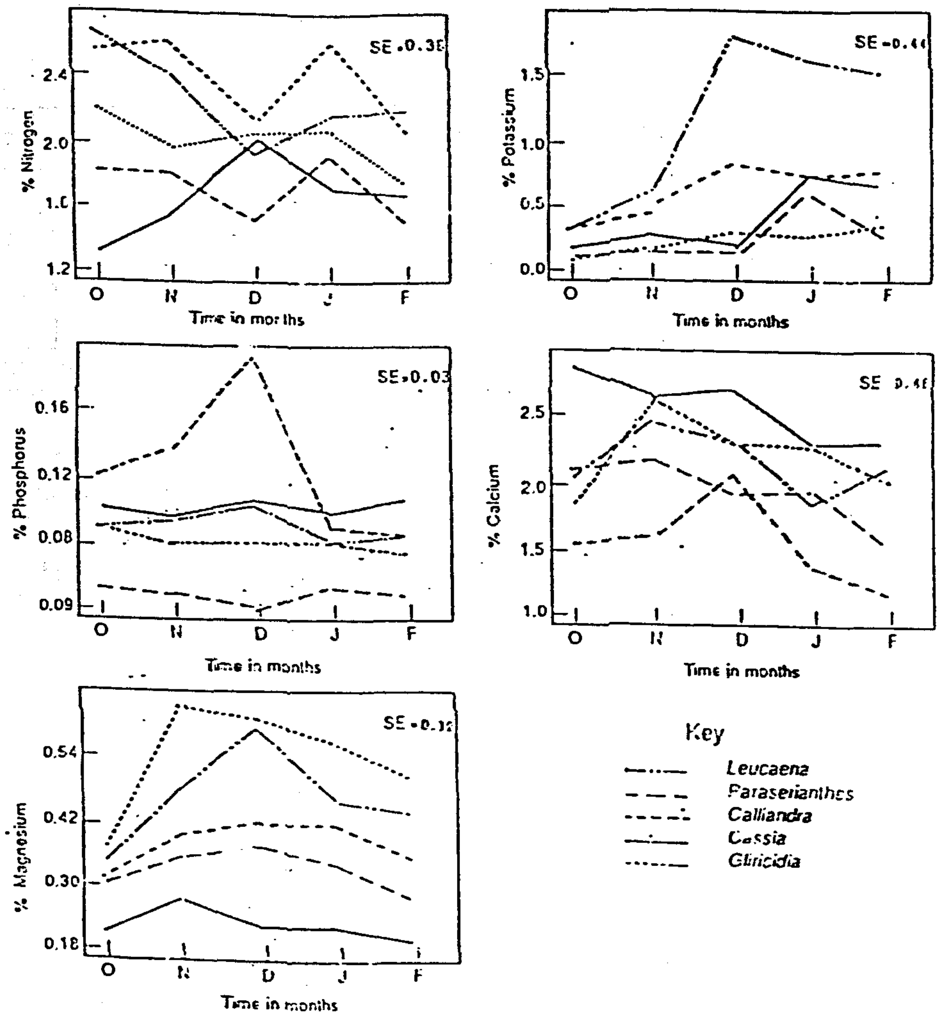


Fig. 8. Monthly variation in nutrient contents of leaf litter of 5 tree species during a 5-month period (Oct-Feb).

The effect on height growth was greatest for G. sepium and lowest for A. auriculiformis and C. calothyrsus (Table 3). The effect on diameter growth was greatest for P. falcataria and lowest for A. auriculiformis. Averaged over the two main plot treatments, height growth of P. falcataria was the highest followed by C. siamea L. leucocephala and C. calothyrsus (Table 3).

For any agroforestry technology, tree/shrub establishment is an unavoidable capital cost. The question is how to minimize such cost. Several factors need to be carefully studied before a decision could be made which could be summed up in one question: What is the best crop for intercropping that would exert minimum competition while generating acceptable income to justify the intercropping.

From the present result, it may not be possible to provide an answer to the above question. However, one can suggest that species less affected by intercropping with maize such as C. calothyrsus, A. auriculiformis and P. falcataria be selected and tested for other characteristics required for hedgerow intercropping technology.

- Biomass yield of C. siamea, P. falcataria and C. calothyrsus were among the highest which is another desirable characteristics for hedgerow intercropping (Table 4).

- Led by C. javanica, C. calothyrsus and P. falcataria produced the highest leaf litter which again is another desirable characteristics for species to be used in hedgerow intercropping.

Table 3. Plant height and stem diameter of eight multipurpose tree species without maize intercropping at 36 months after planting

Tree Species	Plant height (m)			Stem diameter (cm)		
	WM	NM	X	WM	NM	X
Acacia auriculiformis	5.13	5.64	5.38	5.60	6.52	6.06
Acacia mangium	4.35	5.34	4.85	4.82	6.23	5.52
Calliandra calothyrsus	5.94	6.56	6.25	4.55	6.29	5.54
Cassia javanica	4.72	5.75	5.23	4.73	6.48	5.52
Cassia siamea	6.14	7.91	7.02	7.36	9.93	7.33
Gliricidia sepium	5.27	5.56	5.42	3.85	4.83	5.14
Leucaena leucocephala	5.45	7.39	6.42	5.14	6.93	6.04
Paraserianthes falcataria	8.14	10.69	9.41	8.21	12.52	10.36
X	5.64	6.85		5.53	7.47	

		PHT	STD
SE	Between cropping means =	0.19	0.21
	Between species means =	0.44	0.54
	Between cropping x spp. means =	0.62	0.76

WM = tree intercropped with maize at establishment
NM = *established without intercropping*
PHT = Plant height
STD = Steam diameter
SE = Standard error

Table 4. Total biomass yield (Dm t/ha) of ten multipurpose trees as affected by intercropping with maize at one year after tree planting. Yaounde, Cameroon.

Tree Species	Leaf Dry Weight (t/ha)			Wood Dry weight (t/ha)		
	WM	NM	X	WM	NM	X
Acacia auriculiformis	1.35	3.55	2.45	1.38	4.44	2.94
Acacia mangium	1.30	4.85	3.10	0.96	5.82	3.42
Calliandra calothyrsus	3.60	9.10	6.35	7.11	15.84	11.52
Cassia javanica	2.70	7.50	5.10	4.60	14.46	9.36
Cassia siamea	6.10	9.90	8.45	7.44	18.00	12.72
Gliricidia sepium	4.10	5.55	4.85	5.88	15.66	10.80
Leucaena leucocephala	2.35	4.75	3.55	5.46	13.50	9.48
Paraserianthes falcataria	2.60	11.05	6.85	4.68	25.2	14.94
Sesbania formosa	0.65	1.10	0.90	1.20	6.84	4.02
Sesbania grandiflora	0.80	0.44	0.95	3.18	9.60	6.42
Mean	2.55		5.80		4.41	12.96

	Leaf	Wood
SE Between cropping means =	0.89	1.52
Between species means =	0.80	1.63
Between cropping x spp. means =	1.35	2.30

WM = Intercropped with maize
NM = Pure stand
SE = Standard error

Table 5. Total nutrient contents of prunings of ten multipurpose trees. Yaoundé, Cameroon.

Tree species	Content of Leaves				Content of Wood			
	N	P	K	Ca	N	P	K	Ca
	(%)							
Acacia auriculiformis	2.72	0.14	0.77	0.94	1.08	0.10	0.74	0.66
Acacia mangium	2.00	0.11	0.67	1.07	0.68	0.12	0.61	0.69
Calliandra calothyrsus	2.92	0.13	0.42	1.08	0.80	0.10	0.40	0.33
Cassia javanica	2.25	0.21	0.62	1.97	0.08	0.12	0.45	0.64
Cassia siamea	2.11	0.18	0.41	1.96	0.80	0.07	0.39	0.50
Gliricidia sepium	2.78	0.13	0.94	1.22	0.92	0.11	0.82	0.45
Leucaena leucocephala	2.92	0.17	0.84	1.42	0.80	0.23	0.52	0.66
Paraserianthes falcataria	2.45	0.15	0.73	1.17	0.87	0.10	0.40	0.33
Sesbania formosa	2.88	0.25	0.79	1.37	0.80	0.23	0.52	0.66
Sesbania grandiflora	2.72	0.22	1.17	1.60	0.81	0.15	0.62	0.56
Standard error	0.21	0.01	0.18	0.18	0.14	0.03	0.11	0.08

Table 6. Mean nutrient contents of leaf litterfall collected over a period of five months of dry season, of five multipurpose trees.

Tree species	Nutrient contents (%)				
	N	P	K	Ca	Mg
Leucaena leucocephala	2.30	0.09	1.14	2.11	0.47
Paraserianthes falcataria	1.66	0.05	0.33	1.95	0.32
Calliandra calothyrsus	2.42	0.12	0.59	1.50	0.38
Cassia javanica	1.66	0.10	0.40	2.69	0.23
Gliricidia sepium	2.00	0.80	0.33	2.23	0.53
Standard error	0.06	0.01	0.04	0.13	0.01

Table 7. Some characteristics of topsoil (0-5) under stands of five multipurpose trees species at three years after planting.

Tree species	Soil characteristics				
	Organic matter	Organic carbon	Total nitrogen	Available phosphorus	Calcium (meg/100g)
	(%)				
Baseline before planting	3.50	2.04	0.20	10.63	4.67
Calliandra calothyrsus	4.40	2.54	0.19	4.25	7.10
Paraserianthes falcataria	3.80	2.21	0.17	4.20	6.40
Cassia siamea	3.44	1.98	0.15	4.05	6.00
Gliricidia sepium	3.94	2.28	0.17	3.90	6.00
Leucaena leucocephala	3.77	2.18	0.16	4.00	7.00
Coefficient of variation	11.30	11.31	10.91	22.63	19.51
Standard error	0.31	0.18	0.01	0.65	0.90

■ There was no one single species that exceeded others in its content of all nutrients analyzed. However, if the nitrogen content is used as an indicator for selection, C. calothyrsus, L. leucocephala and G. sepium could be the first to be recommended (Tables 5 and 6).

■ Organic matter of soils from under the selected tree species increased over the period of three years compared to the value before planting. The highest increase was recorded for soils from C. calothyrsus plot while the lowest increase was observed for soil under P. falcataria plot. Except for soils from C. siamea, organic carbon for soils under the other species also showed an upward trend, although the increase was not as marked as that for organic matter (Table 7).

Conclusion

The result showed that there is no single tree species that has all the desirable characteristics.

The current study did not evaluate all aspects needed to select a tree/shrub for specific technology and the trial was conducted on only one location.

However, based on this preliminary result, the following could be recommended.

1. In a technology specific screening, assess the potential of C. calothyrsus, L. leucocephala, G. sepium, C. siamea and A. auriculiformis for hedgerow intercropping on non acid soils.

2. Test the above species and A. mangium and C. javanica, for other desirable characteristics for mixed cropping in cocoa based system for shade and soil fertility. Except for those known to be tolerant to acid soils, the trials be limited to non acid soils.

3. Unless periodic re-planting is considered economically viable and acceptable to farmers, use of Sesbanias be limited to short fallow.

4. For the most promising species such as C. calothyrsus, Provenance trial be conducted to identify a genetic material of optimum potential for the region.

EXPERIMENT 2.

Methods: The trial was initiated in August 1988 at Sangmelima in South province. The experimental design was a split-plot completely randomized block with three replications. Main treatments were species in monoculture and species intercropped with groundnut. Split-plot treatments were the ten species. Two months old seedlings of Acacia mangium, Acacia auriculiformis, Cassia siamea, Calliandra calothyrsus, Dialum guineense, Dubocia macrocarpa, Gliricidia sepium, Leucaena leucocephala, Milicia excelsa and Paraserianthes falcataria were planted at 1 m x 1 m spacing.

The plot size was 5 m x 5 m with 25 trees per plot. Plant height and stem diameter at 50 cm above ground level were measured at three months interval for the first one year and annually thereafter. At one year, two-year and three-year after planting, alternate trees were cut at 50 cm above ground level and biomass yield were determined. At year two, biomass yield of the regrowth and coppicing percentage were recorded. Measurements were taken from all living trees excluding the outer rows and mean values were used for analysis. At three years after establishment, soil samples were taken from each plot and analyzed for soil properties.

Results and discussion: Mean values of the various parameters measured are reported in Tables 8 to 10 and Figures 9 to 12. Detailed results and discussions on this experiment are also available in Duguma et al (1993) and IRA/ICRAF (1988, 89, 90 and 91). The highlights of the major observations are as follows.

■ Intercropping with groundnut at establishment did not affect the performance of the trees. All the data were thus re-analyzed as simple Randomized Complete Block.

■ At three years after planting, P. falcataria attained the highest height growth followed by A. mangium, A. auriculiformis, C. siamea and C. calothyrsus (Table 8). The trend in stem diameter increment was different (Table 9). The performance of the local species were among the poorest with only D. macrocarpa attaining a maximum height of 5.9 m in three years.

■ The trend in biomass yield of the primary growth of the species varied with age (Figures 9 and 10). At early stage, A. auriculiformis and A. mangium produced the highest leaf biomass while C. calothyrsus and A. mangium produced the highest wood biomass. At year two, leaf biomass yield of C. siamea was the highest. Wood biomass yield of P. falcataria recorded at the same time was double that of the Acacias or C. calothyrsus. The local species, L. leucocephala and G. sepium yielded significantly lower biomass growth compared to the rest.

■ C. siamea and C. calothyrsus produced the highest leaf and wood biomass of one year regrowth (Fig 11). Biomass yield of the regrowth of P. falcataria and A. auriculiformis was among the lowest which could be due to their poor coppicing ability. Similarly, biomass yield of L. leucocephala and G. sepium was significantly low. This could be due to the low pH of the soil on which they were grown.

■ Coppicing percentage of A. auriculiformis, A. mangium and P. falcataria (all with the best height growth and primary biomass yield) was significantly lower (less than 51%) compared to that of the rest of the species. Coppicing percentage of all the local species, C. calothyrsus, C. siamea, G. sepium and L. leucocephala was over 70% (Fig 12).

Table 8. Plant height of ten multipurpose trees grown in Sangmelima, Southern Cameroon

Tree species	Plant height in m					
	3MAP	6MAP	9MAP	12MAP	24MAP	36MAP
A. auriculiformis	0.41	1.05	1.85	2.80	6.76	9.56
A. mangium	0.33	0.94	1.93	3.10	8.13	10.03
C. calothyrsus	0.71	1.42	2.35	3.04	4.97	6.44
C. siamea	0.30	0.73	1.27	1.92	5.67	8.31
D. guineense	0.09	0.23	0.32	0.80	1.87	2.86
D. macrocarpa	0.28	0.57	0.90	1.40	2.13	5.90
G. sepium	0.50	0.66	0.98	1.50	1.75	3.54
L. leucocephala	0.55	0.78	1.28	1.70	2.29	4.75
M. excelsa	0.22	0.40	0.37	0.86	1.02	1.57
P. falcataria	0.94	1.69	2.73	3.14	6.58	12.11
LSD 0.05	0.16	0.20	0.48	0.44	1.93	1.49

Table 9. Stem diameter of ten multipurpose trees grown in Sangmelima

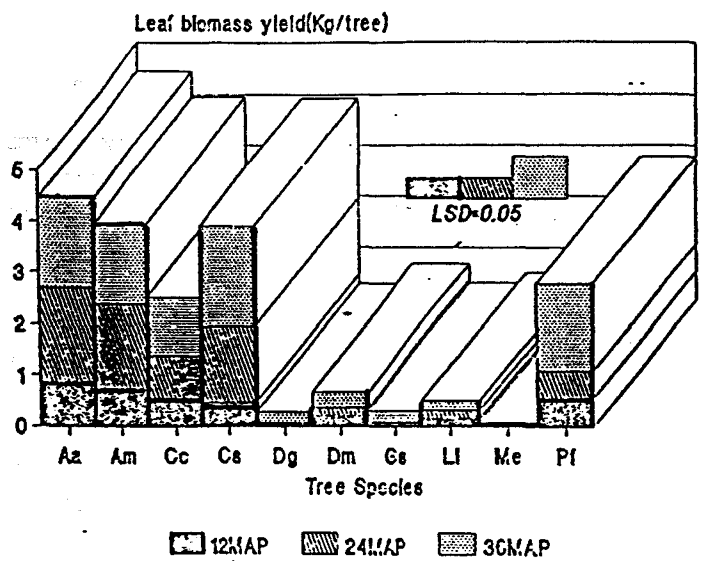
Tree species	Stem diameter (cm)					
	3MAP	6MAP	9MAP	12MAP	24MAP	36MAP
A. auriculiformis	0.95	1.10	2.37	3.10	5.72	8.43
A. mangium	0.93	1.20	2.68	4.00	7.04	10.59
C. calothyrsus	1.23	1.40	2.42	2.80	3.27	4.77
C. siamea	1.25	1.40	2.52	2.90	5.07	7.08
D. guineense	0.20	0.30	0.62	1.10	1.26	2.37
D. macrocarpa	0.93	1.00	1.85	2.50	2.78	5.58
G. sepium	1.45	1.40	1.87	2.30	1.79	2.77
L. leucocephala	1.20	1.10	1.57	1.90	2.04	2.38
M. excelsa	1.10	0.60	1.00	0.67	0.70	0.93
P. falcataria	1.72	2.20	2.98	3.50	6.26	7.53
SED	0.08	0.15	0.21	0.22	0.94	0.70
LSD 0.05	0.17	0.31	0.44	0.46	1.97	1.47

.e 10. Total nitrogen (TN) and organic matter (OM) of soil samples collected from under the stands of 10 MPTS grown in Sangmelima, Southern Cameroon.

.e species	Soils properties		
	TN%		OM%
	0 - 5	0 - 15	0 - 5
auriculiformis	0.12	0.09	2.94
mangium	0.10	0.10	2.17
. calothyrsus	0.18	0.14	3.42
. siamea	0.13	0.11	2.27
. guineense	0.09	0.08	1.71
. macrocarpa	0.14	0.12	2.42
. sepium	0.11	0.10	2.21
. leucocephala	0.14	0.10	2.36
i. excelsa	0.14	0.10	2.67
?. falcataria	0.14	0.11	2.56
S E D	0.02	0.01	0.33
L S D	0.04	0.02	0.69

KEY: TN = Total nitrogen OM = Organic matter

Fig 9. Leaf biomass yield (primary growth) of ten MPTS grown in Sangmelima, Southern Cameroon.



KEY :

Aa = Acecia auriculiformis	Dm = Dubocia macrocarpa
Am = Acacia mangium	Gs = Gliricidia sepium
Cc = Calliandra calothyrsus	Ll = Leucaena leucocephala
Cs = Cassia siemea	Me = Milicia excelsa
Dg = Dielum guineese	Pf = Paraserianthes falcataria

Fig 10. Wood biomass yield (primary growth) of ten MPTS grown in Sangmelima, Southern Cameroon.

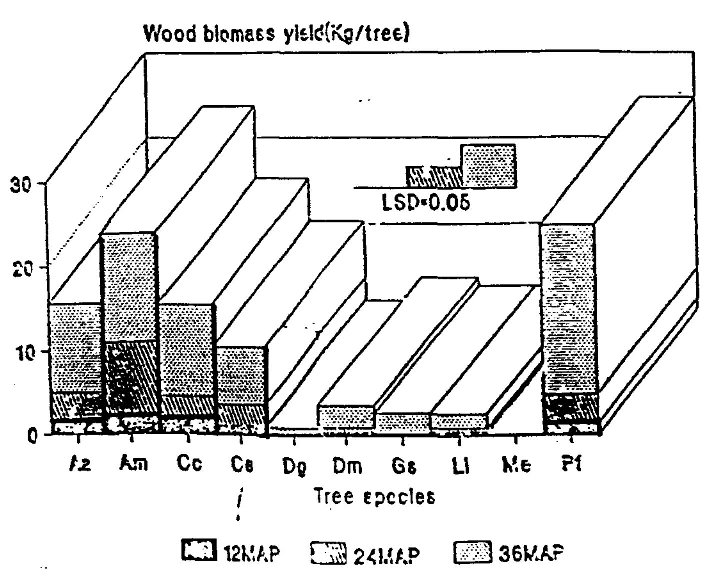
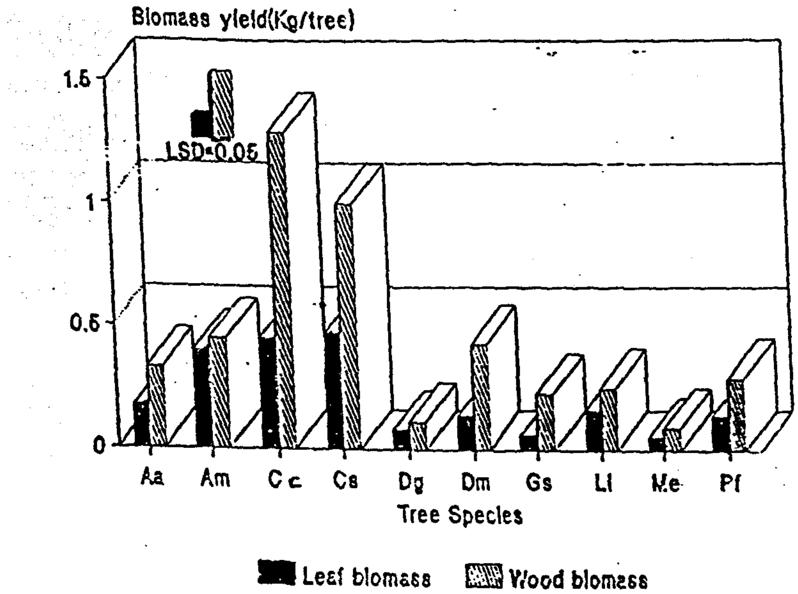


Fig 11. Leaf and Wood biomass yield (one year regrowth) of ten MPTS grown in Sangmelima, Southern Cameroon.



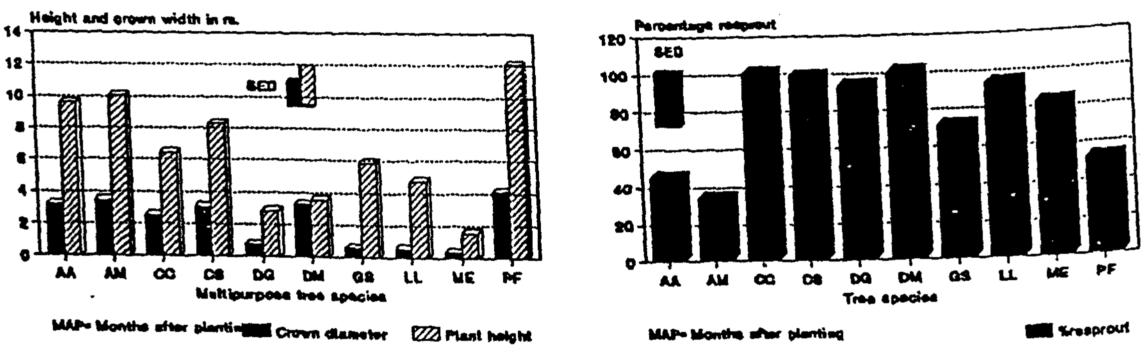


Fig. 12. Plant height, crown diameter and coppicing percentage of ten MPTs grown in Sangmelima, Southern Cameroon

■ Total nitrogen and organic matter in top soil were the only two properties significantly effected by the tree species. Percentage total nitrogen and organic matter of soils from under the stand of C. calothyrsus were the highest, while those of D. guineense were the lowest.

Conclusion and recommendations

As stated earlier, there is no one single species that has all the desirable characteristics, nor the study claims to have assessed all aspects needed to recommend a prototype. Based on the current result however, the following suggestions could be considered.

■ Tree species such as A. mangium, A. auriculiformis and P. falcataria established well on acid soil, are fast growing, are nitrogen fixing but are characterized with poor coppicing ability. These species could therefore be of good potential for further study for agroforestry technologies such as scattered trees on farms for shade provision and soil fertility improvement in cocoa or coffee based cropping system. They may not be suitable for technologies that require periodic cut back.

■ Calliandra calothyrsus established well on acid soil, grew fast, produced high biomass and some soil properties under its stand improved significantly. All the trees that were cut back coppiced, biomass yield of the regrowth was the highest and it is known to be a good nitrogen fixer. This species could thus be the best bet for hedgerow intercropping on acid soils where species such as Leucaena and Gliricidia fail to grow to their full potential.

■ The growth and development of the local species was very poor as compared to that of exotic species. It is recommended that alternative local species be evaluated in future trials. The performance of L. leucocephala and G. sepium was below average and they may not be suitable for the region.

3. MANAGEMENT TRIALS

Background: While conducting vigour phenology trials to identify potentially suitable and adaptable tree species for the recommended technologies, the project has also been working on systems improvement. The target technologies have been hedgerow intercropping and improved fallow.

In 1992, one experiment for cocoa based cropping systems was initiated. Summary report on most of them are presented below.

HEDGEROW INTERCROPPING

EXPERIMENT 1.

Objectives: To compare effect of various mulch types on crop yield and soil properties and to determine mulch level requirement for optimum crop yield.

Methodology: The trial was initiated in August 1987 at IRA research station in Yaounde. In line with the councils thinking at the time, it was agreed that a single hedge/spp. of multi-species hedgerows be established to monitor initial crop response to the various mulch types.

Tree species selected for the trial were Calliandra calothyrsus, Acacia auriculiformis, Sesbania sesban, Gliricidia sepium, Leucaena leucocephala, Cassia siamea and Sesbania grandiflora. Fifteen m long, single hedge of each of the above species were planted at 6 m between and 25 m within hedge spacing. The hedges were planted by direct sowing of the seeds. Each hedge was sub-divided into three sub-plots of 5 m x 6 m to test the effect of various mulch levels (0%, 100% and 200% of the total harvest per plot). Each treatment was replicated three times with hedges in North-south orientation in one block and East-west orientation in two blocks with a view to assessing the effect of orientation on both tree and crop performance which again was in conformity with the council's research emphasis at the time.

The design was split-plot in Randomized Complete Block with the species as main plot treatment and mulch level as sub-plot treatment.

A year after establishing (second season of 1988), the hedges were cut back, the mulch was surface applied and maize was intercropped.

At harvest, maize plant growth and grain yield was assessed on row by row basis as well as on per/ha basis.

In March 1988 (1st season), the above exercise was repeated. From the two years result reported under "Results and Discussion" below, it became necessary to modify the trials.

The modification include:

- Replacing the three mulch level comparison to with and without mulch treatments,
- Standardize the amount of mulch to be applied for all the species by importing from external source for those species characterized with low biomass yield;
- Imposition of fertilizer test (0 kg/ha and 60 kg/ha of N_2 in form of NPK 20-10-10 as split plot treatment.

The modification was effected beginning second cropping season of 1990. The data were then analyzed separately for mulch and no mulch plots.

At the beginning, the plan was to crop the plot every season (twice a year). However, due to the low biomass production and also in agreement with the farmers' practice (one plot cropped only once a year), cropping frequency for all the trials was limited to once a year.

Calender of activities for the trial under reporting is presented in Table 11.

Table 11. **Calender of cropping/fallowing phases in hedgerow intercropping I.**

Year	Seasons		
	Mar - June	Aug - Nov	Crops intercropped
1987	-	Trees established	-
1988	Trees re-stocked	Pruning/cropping	Maize
1989	Pruning/cropping	Fallow	Maize
1990	Fallow	Pruning/cropping	Maize
1991	Fallow	Pruning/cropping	Maize
1992	Fallow	Pruning/cropping	Maize & Cassava
1993	Cassava fallow	Fallow	Cassava

Results and discussion: Early establishment of the hedges was poor which led to restocking in 1988.

The result of the 1988 cropping showed the highest fresh leaf biomass yield of 8.1 t/ha from C. siamea plot, followed by that of A. auriculiformis (4.2 t/ha). The trend in wood biomass yield was similar to that of the leaf (Table 12).

Table 12. Leaf and wood fresh biomass yield of six multipurpose tree species at one year after planting.

Species	Leaf fresh biomass	Wood fresh biomass
A. auriculiformis	4.2	2.0
C. calothyrsus	2.7	2.0
L. leucocephala	1.2	1.1
G. sepium	3.1	1.3
S. sesban	2.0	2.1
C. siamea	8.1	6.0

Maize height growth and grain yield were not affected by mulch level or mulch type (species). However, both variables were affected by the proximity of the crop rows to the hedge, where the plant height and grain yield from the maize rows adjacent to the hedges was significantly reduced (Figures 12 and 13). The non significant effect of the treatment factors on crop growth and yield could be due to the low level of biomass yield and subsequent low level of nutrient recycled (Table 13), while the significant reduction in both parameters of crops from rows adjacent to the tree could be due to the above and below ground competition for resources such as light and nutrients. The plot was re-cropped during the first season of 1989 and again there was no significant difference between the effects of mulch type or mulch levels on crop yield, the major factor suspected being the low biomass yield (the highest was equivalent of 62 kg/ha of N). The trial was thus left to fallow during the second season of 1989 and first season of 1990 and re-cropped during the second season of 1990. After the initial two croppings, all the Sesbania species died following the repeated pruning. Due to the high variability in mulch production, the mulch level for all the species was standardized for subsequent croppings.

1990 was the year when the rainy season started late and the total rain received was unusually low. The yield from the plot with hedges but no mulch applied was generally very low. Thus, the data from hedges with mulch + fertilizer was compared against the yield from no hedge and no mulch treatment (Table 14).

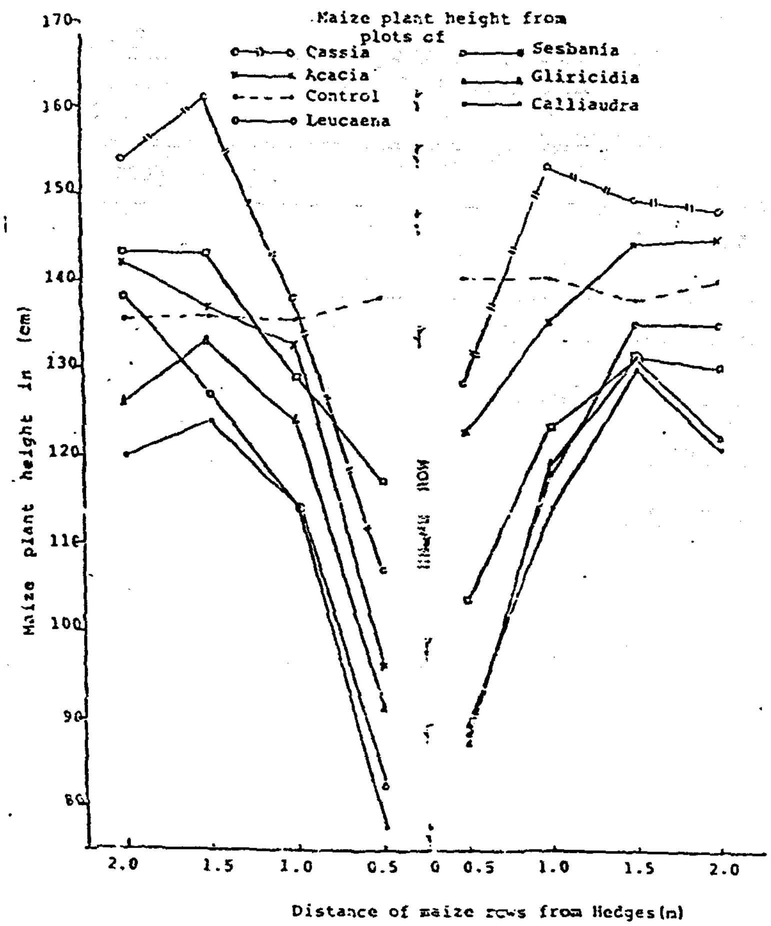


Fig 12: Average height of maize plants as affected by distance from tree hedges in Hedgerow Inter-cropping System.

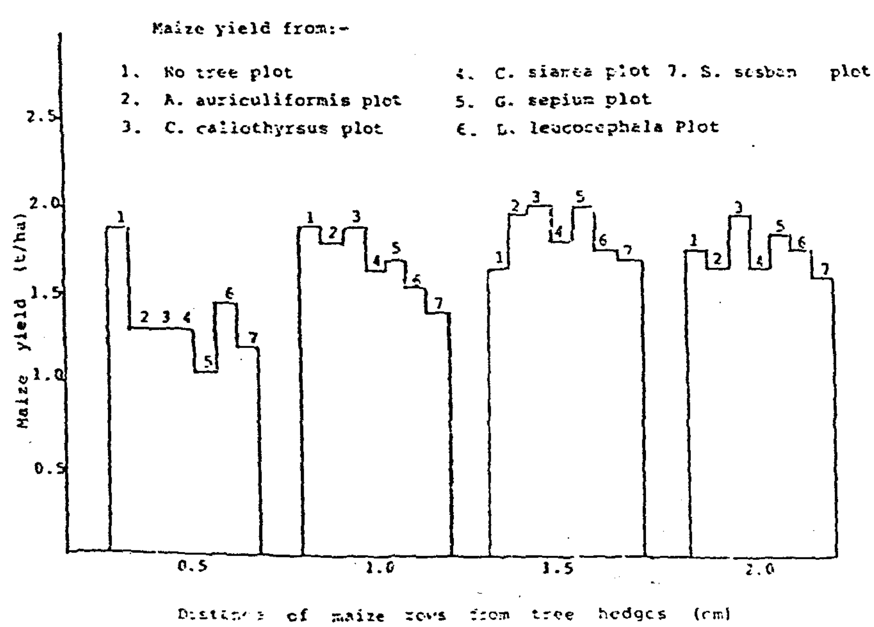


Fig 13: Maize grain yield as affected by row distance from tree/shrub hedges.

Table 13. Total nitrogen equivalent (kg/ha) applied as green manure, 1988.

Tree species (mulch type)	Total nitrogen equivalent (kg/ha) 0% mulch applied	100% mulch applied	200% mulch applied
<u>A. auriculiformis</u>	-	19.6	39.2
<u>C. calothyrsus</u>	-	14.0	28.0
<u>L. leucocephala</u>	-	6.0	12.0
<u>G. sepium</u>	-	16.0	32.0
<u>S. sesban</u>	-	10.0	20.0
<u>C. siamea</u>	-	31.0	62.0

Table 14. Maize plant height (HT) in m, grain yield (GY) in t/ha and stover biomass yield (SY) in t/ha as affected by mulch type and fertilizer application.

Mulch type	HT (a) 0	HT (a) 60	HT (a) Spp mean	GY (b) 0	GY (b) 60	GY (b) Spp mean	SY (c) 0	SY (c) 60	SY (c) Spp mean
Control (no mulch)	1.36	1.53	1.44	1.34	1.61	1.47	3.43	4.70	4.06
<u>A. auriculiformis</u>	1.71	1.84	1.77	1.38	1.62	1.50	4.67	6.25	5.46
<u>C. calothyrsus</u>	1.54	1.68	1.61	1.96	2.50	2.23	4.20	5.65	4.92
<u>C. siamea</u>	1.93	2.17	2.05	2.42	3.45	2.93	5.41	8.40	6.91
<u>G. sepium</u>	1.71	1.99	1.85	1.87	2.60	2.23	5.13	6.07	5.60
<u>L. leucocephala</u>	1.68	1.88	1.78	1.80	2.43	2.11	4.04	5.23	4.62
Fertilizer mean	1.65	1.85		1.79	2.37		4.01	6.05	

	SE(a)	LSD P=0.05	SE(b)	LSD P=0.05	SE(c)	LSD P=0.05
Between spp mean	0.18	NS	0.32	0.72	0.70	1.55
Between fert. mean	0.25	0.06	0.07	0.15	0.24	0.53
Between fert. mean for same spp	0.19	NS	0.34	NS	0.84	1.30
Between fert. mean for diff. spp	0.06	NS	0.17	NS	0.60	1.81

a = maize plant height
b = maize grain yield
c = maize stover biomass

Table 15. Effect of mulch type and fertilizer application on maize grain yield under hedgerow intercropping system (1991).

Mulch type/ Hedge species	No mulch applied			Mulch applied		
	0 kg/ha N	60 Kg/ha N	X	0 kg/ha N	60 Kg/ha N	X
No hedge	2.43	2.83	2.63	2.09	2.83	2.46
L. leucocephala	2.55	2.53	2.54	3.12	4.01	3.57
C. calothyrsus	2.64	3.75	3.19	3.47	3.84	3.65
C. siamea	2.13	2.92	2.53	3.01	3.97	3.19
G. sepium	2.16	2.83	2.49	2.59	3.20	2.89
A. auriculiformis	2.51	2.69	2.60	2.77	3.49	3.13
Fert. mean	2.40	2.92		2.84	3.56	

S E of diff. of means

	No mulch applied	Mulch applied
1. For spp mean	0.29	0.28
2. For fert. mean	0.11	0.17
3. For fert. mean with same level of spp	0.27	0.41
4. For fert. mean with diff. level of spp	0.35	0.53

Table 16. Effect of mulch type and fertilizer application on maize stover biomass under hedgerow intercropping system (1991).

Mulch type/ Hedge species	No mulch applied			Mulch applied		
	0 kg/ha N	60 Kg/ha N	X	0 kg/ha N	60 Kg/ha N	X
No hedge	19.25	23.47	21.36	19.25	23.76	21.51
L. leucocephala	13.05	15.92	14.49	15.63	20.35	17.99
C. calothyrsus	14.43	18.53	16.48	14.89	20.61	17.75
C. siamea	14.48	20.00	17.24	24.69	29.81	27.25
G. sepium	11.47	17.49	14.48	11.47	17.81	14.64
A. auriculiformis	12.24	17.01	14.13	19.92	23.79	21.85
Fert. mean	14.16	18.74		17.64	22.69	

S E of diff. of means

	No mulch applied	Mulch applied
1. For spp mean	2.32	2.27
2. For fert. mean	1.16	1.49
3. For fert. mean with same level of spp	2.83	3.43
4. For fert. mean with diff. level of spp	3.06	3.64

The 1990 result showed that maize height growth was significantly affected by fertilizer application but not by mulch type (spp) or their interaction.

The effect of both treatment factors on grain yield was significant. Interaction effects were not. The highest maize yield (2.93 t/ha) was recorded from plots treated with C. siamea mulch, followed by that of C. calothyrsus and G. sepium. The difference between the effects of the three treatments (Calliandra, Gliricidia and Cassia mulch applied) was not statistically significant (at P 0.05).

The lowest yield of 1.47 t/ha was recorded for control plot but this was not significantly different from the yield from A. auriculiformis plot.

The trend in maize stover yield response was similar to that of the grain yield except for the stover yield from A. auriculiformis plot which appeared to be higher than the yield from C. calothyrsus and L. leucocephala plots.

Due to changes in the focus of the 1991 APR, the above result was not reported in that year's annual progress report by the IRA/ICRAF project.

Maize grain yield and stover biomass recorded for the 1991 cropping season are presented in Tables 15 and 16.

Averaged over two fertilizer levels, grain yield recorded for plots with hedges (excluding the Calliandra plot) but mulch removed was significantly lower than the yield from plots with no hedge (control). With the frequent pruning carried out to avoid shading, the results suggest the possibility of competition between trees and crops for nutrients. The yield from C. calothyrsus plot with mulch removed was the only one that was higher than the control. This could be due either to differential root distribution of Calliandra or litter accumulated during the growing periods which probably compensated for the effect of competition.

With the application of the mulch of C. calothyrsus, L. leucocephala, G. sepium and A. auriculiformis, the yield increase, over the control, ranged from 17% to 48%. With or without mulch, the application of 60 kg of nitrogen fertilizer enhanced maize yield by between 22% and 25%.

The effect of the various treatment factors on stover yield was significant. The trend in response of the stover yield was similar to that of the grain yield.

During the second season of 1992, the trees were cut back and the plot was re-cropped, with maize and cassava. The cassava is still in the field while the maize was partially harvested by the striking workers and could not be analyzed.

This was the year marred with repeated strike by the workers of the host institute that delayed the cropping activities, as well as harvesting and data collection.

There was also an act of vandalism by the workers who either burnt IRA field trials or harvested the crops. This trial was thus partly affected by the latter.

EXPERIMENT 2.

Objectives: The main objective of the trial was to assess the effect of mulch type + fertilizer on crop yield and soil characteristics.

Methodology: Following the poor performance of some of the species included in Experiment I above, four relatively better adapted MPTS such as A. auriculiformis, C. calothyrsus, G. sepium and L. leucocephala were selected and a second trial was initiated in 1988. Unlike in Experiment I, where the hedges were established by direct sowing of seeds, two months old seedlings were transplanted.

A 20 m long hedge of each species was established at 4 m between hedges and 0.25 m within hedge spacing.

Each plot of 20 m x 4 m was sub-divided into three sub-plots of 4 m x 6 m to compare the effect of 0, 30 and 60 kg/ha of N applied in form of 20-10-10 NPK. The design is split-plot in randomized complete block, with species as main plot treatment and the fertilizer levels as sub-plot treatment. Each treatment was replicated 4 times.

Starting with a year after establishment (second season of 1989), the trees were cut back, the mulch was applied and intercropping was carried out once every year.

Except in 1990, when maize and groundnut were intercropped, sole maize was used as test crop.

Results and discussion: Mean leaf biomass of the species for the period 1989 to 1992 is reported in Table 17. Probably due to the early repeated prunings, (second season of 1989 and first season of 1990, most of the A. auriculiformis plants died after two years. C. calothyrsus and L. leucocephala produced the highest biomass over the four years period.

Maize grain yield response to mulch type and fertilizer levels over the four years period is presented in Table 18.

The difference in maize yield response to the various mulch type was statistically significant (P.0.05) throughout the four years period. Except in 1989, yield response to C. calothyrsus was the highest followed by that of L. leucocephala and G. sepium. The difference between the mean yield of C. calothyrsus and L. leucocephala was not significant. The lowest yield was always recorded from control plot.

Similarly, yield response to the various fertilizer levels was significant. The highest maize yield was recorded for plot with 60 kg/ha of N_2 application. However, the difference between the mean yield response to the 30 and 60 kg/ha N treatments was not significant in some years.

Maize yield response to the interaction effect of the two treatment factors is reported in Table 19. The effect was observed to be significant only in 1989 and 1990.

Table 17. **Mean leaf dry biomass yield of four multipurpose trees managed in hedgerow intercropping system.**

Species	1989		1990	1991	1992	
	1st Pruning	2nd Pruning	Total of Two prunings	Total of Two prunings	1st Pruning	2nd Pruning
			(t/ha)			
C. calothyrsus	4.11	0.58	3.17	6.60	3.88	1.84
L. leucocephala	3.23	0.55	3.39	3.69	4.38	2.21
G. sepium	1.92	0.38	2.65	2.20	0.72	3.01
A. auriculiformis	1.52	0.04	0.13	-	-	-
S E	-	-	0.35	0.69	0.30	0.35
LSD	0.47	0.18	-	-	-	-
CV %	9.18	23.13	15.40	16.80	14.02	20.91

Table 18. **Maize grain yield (in t/ha) response to mulch type (average over fertilizer level) and fertilizer (average over mulch type).**

Mulch type	1989	1990	1991	1992
Control (no hedge)	2.80	1.86	3.65	3.35
C. calothyrsus	3.71	2.97	4.79	4.19
L. leucocephala	4.34	2.48	4.03	4.00
G. sepium	3.71	2.64	4.32	3.97
A. auriculiformis	3.71	2.81	3.13	-
S E	-	-	0.35	0.25
L S D	0.27	0.85	-	-
C V%	8.04	40.57	10.64	8.10
Fertilizer level (kg/ha of N_2)				
0	3.15	2.15	3.38	3.54
30	3.72	2.52	3.94	3.86
60	4.10	2.77	4.64	4.23
S E	-	-	0.13	0.08
L S D	0.99	0.16	-	-
C V%	23.33	9.84	10.64	5.90

ɜ 19. Maize grain yield (t/ha) response to interaction effect of mulch type and fertilizer application.

h type	Fert. level (kg/ha of N_2)	1989	1990	1991	1992
rol (no hedge)	0	2.18	1.41	2.74	3.00
	30	3.00	1.93	3.74	3.29
	60	3.22	2.24	4.46	3.77
:alothyrsus	0	3.45	2.63	4.33	3.74
	30	3.60	3.06	4.86	4.26
	60	4.08	3.21	5.17	4.57
leucocephala	0	4.11	2.24	3.86	3.71
	30	4.37	2.47	4.16	3.98
	60	4.53	2.73	4.94	4.27
sepium	0	2.85	1.86	3.27	3.70
	30	3.07	2.93	3.98	3.91
	60	4.43	3.12	4.85	4.31
auriculiformis	0	3.16	1.41	2.69	-
	30	3.75	1.93	2.95	-
	60	4.23	2.24	3.74	-
S E		-	0.12	0.30^{NS}	0.32^{NS}
L S D		0.59	-	-	-
C V%		8.04	9.84	10.64	5.90

NS = not significant.

ble 20. Effect of mulch type and fertilizer application on groundnut yield, Yaounde, 1990.

Mulch type	Fertilizer level (N_2 in kg/ha)			Mean
	0	30	60	
ɔntrol (no hedge)	769	1065	1103	979
. calothyrsus	818	963	1159	980
. leucocephala	728	761	849	779
. sepium	691	921	1042	884
. auriculiformis	653	839	871	788
ertilizer mean	732	910	1005	

	C V	LSD P=0.05
ɜetween mulch type	19.05	137.18
ɜetween fertilizer level	12.21	68.14
ɜetween ferr. x mulch type	12.21	152.37

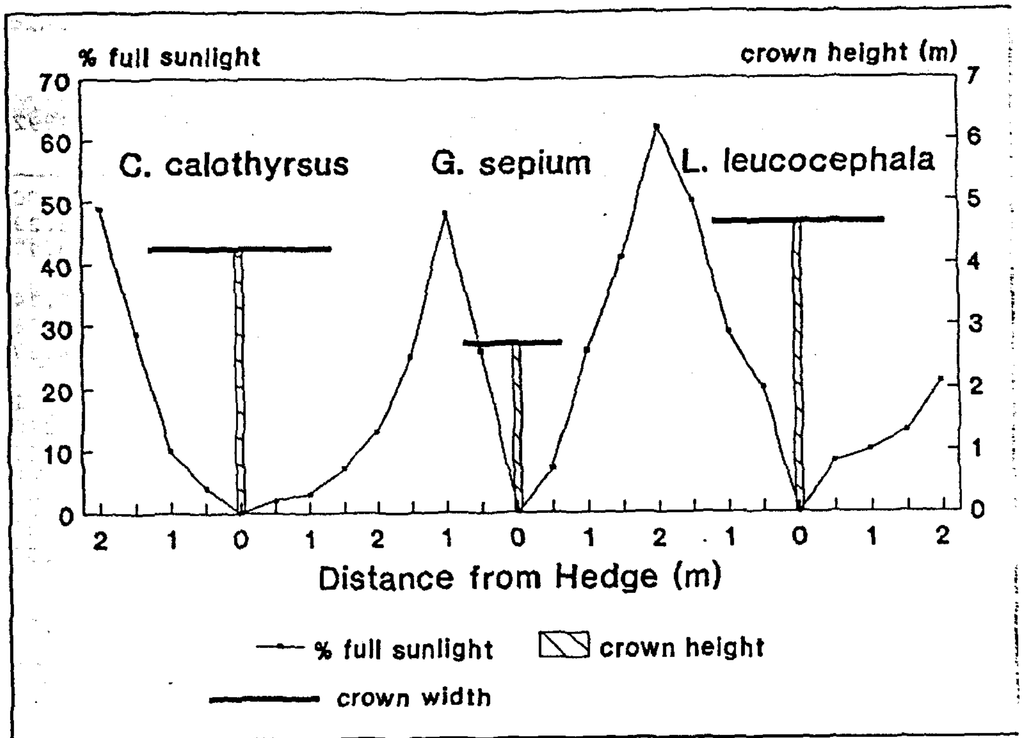


Fig. 14. Percentage full light received at 20 cm above ground level between tree hedges at various distances from the hedgerows.

The groundnut yield response to mulch type and fertilizer level is presented in Table 20. Unlike the maize yield, the groundnut yield was the highest for control plot and lower for plots treated with various mulch types. On the other hand, application of N_2 fertilizer did improve the yield. The lower productivity in plots with hedges could thus be due to competition both from the trees and the maize crops. The difficulty in applying mulch from the second pruning is another practical problem experienced by including groundnut planted at a density practiced by the farmers in a hedgerow intercropping system.

By the time the second pruning was due, the groundnut plants effectively covered the ground and surface application of the mulch was extremely difficult and time consuming that probably no farmer would like to practice it.

In 1992, percentage of full sunlight, received at various distances between the hedges were measured and the result is reported in Fig 14.

The result showed lower percentage of full light received in plots of fast growing species such as C. calothyrsus and L. leucocephala as compared to that recorded in G. sepium plot. The highest percentage was recorded at midway between L. leucocephala and G. sepium hedges characterized by narrow crown and short height respectively. This indicates the need for differential pruning regimes for different species depending on the type of alley crops to be managed in the hedgerow intercropping system.

COMMENTS AND CONCLUSION ON EXPERIMENT I AND II.

■ When these experiments were initiated, practical experience from field experiments on research methodology in agroforestry was either very scanty or non existent. Even today, most of the hypothesis advanced are largely based on observations from trials initiated to address land use associated problems and not on trials established to develop research methodology. Based on recent thinking therefore, the two experiments suffer from the relatively small plot size (experimental unit) arising from the single hedge arrangement per species and the short hedge length. According to Rao and Roger, (1990), minimum hedges of 3 for 6 m alley treatment to 7 for 2 m alley treatment is recommended to effectively account for border effects and obtain efficient data on crop and hedge. Even this, however, is very subjective as the degree of interference of adjacent plots, particularly with reference to the under ground interaction, largely depends on the extent to which the root system extends to the surrounding areas. There are reports that indicate L. leucocephala roots can grow up to 15 m across which suggests that in a 4 m alley with this species, a minimum border guard area of about 11 m is required to contain below ground border effect.

Based on known or existing biological facts, it is true that the plot size in the above two experiments are too small. However for the purpose of the study which was to obtain preliminary information on the range of species, relevant information has been obtained. From the current results, C. calothyrsus, L. leucocephala and to a lesser extent G. sepium are the most promising species for hedgerow intercropping. The authors thus recommend that further investigation on the effect of the mulch of these species on crop yield be considered under more controlled environment. This suggestion does not preclude other potentially suitable species identified from other on-going screening activities in the region.

■ The issue of attempting to compare several species was observed to pose some problems. Effect of mulch of different hedge species on crop yield is influenced by several factors including:

a. Biomass production potential of the species,
b. Nutrient content of plant components,
c. Decomposition rate of pruning,
d. Root biomass distribution and decomposition,
e. Rooting habit,
f. Symbiotic associations
g. Absence or presence of appropriate inoculum etc.

Tree/shrub species are known to be highly varied in their characteristics regarding the above factors.

It is possible that a species may produce high biomass but has lower essential nutrients in its tissues while the characteristics of another species could be exactly the opposite. In a simple comparison of the effect of the mulch of such two species on crop yield, it is possible to observe no difference between the two as the contribution from high biomass yield can easily be compensated by high mulch quality but low mulch level. Possible solution to such problem could therefore be:

a. Compare a system with just one species or a system with multiple species against a traditional practice.

b. Where systems with different species are to be compared, standardize suspected factors that contribute to the improvement of the system. e.g. applying the same amount of mulch by supplementing from external source for those species characterized by low biomass yield.

■ *As stated earlier, it is appropriate to ensure that adequate plot sizes are used in any* experiment. Above ground border effects can be controlled through appropriate management. Controlling below ground border effect through increased plot size may not be attainable in this zone. The most appropriate approach could be root pruning or placement of root barriers. The question is, can this be done in collaborative projects operating with very limited budget?

■ The IRA/ICRAF project often used maize as test crop for its trials in areas of soil fertility, the reasons being that it is fertility sensitive crop, the seeds are readily available, it is a short cycle crop and easy to manage. However, it is not the only crop or even the most important crop in the region.

On the other hand, the traditional practice involves cropping of several species of different maturity cycles, on a relatively small plot of land in undefined orientation. Each traditional crop has its own value and role and it is often difficult to select the "most important" crop. A crop that does not necessarily attract high price could be an important component of family diet. A crop that appears to be important both for its role as a component of the family diet and for its cash value is groundnut. This crop may fit into a technology such as improved fallow but difficult to manage in hedgerow intercropping.

The question is therefore, should a technology be developed to accommodate the existing traditional cropping practice or should the practice be modified through appropriate research to fit into the technology being developed?

To answer the above question, more socio-economic studies are needed for the region. Meanwhile, it is becoming clearer that the recommended technologies may not accommodate the existing farmers practice as it is and future research efforts should be geared towards developing appropriate cultural practice to enable the technologies being developed achieve the desired objectives.

EXPERIMENT 3.

Objectives: *The objective of the trial was to identify effective and viable fallow management* in hedgerow intercropping with animal components (alley farming intervention).

Methodology: The trial was initiated in August 1987. The treatments being compared are: Continuous cropping with no hedges (T1), Continuous cropping with hedges (T2), Two years grazing followed by two years cropping rotational fallow with hedges (T3) and Two years cropping followed by two years grazing rotational fallow with hedges (T4).

The hedges are of multispecies (L. leucocephala and G. sepium). Four, eleven meters long hedges of the two species (two hedges per species) were planted at 4 m between hedge and 0.25 cm within hedge spacing per experimental units. The plot size is 16 m x 11 m = 176 m^2.

The first cropping was carried out during the first season of 1989. At this stage, the trees were not pruned and no mulch was applied. The cropping was done to exploit the initial soil fertility and minimize cost of tree establishment.

The trees were pruned, the prunings were applied in T2 and T4 and maize was planted for all the treatments except T3, during the second season of 1989.

In 1990, the same exercise was repeated with maize and groundnut as test crops. During those two years, the mulch from the grazing/cropping fallow treatment (T3) should have been fed to animals. This aspect of the study was supposed to have been carried out by the Institute of Animal Research (IRZ) who signed a memorandum of agreement with the project accepting this responsibility. However, in 1989, the scientist responsible for the project travelled abroad for a postgraduate studies. He returned to the country towards the end of 1990 and selected six animals and started the feeding trial. After continuous feeding and monitoring of the animals weight gain for 15 weeks, the animals were stolen and the feeding trial was interrupted. By then, the two years cropping phase was through and the feeding trial should have moved to the T2 treatment while the T3 treatment was to be cropped. In anticipation that IRZ would re-start the exercise the following year, the cropping study continued for one more season. In May 1992, new set of animals were selected and the feeding trial re-started for the second time, but the monitoring did not last more than three months before the workers of the Ministry of Scientific and Technical Research started on their prolonged strike on non payment of salary, which completely paralysed research activities in the country to date. The results on agronomy aspect and the result on feeding study carried out for the brief period are reported below.

Results and discussion: Yearly leaf biomass yield and crop grain yield for the period 1989-92 are presented in Tables 21 and 22.

Initial (1989) biomass yield appeared to be lower than subsequent yearly biomass from the regrowth. Although the leaf biomass yield presented in Table 21 refers to the total for L. leucocephala and G. sepium, the analysis of individual species biomass yield showed that, that of L. leucocephala was consistently higher than the biomass yield of G. sepium (IRA/ICRAF 1989, 1990, 1991 and 1992). The difference between the biomass yield of T2 and T4 was less than 1 t/ha while that of T2 and T3, recorded in 1992 was about 2.1 t/ha, which obviously is due to the longer growing period the trees in T3 were subjected to before pruning.

The yearly maize grain yield for all the treatments appeared to fluctuate. Yearly analysis however showed consistent higher maize yield for treatments with trees compared to the control. The difference between maize yield of T2 and T4 was not significant for the first three years the comparison was made. The 1992 result showed an increase in maize yield of about 100% for the treatment that was under tow years of fallow when compared to the yield from T1 which is continuous cropping with no trees.

By looking at the 1992 result alone, one would be tempted to select the T4 as best alternative. However, comparison of the total yield from 1989 to 1990 shows a total output of 11.11 t/ha from T1 (Continuous cropping without trees) treatment as compared to only 6.28 t/ha from T3 (Grazing/cropping two years rotational fallow treatment. Selection of a particular system thus depends on cost benefit analysis of the two treatments which is not included in this report. However, from a hypothetical example:

- Assuming the cost of tree establishment being a capital cost and excluded from cost benefit analysis;

- Assuming the major variable costs and their estimation are:

  a. Land preparation = 2.33x cu/ha/year
  b. Weeding = 1.33x cu/ha/year
  c. Harvesting = x cu/ha/year
  c. Pruning = 2x cu/ha/year; where cu is currency unit.

The total variable cost of system (T1) = (2.33x + 1.33x + x) 4 cu/ha
= 4.66x x 4
= 18.64x cu/ha

The total variable cost of system (T3) = 2.33x + 1.33 x + x + 2x cu/ha
= 6.66 x cu/ha.

The total variable cost of system T1 is thus 280% of the cost of T3 while the yield is only 177% of the yield from T3.

Continuous cropping, even with trees, may not be economically and/or biologically viable and hedgerow intercropping with a year or two years fallow, after probably three to five years of cropping cycles is an alternative that could be considered. When and where possible, farmers still strongly believe in fallowing and this could also enhance the probability of the system for adoption.

Table 21. Leaf biomass yield (in t/ha) of L. leucocephala (L) and G. sepium (G) managed in alley farming system.

Treatment	1989 2nd season	1990 1st season	1991 1st season	1992 2nd season
Continuous cropping + trees	4.60	5.31	6.50	7.54
Grazing/cropping + trees	-	-	-	9.55
Cropping/grazing + trees	5.81	6.78	6.69	-

Table 22. Maize grain yield response to various fallow management techniques in alley farming system.

Treatment	1989 2nd season	1990 1st season	1991 1st season	1992 1st season
	(t/ha)			
Continuous cropping no trees	3.07	1.52	2.98	3.54
Continuous cropping + trees	4.25	2.13	3.70	4.79
Grazing/cropping + trees	-	-	-	6.28
Cropping/grazing + trees	4.07	2.72	4.48	-
S E D	-	-	0.29	0.35
L S D = 0.05	0.78	0.43	-	-
C V%	11.47	14.21	9.10	11.40

Contrary to the trend in maize yield response and similar to the result of Experiment II above, groundnut yield recorded for the control plot was significantly higher than the yield from plots with trees (Table 23).

Table 23. Groundnut grain yield response to various fallow management techniques in alley farming system.

Treatments	Groundnut grain yield (kg/ha)
Continuous cropping no trees	786
Continuous cropping + trees	680
Cropping/grazing + trees	559
L S D 0.05	133.40
C V%	15.62

Before the introduction of the animals into the grazing/cropping treatment plots, the natural vegetation was enumerated and identified. Excluding the two legume trees planted, a total of 21 trees, shrubs and herbaceous plants were identified. These include: Achyranthes aspera, Aerva lanata, Albizia glaberrima, Axonopus compressus, Bidens hipinnata, Cissus sp., Combretum sp., Commelina africana. Crotalaria sp., Erigeron floribundus, Eupatorium odoratum, Euphorbia hirta, Momordica foetida, Oplimemnus burmanii, Oxalis barreliera, Panicum maximum, Pennisetum purpureum, Pennisetum polystachion, Phyllanthus sp., Sida rhombolifolia and Talium triangulare.

The weight gain by the animals was recorded on weekly basis and weight gain per day for a period of 15 weeks for four of the six sheep that were monitored for the brief period the exercise lasted is presented in Fig 15. The daily weight gain over the 15 weeks varied from 19.7 gm to 30 gm. There is an indication that with the diet supplement from the system during the fallow phase, additional income could be generated. However, because of the inconsistency in data collection, meaningful economic analysis could not be done, at least for now.

Comments and conclusions

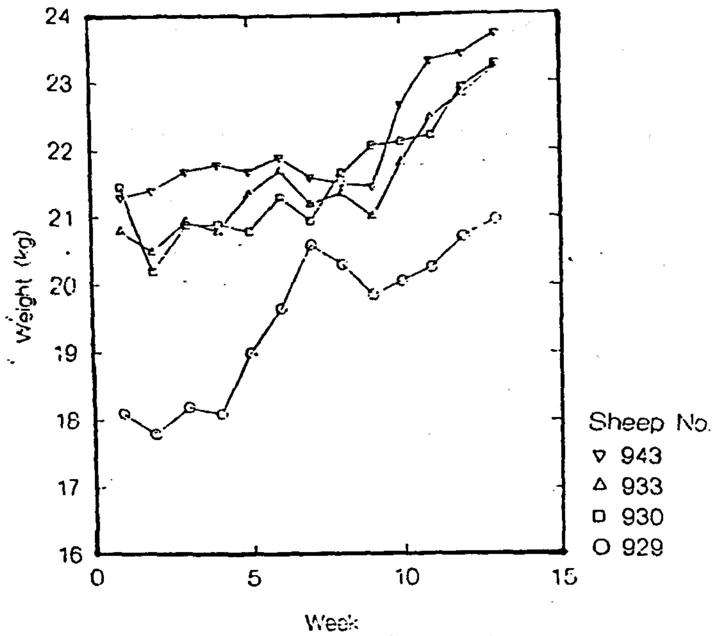
- Hedgerow intercropping with a year or two years fallow followed by certain cropping cycles (less than 5?) could be better alternative to continuous cropping.

■ During the fallow phase, the system can still generate additional income by way of using the tree biomass to feed animals and recycling the animal manure back to the farm for soil fertility improvement.

■ Groundnut, although is an important crop in the humid lowlands, may not be adapted to hedgerow intercropping as it is currently envisaged, unless the management technique is improved.

■ Intercropping groundnut in hedgerow intercropping system decreases the crop yield. Research needs to focus on modifying the management technique (cropping practice) or develop different technology (relay cropping) for this crop.

Figure 15 Weekly Weight Change of Sheep Grazing in ICRAF-IRZ Alley Farming Fallows



EXPERIMENT 4.

Objectives: To identify appropriate hedge arrangement that minimizes proportion of land occupied by hedges in hedgerow intercropping system

Methodology: The species selected for this trial was L. leucocephala. Two months old seedlings were transplanted in August 1989. The hedge arrangements (treatments) being compared are: T1 = Conventional hedge arrangement (4 m x 0.25 m). T2 = Hedge as a block at one edge of the plot (0.5 m x 0.5 m), T3 = Hedge in two blocks on two edges of the plots (0.5 m x 0.5 m) and T4 = Hedge as a block in the middle of the plot (0.5 m x 0.5 m).

In March 1991, the trees were cut back, the prunings were surface applied, and maize was intercropped. Maize was planted at 0.5 m x 0.5 m with the rows adjacent to tree hedges planted at 0.5 m

in all the treatments. The exercise was repeated annually since then. The plot size was 256 m^2, the design is RCB and each treatment is replicated four times.

Results and discussion: From the result of the first cropping carried out in 1991, the biomass yield (Table 24) of L. leucocephala and maize (IRA/ICRAF, 1991) was not affected by the hedge arrangement. Maize grain yield from the conventional hedge arrangement plot was the lowest when compared to the yield from the other three alternative arrangements

(Table 25). This was due to the extra land available for maize cropping in those plots with block arrangement of hedges as compared to the conventional arrangements where more lands are occupied by the scattered hedges throughout the plot.

Table 24. Leaf biomass yield of *L. leucocephala* as affected by various hedge arrangements.

Hedge arrangement	1991			1992		
	1st Pruning	2nd Pruning	Total	1st Pruning	2nd Pruning	Total
I. Conventional hedge arrangement (4 m x 0.25 m)	1.87	0.76	2.63	2.47	1.32	3.81
II. Hedge as a block at one edge of the plot (0.5 m x 0.5 m)	2.41	1.03	3.44	3.80	1.81	5.60
III. Hedge as a bloc in the middle of the plot (0.5 m x 0.5 m)	2.18	0.76	3.07	2.07	1.78	3.87
IV. Hedges at two edges of the plot (0.5 m x 0.5 m)	3.04	0.92	3.96	2.36	2.03	4.31
S E D	0.84	0.14	0.68	0.31	0.36	0.59
C V%	35.40	23.47	29.37	21.50	21.40	19.00

Table 25. Effect of hedge arrangement on maize grain yield.

Hedge arrangement	1991	1992	
		A	B
I. Conventional hedge arrangement (4 m x 0.25 m)	4.16	5.00	3.75
II. Hedge as a block at one edge of the plot (0.5 m x 0.5 m)	4.67	5.46	4.69
III. Hedge as a block in the middle of the plot (0.5 m x 0.5 m)	4.56	5.62	5.28
IV. Hedges at two edges of the plot (0.5 m x 0.5 m)	4.54	5.72	4.63
S E D	0.056	0.22	0.17
C V%	1.94	5.70	5.40

A = Based on unit area
B = Based on land equivalent.

The 1992 result showed significant effect of the various arrangements on tree biomass yield as well as on maize grain yield. The highest leaf biomass yield of 5.6 t/ha was recorded for plots with hedges as block planted at one edge of the plot. Leaf biomass yield and maize grain yield from the conventional hedge arrangement plot were the lowest. The margin of difference between the highest and the lowest maize grain yield was higher for data estimated based on land equivalent (41%) compared to the data computed based on unit area (14%).

The consistently low maize yield response for the conventional hedge arrangement could be due to both competition effect and the larger proportion of land lost to the trees planted all over the plot.

There could also be an added advantage of mining the soil from adjacent plots where the hedges are planted on the plot edges, compared to the conventional arrangement and planting of the hedges as a block in the middle of the plot which largely depends on resources available in the plots.

Comments and conclusions

■ The preliminary result indicated that in hedgerow intercropping, crop yield can be significantly improved by growing the trees at one corner and applying the mulch to the portion of land under cropping as compared to growing the hedges all over the plot. On a sloppy land where hedges are planted for the purpose of erosion control, the conventional arrangement of hedges may be more attractive. Placing the hedges at one corner of the plot may also eliminate the ground cover and weed control service function of the trees.

On the other hand, such arrangement minimizes tree crop competition, facilitates easy farming operations, allows flexibility on when to prune the trees during the crop growing period and releases more land for cropping.

■ Obviously the designs or hedge arrangements with hedges on the plot edges allow the trees to exploit nutrients from adjacent plots. Subject to availability of resources, placement of root barriers is necessary to evaluate the potentials of the various designs in the future.

■ Additional data aimed at assessing the impact of the various hedge arrangements on soil physical properties and weed density are also necessary before selecting a particular hedge arrangement.

EXPERIMENT 5

Objectives: In almost all agroforestry field experiments, biomass estimation is a common feature and involves separation of the various plant parts and weighing each component. The practice is tedious and time consuming. In forestry research, it is a common practice to use parameters such as diameter at breast height and tree height to predict yield.

The objective of the present study is therefore to develop a function or model that will allow biomass estimation using easily measurable parameters such as stem diameter, branch number and/or tree height under hedgerow intercropping management practice.

The tree species selected for the trial are C. calothyrsus, L. leucocephala, G. sepium and P. falcataria. Two experiments were initiated in Yaounde and Ebolowa in April 1990.

The trees were established in hedges and managed in a typical alley cropping management technique.

Pollarding of the trees and data collection started a year after establishment. Excluded were, L. leucocephala, G. sepium and P. falcataria grown in Ebolowa, due to the slow growth of the species.

Twenty plants/sp. where selected and plant height, stem diameter at 0.3 m above ground level were measured, initially at three months interval and later at the time of pruning and cropping. Biomass yield, separated into leaf and wood were determined at initial pollarding and at every pruning regime as required in hedgerow intercropping management practice. Branch number were also recorded at the same time.

Correlation between the various variable, their products and sums were examined. Those variables with significant correlation value were selected and used to develop and test regression models. Models with best fit (high percentage variation accounted for and significant t-value for coefficients) were selected for biomass yield prediction.

Results and discussion: All models selected for all the species grown at the two locations are reported in IRA/ICRAF, 1991 and 1992. The models developed in 1991 and 1992 for leaf biomass estimation of C. calothyrsus grown in Yaounde are presented in Table 26.

The models developed for the data collected on primary growth was rather complicated with several terms involved. The fit was observed to be the best for P. falcataria and L. leucocephala, the two species with fewer branches or are single stemmed at 0.30 m above ground level (IRA/ICRAF, 1991). Most of the C. calothyrsus and G. sepium plants are multi-stemmed from ground level and often these branches are of equal stem diameter, which made the determination of stem diameter and branch number extremely difficult, which seems to be responsible for the rather complicated model, and low percentage variance accounted for, for the models developed for the two species with a data from primary growth.

For the data of secondary growth obtained in 1992, the terms of the regression line (best fits) involved, primarily, sums of the independent variables (Table 26). The regression models with products were either not significant or the percentage variance accounted for was very low (IRA/ICRAF, 1991).

CONCLUSION

- Efficient models can be developed for biomass estimation. However, at early stage, it is necessary to develop and examine or test the models more often (at every pruning) as there seem to be variability with time.

- The authors would like to suggest that the exercise continue for two more years to observe any consistency which may lead to a single model/species, particularly for secondary growth, that can be used for biomass estimation at every pruning regime.

EXPERIMENT 6

Objectives: In a hedgerow intercropping system, trees are often cut back at a year after establishment, regardless of the condition of their vigour. This practice, particularly under on-farm conditions, has led to the poor establishment, die back and subsequent low biomass yield.

The IRA/ICRAF project thus initiated a trial to identify appropriate time of first pruning/pollarding to ensure optimum biomass yield at subsequent pruning.

Table 26. Regression models with significant t-values for estimated regression coefficients and highest percentage variance accounted for (% VAF) for prediction of leaf biomass yield of C. calothyrsus grown in Yaounde.

Year	Pruning regime	Regression model	% VAF
1991	1st pruning	$LB = 0.32 - 0.09\ NB + 0.015\ NB^2 + 0.115\ HTDM - 0.004 HTNB^2 - 0.046 HT^2 - 0.05 DM^2 + 0.005 HT^2 NB$	29.70
1992	1st pruning	$LB = -3.48 + 0.15 HT + 0.42 DM + 0.27 BN$	74.80
1992	2nd pruning	$LB = 3.85 + 0.007 HT + 0.008 DM + 0.15 BN$	65.20

LB = Leaf biomass yield
NB = Number of branches
HT = Plant height
DM = Stem diameter at 0.30 above ground level.

Materials and methods: The trial was initiated at the IRA research station in Ebolowa. Tree species included are C. calothyrsus, L. leucocephala, G. sepium and P. falcataria. The trees were planted at 4 m x 0.25 m spacing. The three treatments being compared are: (1) Pollarding at 12 months after planting, (2) Pollarding at 18 months after planting, and (3) Pollarding at 24 months after planting. Subsequent prunings are to be carried out at the frequency required in management of hedgerow intercropping systems.

The design of the experiment is split-plot in Balanced Incomplete Block. The tree species constituted main plot treatment while the pollarding time made up sub-plot treatments.

Results and discussion: Initial mean leaf (LB) and wood (WB) biomass are reported in Table 27.

Preliminary results showed significant main plot and interaction effects (linear) on biomass yield. C. calothyrsus yielded highest biomass at all pollarding times followed by P. falcataria, L. leucocephala and G. sepium in decreasing order.

The soil of the experimental plot is characterized by very low pH and poor fertility level (Table 28) which could be responsible for the overall low biomass production of L. leucocephala, G. sepium and P. falcataria.

Understandably, the biomass yield of the primary growth increased with increasing or delayed first time of pollarding, which is mainly due to the differential growing period. However, the trend in biomass yield of the regrowth, estimated in 1993, also appeared to be the same (Table 29). Except C. calothyrsus, the biomass yield of the other three species were below average or very poor. Leucaena and Gliricidia are the two unsuitable species for the region.

Table 27. Effect of first pollarding time on leaf (LB) and wood (WB) biomass yield of four multipurpose tree species.

Species	First Pollarding time						Species mean	
	12 MAP		16 MAP		24 MAP			
	LB	WB	LB	WB	LB	WB	LB	WB
	(t/ha)							
C. calothyrsus	3.90	14.71	6.06	23.44	9.38	34.20	6.45	24.12
G. sepium	0.57	1.81	1.56	4.69	2.42	5.62	1.52	4.04
L. leucocephala	1.75	1.86	2.63	2.87	3.24	5.70	2.54	3.48
P. falcataria	1.94	4.86	2.88	8.66	3.31	10.12	2.73	7.88

		LB	WB
S E D	Between species mean	0.20	0.56
	Between time for same spp.	0.35	0.83
	Between time for diff spp.	0.35	0.88

Table 28. Soil characteristics of first pollarding time experimental site

Soil characteristics	Soil depth (cm) 0 - 5	0 - 15	15 - 30	30 - 45
Organic matter (%)	7.39	4.25	2.97	3.73
Organic carbon (%)	4.29	2.72	1.92	1.27
Total nitrogen (%)	0.29	0.18	0.15	0.14
C/N ratio	14.52	13.15	11.46	9.07
Total P(ppm)	17.87	11.12	7.10	7.32
Ex. Al meg/100 g	1.28	2.23	3.14	3.15
C.E.C.	10.59	8.23	6.64	6.60
pH H_2O	4.46	4.37	4.35	4.37
pH kCl	3.58	3.51	3.59	3.56

Table 29. Effect of first pollarding time on leaf (LB) and wood (WB) biomass yield (t/ha) of four MPTS grown in Ebolowa, 1993.

Species	First Pollarding time 12 MAP		16 MAP		24 MAP		Species mean	
	LB	WB	LB	WB	LB	WB	LB	WB
				(t/ha)				
G. sepium	0.31	0.63	0.47	1.90	0.87	3.34	0.55	1.96
C. calothyrsus	2.13	9.99	3.20	23.38	3.53	26.67	2.95	20.01
P. falcataria	0.46	0.40	0.76	2.16	0.78	2.77	0.67	1.78
L. leucocephala	0.32	1.75	0.40	2.33	0.46	3.43	0.39	2.50

EXPERIMENT 7: ON-FARM HEDGEROW INTERCROPPING TRIAL

Background: When the IRA/ICRAF project started its field activities in Cameroon, the National Cereals Research and Extension Programme, sponsored by the USAID and implemented by IITA and IRA, was conducting an on-farm research through its Testing and Liaison Unit (TLU). The team consisted of Social Scientists and Systems Agronomists. The main focus of their field activity of testing the response of improved varieties of maize, developed by the project, to various fertilizer types and levels. Considering the fact that the team had qualified staff for on-farm research, long term experience in on-farm research and the objectives (to identify appropriate management technique for improved productivity of maize varieties) was in line with the mission of the IRA/ICRAF project, it was agreed that the two projects collaborate to develop a "low input" farming system for "improved and sustainable" productivity of the improved varieties of maize under farmers' condition.

The first joint on-farm hedgerow intercropping was thus initiated in May, 1988, in a village called Abondo, about 40 km from Yaounde. The village was selected by the TLU team for the fertilizer study.

The objectives of the study was to assess potentials of some MPTS in fertility improvement and to test the response of improved variety of maize to fertilizer + mulch application under hedgerow intercropping system under farm condition. It was also intended to monitor farmers response to the technology.

In 1998, eight volunteer farmers were selected and hedges of L. leucocephala, G. sepium and P. falcataria were established. The trees were planted at 4 m x 0.25 m spacing and the number of hedges were 4/species/farm. Following the poor establishment of P. falcataria, C. cajan was replaced later.

The length of the hedges varied from farm to farm (15 to 20 m) and each farm was considered as a block. Plot of each species was sub divided into three sub-plots of 16 m x 6 m to test three fertilizer levels: 0 kg/ha, 30 kg/ha and 60 kg/ha of N_2.

In 1989, only two farmers accepted to prepare their land for treatment application, the other six did not join for reasons such as sickness and shortage of labour/time.

In 1990, four new farmers joined the group, this brought the total number of farmers to 12. When the four new ones were busy establishing the hedges, five of the 8 old farms were cultivated and the treatments were applied accordingly.

In 1991, some farmers wanted to crop their farms during the first season while others wanted to do same during the second season and few others, particularly those with medical problems could not participate. Thus, only three farms were cropped and monitored.

Several meetings were held to get the farmers coordinated and convince them to agree on uniform participation (in terms of cropping season and type of crop to be cropped). However, through the periodic meeting, it became clear that, two factors:

a. Methodological approach (the on-farm group that worked with the farmers earlier attempted to reward some farmers who agreed to coordinate the other farmers by providing them with financial incentives without informing all the participating farmers);

b. Within village household disagreement on domestic issues

were responsible for lack of interest to work in harmony with one anothers. The Testing and Liaison Unit team thus decided to leave the village in favour of another village called Nkolfeb. Having invested substantial resources, the IRA/ICRAF project could not abandon the village as easy as the cereals group. Thus in 1992, another attempt was made to monitor the trials. Four of the 12 farmers agreed to prepare their land and carry out the cropping and testing of the various treatments. Unfortunately, due to the persistent strike by the workers of IRA, the farmers harvested their crop before data was collected. Currently, the project is attempting, for the third time, to re-organize the activity. At the last meeting held on June 4, 1993, ten farmers showed up and agreed to continue the trial.

Major observations and/or conclusions from the four years results are:

Agronomic:

1. P. falcataria was poorly adapted, when planted by direct seedling (IRA/ICRAF 1989).

2. C. cajan, and L. leucocephala produced higher biomass yield under on-farm condition, but overall biomass yield of all the species was lower than that observed under on-station condition (IRA/ICRAF 1989, 1990 and 1991).

3. Maize yield response was significantly lower with no mulch application compared to with mulch application (IRA/ICRAF 1989, 1990 and 1991).

4. Application of fertilizer + mulch significantly improved crop yield as compared to no fertilizer treatment but the difference between the effect of 30 kg/ha and 60 kg/ha N_2 application was not statistically significant.

5. One of the farmers confirmed that crop yield from the plots with hedges was significantly improved but added that he would not like to convert all his plots to hedgerow intercropping system as, according to him, the system is not suitable for tomatoes and groundnut cultivation. He thus thinks that it is the best mainly for maize production.

Methodological:

- Raising seedlings on-station to supply the farmers was a very expensive approach.

- To get full cooperation from the farmers for agroforestry research for soil fertility, where immediate benefit is not obvious in short term, some sort of incentive seems to be very essential.

■ Any incentive to individuals or groups should be known to every participant to eliminate mistrust and ensure sustained collaboration.

Based on the above observations and/or experience and also additional information obtained from on-station experiments, a second on-farm trial was initiated in 1991 in a village called Nkolfeb, about 40 km from Yaounde and 30 km from Abondo. Major methodological changes made include:

1. Provide the farmers with seeds and necessary materials to raise their seedlings in groups.

2. Through a popular vote, elect a village representative, who would coordinate day to day activities and liaise between the farmers and the researchers. Such representative whose term of office is for two years, to be compensated by the project for his time and transportation (currently he is paid by the NCRE project).

3. Select C. calothyrsus as a hedge species and C. cajan as short fallow species.

Objectives: To identify appropriate integrated hedgerow and improved fallow management system for optimum and sustained crop production.

Materials and methods: In 1991, eight farmers planted hedges of C. calothyrsus. In 1992 sixteen additional volunteers joined the group, received C. calothyrsus seed and polyethylene bags, raised seedlings and established the hedges during the second season of 1992. In Ebolowa, another group of five farmers established the hedges in 1991 while additional six farmers are currently nursing the seedlings.

The hedges are planted at 4 m x 25 cm. The number of hedges per farm and hedge length depended on farm size. The minimum number is three and minimum hedge length is 15 m. The specific treatments being compared are:

1. **Hedgerow + Cajanus fallow** where crops (maize and cassava) are grown between hedges during the first cropping season and, soon after maize is harvested, C. cajan is planted between the cassava rows during the second season (HR + IF).

2. **Hedgerow + natural fallow:** The treatment starts with maize and cassava intercropping during the first cropping season. Following maize harvest after 4 months, the plot is left with cassava monocrop during the second season with maize space being gradually invaded by natural vegetation (HR + NF).

3. **No hedge + natural fallow (control):** This is the traditional practice with the only modification being the number of food crops are restricted to two, maize and cassava (-HR-NF).

4. **No hedge + Cajanus:** This begins with the traditional practice (intercropping of maize and cassava) and following the harvesting of maize, C. cajan is planted between cassava plants (-HR + IF).

In effect, it is a comparison of four systems: hedgerow intercropping, improved fallow, integrated hedgerow/improved fallow system and a traditional system.

The average plot size (experimental unit) is 16 m x 10 m = 160 sqm. The design of the experiment is split-plot with the hedge and no hedge as main plot treatment and C. cajan and natural fallow as sub-plot treatments. Each farm represents a block or a replicate. In 1992, six of the eight farms were cropped and the results are reported below.

Results and discussion: The result of the initial soil analysis showed very high variability between farms (IRA/ICRAF, 1992).

The establishment of C. calothyrsus was excellent and the biomass yield was generally high. C. cajan, planted during the second season, in the C. cajan fallow treatment plots, could not compete with the cassava and did not survive.

The difference in maize and cassava yield response to the hedges and no hedge treatment was not statistically significant either (Table 30).

Table 30. Maize grain yield and cassava tuber yield response to the mulch of C. calothyrsus (1 year old hedge).

Treatment	Maize yield	Cassava yield
	(t/ha)	
Hedge + natural fallow	4.16	5.44
Hedge + C. cajan fallow	4.44	4.99
No hedge + Natural fallow	4.10	6.11
No hedge + C. cajan fallow	4.18	8.47

However, cassava tuber yield appears to be higher for plots without hedges as compared to the plots with hedges.

Comments, conclusions and/or suggestions

- The current result is preliminary and further monitoring is required before any conclusion could be made.

- The purpose of deciding to introduce or integrate short fallow species into hedgerow intercropping system was to improve biomass production -thus OM of the soil. Short fallow shrubs such as C. cajan are known to improve soil fertility. However, in humid lowlands, where several crops are grown at the same time on a relatively small plot of land, it is still posing a major problem of when and how to establish the shrub species. The present experience showed that the Cajanus could not compete with the cassava. This issue is addressed in detail under improved fallow section reported in subsequent paragraphs.

■ Encouraging the farmers to raise their seedlings significantly reduced the cost of running the on-farm experiment. In spite of the labour shortage, more farmers seem to be willing to invest to try the technology.

Unlike Leucaena and Gliricidia tried in Abondo, C. calothyrsus appears to be well adapted to the region and the establishment of the hedges on most of the farms is very good.

IMPROVED FALLOW TRIALS

EXPERIMENT 8: ON-STATION, YAOUNDE

Background: Early research on improved fallow focused on identifying efficient and cost effective method of establishing the shrub species. The method observed to be the best for successful establishment of the shrubs (sowing of the shrub seeds on a cleared and prepared plot) was also the most labour intensive. However, for the purpose of assessing the potential of the technology for soil fertility improvement, the method was adopted and the first improved fallow experiment aimed at evaluating the effect of the technology on crop yield and soil fertility was initiated in 1989.

Objective: To evaluate effect of a one-year, two years and three years fallow of six selected shrub legume species on soil properties and crop yield.

Materials and methods: The shrub species included were: (1) Cajanus cajan, (2) Crotalaria anagyriodes, (3) Desmodium distortum, (4) Desmodium discolour, (5) Pureria phasioloides and (6) Mucuna utilis. Natural fallow and the combination of species 1 to 4 made up the eight main plot treatments. Each main plot was divided to three sub-plots to test the effect of the one, two and three years fallow period.

The design was split-plot in RCB. Each treatment was replicated four times. The size of the main plot was 5 m x 12 m while that of the sub-plot treatment was 5 m x 4 m.

Results and discussion: Crop yield response to the one, two and three years fallow of the introduced shrubs is reported in Table 31.

The effect of the shrubs on crop yield was statistically significant ($P=0.05$) for the one and two years fallow cycle. Crop yield from the natural fallow was the lowest as compared to the yields from the fallow of the introduced shrubs. The difference between the mean yield response to the fallows of the introduced shrubs was not significant.

At year three, the crop response to the shrubs fallow was not statistically significant. The shrub included in the study were seasonal, annual or bi-annual types. After two years, most of the erect shrubs died and essentially there was no vegetative growth. The cover crops such as Mucuna and Pureria often colonized the adjacent plots and over the period of three years, seeds of the annual and/or bi-annual shrubs were dispersed and some of the shrubs established themselves in the natural fallow plots, which probably is responsible for the non significant effect observed for the three years fallow treatment.

ble 31. Effect of fallows of introduced shrubs on crop yield

Fallow species	1990		1991	1992
	1 year fallow		2 years fallow	3 years fallow
	Maize	Groundnut	Maize yield	Maize yield
	(t/ha)			
. *Cajanus cajan*	1.51	0.97	5.90	4.28
. *Crotalaria anagyriodes*	2.59	0.72	4.96	3.80
. *Desmodium discolour*	2.18	0.86	4.66	4.20
. *Desmodium distortum*	1.82	0.73	4.25	3.91
. *Mucuna utilis*	1.74	0.69	5.14	4.10
. *Pureria phasioloides*	1.85	0.59	5.31	4.18
7. 1 + 2 + 3 + 4	2.30	0.87	5.42	4.20
3. Natural fallow	1.26	0.57	3.35	3.78
S E D	0.085	0.046	0.31	0.22
C V%	5.78	8.64	9.00	7.60

Soil samples were collected from the two-year fallow treatment plots and were analyzed for soil chemical properties. Soil properties, significantly affected by the introduced shrubs are presented in Tables 32 and 33.

The effects of the shrubs on soil pH did not seem to follow a particular trend. With the introduction of the shrubs, total nitrogen and organic carbon level were significantly improved at 0 - 5 and 0 - 15 cm depth when compared to the level before the shrub introduction.

The soil properties also improved by the introduction of the shrubs as compared to the natural fallow. The difference between the properties before and after cropping was not very clear.

Comments, conclusions and suggestions

■ In short term, the introduction of the shrubs improved crop yield as compared to natural fallow.

■ The species studied have similar effect or may have different characteristics that might have evened out their effects..

■ Introduction of the shrubs significantly improved soil OC and total nitrogen at 0 - 15 cm depth.

- Methodologically:

  - comparing erect species along with cover crops on small plots caused interference of adjacent plots;

  - like in hedgerow intercropping, comparing several species without standardizing factors of interest is likely to mask the actual species effect.

As per the recommendation made in the annual report of 1992, this experiment was modified in 1993 as follows:

- The number of species reduced to two -C. cajan and Sesbania pachycarpa, to be compared against natural fallow.

- Fallow cycles to be limited only to one year.

EXPERIMENT 9: ON-STATION, EBOLOWA

Background: A trial was initiated at IRA research station in Ebolowa to assess the effect of various fallow cycles and cropping cycles, using C. cajan and D. distortum. However, a cover crop, Mimosa invisa, introduced to the station by the cocoa researchers, colonized the plots. The shrub is a nitrogen-fixing legume, and thus it was decided to include it in the trial, by replacing D. distortum, characterized by slow growth.

Table 32. Some soil (0 - 5 cm) properties as affected by two years fallow of selected legumes before (BP) and after (AP) cropping.

Legume species	Soil properties (0 - 5 cm)							
	pH 1:1 H_2O		TN_2* (%)		OM (%)		OC (%)	
	PB	AP	BP	AP	BP	AP	BP	AP
Initial soil property	5.20		0.16		-		1.84	
1. Cajanus cajan	5.51	5.15	0.23	0.27	4.44	4.65	2.85	3.18
2. Crotalaria anagyriodes	5.69	5.58	0.23	0.22	4.68	5.05	2.71	2.88
3. Desmodium discolour	5.95	5.21	0.20	0.21	4.42	5.08	2.56	2.69
4. Desmodium distortum	5.72	5.63	0.21	0.22	4.47	4.48	2.36	2.38
5. Mucuna utilis	5.39	5.11	0.22	0.24	4.51	5.03	2.47	2.94
6. Pureria phasioloides	5.62	5.60	0.23	0.23	4.54	5.05	2.64	2.88
7. 1 + 2 + 3 + 4	6.00	5.04	0.23	0.24	4.52	5.48	2.62	2.72
8. Natural fallow	5.22	4.85	0.18	0.20	3.67	4.37	2.21	2.23
S E D	0.18	NS	0.01	NS	NS	NS	0.14	0.21

ɔle 33. **Some soil (0 - 15 cm) properties as affected by two years fallow of selected legumes before (BP) and after (AF) cropping.**

egume species	Soil properties (0 - 15 cm)							
	pH 1:1 H_2O		TN_2 (%)		OM (%)		OC (%)	
	PB	AP	BP	AP	BP	AP	BP	AP
itial soil property	5.75		0.17		-		1.74	
Cajanus cajan	5.84	5.95	0.23	0.27	4.46	4.75	2.59	2.77
Crotalaria anagyriodes	5.67	5.91	0.23	0.22	4.18	4.47	2.43	2.77
Desmodium discolour	5.84	5.65	0.20	0.21	4.13	4.40	2.39	2.49
. Desmodium distortum	6.09	6.09	0.21	0.22	3.98	3.97	2.36	2.29
. Mucuna utilis	5.45	5.42	0.22	0.24	4.35	4.82	2.53	2.66
. Pureria phasioloides	5.77	5.67	0.23	0.23	4.02	4.40	2.34	2.55
. 1 + 2 + 3 + 4	5.91	5.53	0.23	0.24	4.00	4.50	2.32	2.62
. Natural fallow	5.26	5.01	0.18	0.20	3.37	4.05	2.02	2.11
S E D	0.33	NS	0.01	NS	0.28	0.18	0.14	0.18

)bjectives: The aim of the trial was to identify appropriate combination of fallow cycle and ropping regime for optimum and sustainable crop production using selected shrubs.

Materials and methods: Initially, the species included were C. cajan and D. distortum. Following the poor performance of D. distortum, M. invisa was replaced at a year and a half after the initiation of the experiment. The fallow cycles compared were one, two and three seasons fallow which was later modified to one and two seasons fallow. The various fallow cycles were to be followed by three cropping regimes: one, two and three seasons cropping. The plot size (experimental unit) was 5 m x 6 m and each treatment was replicated four times.

Results and discussion: Crop yield response to the one season fallow (1990 result) of C. cajan and D. distortum is reported in Table 34. The effect was not statistically significant and higher yield (not significantly different) was actually recorded for the control (natural fallow) plot. The natural fallow plot was highly infested by the M. invisa which is a nitrogen fixing legume which could be responsible for the high yield for the control plot.

Following the replacement of D. distortum by M. invisa, the trial was cropped twice, second season of 1991 and first season of 1992. Maize yield recorded for the one year fallow treatment (1991) and the two-season fallow (1992) are reported also in Table 34. When cropping the two-season fallow treatment, the one season fallow treatments to be followed by two and three seasons cropping treatment plots were also planted with maize and thus the yields were compared to that of the two seasons fallow treatments.

Crop yield was generally low for both years and it was the lowest for the two seasons fallow cropped in 1992.

Maize yield of the second cropping treatment after one season fallow was lower than that from first cropping treatment after two seasons fallow by about 50%.

The effect of the two shrubs were comparable and better than natural fallow, but their growth rate as well as the level of crop yield improvement was very low.

During the second season of 1992, an attempt was made to re-establish the shrubs and crop (maize) in various plots as per the treatments. However, both the shrubs and the maize could not pick up. The growth of the shrubs, particularly that of C. cajanus, was stunted while the colour of the maize plants turned yellowish with curled leaves and very poor growth. Some plants were up- rooted and the roots were examined. Except the non normal development of the roots (shallow distribution and very low biomass compared to a healthy plant) no obvious external symptom was observed. Plant and soil samples from the spots where the maize growth appeared to be the best and/or the poorest were collected and submitted for analysis.

Table 34. Effect of one and two seasons fallow of C. cajan, D. distortum, M. invisa and natural fallow, followed by one, two and three seasons cropping on maize grain yield.

Fallow species	Fallow cycles (seasons)	Cropping cycles (seasons)	Maize Yield in t/ha		
			1990	1991	1992
C. cajan	1	1	2.05	1.31	-
		2	-	1.28	0.52
		3	-	1.48	0.48
	2	1	-	-	1.26
		2	-	-	1.25
		3	-	-	1.26
D. distortum	1	1	1.81		
		2	-	-	-
		3	-	-	-
	2	1	-	-	-
		2	-	-	-
		3	-	-	-
M. invisa	1	1	-	2.26	-
		2	-	2.08	0.53
		3	-	2.03	0.57
	2	1	-	-	0.88
		2	-	-	1.17
		3	-	-	1.32
Natural fallow	1	1	2.38	0.84	-
		2	-	0.87	0.28
		3	-	0.99	0.21
	2	1	-	-	0.59
		2	-	-	0.43
		3	-	-	0.42
S E D			0.23^{NS}	0.15	0.05

'he result of both the initial soil analysis (Table 35) and the analysis after three years of ropping (Table 36) showed a very low pH level and high aluminum saturation which is uspected to be the cause for the poor performance of both the shrubs and the crops.

Comments and conclusions/suggestions

■ While the introduction of the shrubs appears to enhance crop yield at early stage, it does not seem to ensure sustainability even for a period as short as three years on the soils of the region.

■ The soils are very acid, where, after three croppings, even the legume shrubs such as C. cajan could not grow again. Two hedgerow trials were initiated in 1990 using tree species such as L. leucocephala, G. sepium, P. falcataria and C. calothyrsus. So far, it is only C. calothyrsus that showed a fairly normal growth. The performance of G. sepium and L. leucocephala was the poorest, further strengthening the theory of soil acidity being a major problem.

■ The result of the soil analysis also indicated aluminium toxicity as probably the major production constraint.

■ The location is thus very challenging and is probably where agroforestry technology is highly needed to address constraints associated with the land use systems of the area.

■ Due to logistic problems, the IRA/ICRAF project could not fully expand its activities in this area, although acknowledges that there is the need for it.

■ The authors thus propose that:

(a) To insure full operation, ICRAF or IRA consider placing a full time resident senior scientist at Ebolowa.

(b) Accordingly, allocate special operational budget for the station.

(c) Consider stronger collaboration with IITA's HFS for activities to be carried out at the site.

Priority research topics could be:

(a) Large scale liming study;

(b) Screening of multipurpose tree species/provenances;

(c) Testing crop residues, animal manure and/or tree/shrub mulch to improve OM level and neutralize acidity;

(d) Identification of acid tolerant local rhizobium and or mychorriza for inoculation study with a view to improve tree establishment etc.

Table 35. Initial soil characteristics of improved fallow trial, Ebolowa.

Soil Characteristics	Soil Depth (cm) 0- 5	0-15	15-30	30-40	40-50
Gravel (> 2mm) %	0.73	0.63	0.41	0.37	0.64
Soil moisture %	10.05	9.45	10.90	12.60	10.00
Clay content %	47.00	49.30	51.52	53.20	57.22
Silt content %	11.45	11.74	11.47	12.15	10.45
Sand content %	38.17	37.87	34.62	33.05	30.00
Total organic matter %	4.85	3.20	2.33	2.42	1.79
Organic carbon %	2.81	1.86	1.35	1.41	1.04
Total nitrogen %	0.19	0.14	0.12	0.11	0.14
C/N ratio	14.85	13.00	12.52	12.30	10.97
Total P_2O_5 %	16.02	11.62	7.77	7.22	5.67
Extractable Al	2.08	2.78	3.00	3.17	3.13
CEC	9.20	8.60	7.39	7.65	7.96
PH:H_2O	4.27	4.37	4.32	4.38	4.48
PH:KCl.	3.48	3.58	3.63	3.67	3.72

Table 36. Soil chemical properties of improved fallow trial site at Nkoemvone, Ebolowa (after three croppings).

Sampling site	Depth (cm)	Soils properties pH H_2O	pH Kcl	P Bray-1	EC ms.cm	Ca ------(cm01(+)/kg------	Mg	K	A
Good growth	0 - 15	4.49	4.12	<1mg/kg	95.1	1.33	0.36	0.14	2.15
	15 - 30	4.58	4.19	"	75.8	0.79	0.24	0.09	2.48
Poor growth	0 - 15	4.50	4.06	"	57.2	0.46	0.13	0.16	3.05
	15 - 30	4.56	4.11	"	33.7	0.11	0.11	0.06	3.22

Currently, an IITA/University of Reading project, initially designated to be carried out at Mbalmayo, is being considered to be moved to this site to address the topic "C" above. Meanwhile, the IRA/ICRAF project is proposing one experiment to be initiated in 1994 (see appendix 9).

:XPERIMENT 10

:ackground: In traditional farming practice, land preparation begins by slashing the egetation and burning the cut vegetation before ploughing the land. The main reason for urning, according to those who practice, is to get the land free of all the debris. The armers do also know that crops planted immediately after burning the slashed vegetation often gives high yield. Several research results however have proved that although initial ncrease in crop yield planted after burning the vegetation is evident, long term effect of burning on subsequent crop yield and soil properties is deleterious.

The potential of improved fallow depends on how efficiently the biomass of the introduced shrubs is used. A trial was thus initiated in 1990 to address this issue.

Objectives: To identify appropriate residue management in improved fallow practice.

Materials and methods: A trial was initiated in 1990 to compare the effect of four residue management techniques on crop yield and soil properties. The techniques compared include: Burning of the biomass of the fallow shrubs (T1), Surface application of the biomass (mulching) (T2), Incorporating of the biomass (T3) and Removal of the biomass (T4). The species selected for the trial was C. cajan.

The design of the experiment was Randomized Complete Block, with each treatment replicated four times. Plot size (Experimental unit) was 8 m x 8 m.

Maize and groundnut was used as test crops. The shrub was established during the second season of 1990. During the first season of 1991, the shrub was harvested, the treatments were applied and maize and groundnut were cropped. C. cajan was replanted at the beginning of the second season of the same year and the second cropping was done during the first season of 1992. The shrub was re-established the third time at the beginning of the second season of 1992 but burnt down by the striking workers before the third cropping could be repeated during the 1993 cropping season.

Decomposition rate of the above ground biomass was monitored over a period of 5 months. Soil samples were collected from each treatment plot just before shrub harvesting, after implementing the various residue managements and at crop harvest at 0 - 5 cm and 5 - 10 cm depth from the four treated plots and forest land. The samples were analyzed for soil organic matter fraction per floating, fine, light, remaining and lost dry weights. The organic matter fraction, as affected by the treatments, are reported under results and discussion below.

Results and discussion: Maize and groundnut yield as affected by the various residue management techniques are reported in Table 37. For the two consecutive cropping years, the highest maize yield was recorded for plots where the residue was incorporated while groundnut yield was the highest for the burning treatment. The yield of the two crops was the lowest with the removal of the residue.

The difference in response of the yield performance of the two crops to the different residue management techniques indicates that, there may not be one single method suitable for the several crops the farmers intercrop at the same time on the same plot.

The rate of the decomposition of the C. cajan plant tissue monitored over a period of five months (13 March to 19 August) is reported in Table 38. Contrary to expectation, the decomposition of the woody component was observed to be better than the leafy component. At five months after placement of the samples, 33% of the leaves decomposed while percentage of the stem that decomposed was 50%.

Organic matter fractions per various dry weights for samples collected from the residue removed, burnt, mulched and incorporated treatments were compared to that of samples from secondary forest and the result is reported in Table 39.

Organic matter fractions per floating and fine dry weights were significantly affected by the various treatments while the fractions per light and lost dry weights were not. The OM fraction per floating dry weight was the highest for samples from forest soil and the lowest for samples from plots with the residue management treatments excluding the control plot. Comparison between the effect of the four management techniques showed the highest OM fraction per floating dry weight for samples from control plot.

Analysis of the effect of the treatments on the OM fraction per fine dry weights (significant at P=0.05) showed the opposite trend compared to what was observed for the per floating dry weights. The highest OM fractions were recorded for samples from incorporating, burning, samples from forest soil and mulching in decreasing order.

The comparison of the OM fractions to the crop yield showed negative correlation for the fractions per floating dry weights and positive correlation for the fractions per fine dry weights which suggests that it is the OM fraction per the fine dry weight that has an influence on crop performance. As stated earlier, OM fraction per the fine dry weight increased with the burning and incorporating treatments, to which the maize and groundnut yield response were also the highest.

Table 37. Maize and groundnut grain yield as affected by residue management techniques.

Residue management	Crop yield in t/ha			
	1991		1992	
	Maize	Groundnut	Maize	Groundnut
Residue burnt	1.40	0.98	2.67	0.93
Residue mulched	1.70	0.35	3.00	0.86
Residue incorporated	2.30	0.55	3.34	0.70
Residue removed	1.20	0.20	2.00	0.55
S E D	0.10	0.03	0.16	0.03
C V%	17.00	11.00	8.50	6.10

Table 38. Decomposition rate of <u>Cajanus</u> <u>cajan</u> plant parts as affected by decomposition time (initial fresh weight of plant part used = 200 gm; data collected from March 13 to August 19, 1992).

Day after placement	Dry weight of plant tissues		
	Leaves	Stems	Mean
0	72.07	93.27	82.67
1	71.30	89.53	80.42
12	67.57	74.60	71.08
21	64.60	71.60	67.92
33	63.47	67.30	65.39
47	61.73	66.60	64.17
75	60.40	58.46	59.43
103	59.60	54.53	57.07
130	51.33	48.60	49.97
158	48.30	46.83	47.57
Mean	62.04	67.10	

SED = (1) Plant tissue = 0.75
(2) Days after placement = 1.68
(3) 1 x 2 = 2.38

% Decomposed
over the period of 158 days: Leaf = 33%, Stem = 50%

Table 39. Effect of Residue management on soil organic matter fraction per floating (A) light (B), fine (C) lost (D) and remaining dry weights (Samples taken from 0 - 5 cm depth at treatment application during the first cropping phase).

Residue management	Organic matter fraction			
	A	B	C	D
Residue removed	0.25	0.21	0.42	31.2
Residue burnt	0.17	0.30	1.16	30.1
Residue surface applied	0.18	0.25	0.74	35.1
Residue incorporated	0.19	0.42	1.75	34.7
Sample from forest soil	1.58	0.38	0.79	32.6
S E D	0.056*	0.087^{NS}	0.31*	4.83^{NS}
C V%	16.70	39.40	45.20	20.90

* = Significant at P:0.01
NS = Not significant at P:0.05

Comments and conclusions/suggestions: In humid lowlands of Cameroon, burning of slashed vegetation is a standard activity in land preparation. Several authors have enumerated the long and short term negative aspect of the practice and several research efforts are still in progress to be more implicit in under-standing the impact. The fact however is, the farmers are practising it still and with the rudimentary farming tools available to them and the ever worsening labour shortage problem, they are very likely to live with it for a long time to come.

Be it improved fallow or hedgerow intercropping, the practice has a very significant implication on the introduction of any agroforestry technology aimed at improving soil fertility.

In which ever season the farmer decides to cultivate a land, he has a maximum of two months (for the first season) and less than one month (for the second season), for land preparation. The biomass of the introduced shrubs should therefore be disposed off within these time limits. The decomposition study for Cajanus cajan showed that by two months and a half, only about 32% of the above ground biomass of C. cajan decomposed. Since the primary objective of the farmer is to get his plot clean of any residues, the only options available to him are burning or removing the slashed vegetation. The second scenario being not practical, he is likely to opt for the burning.

The current study showed that the way the residues are managed and the various particle sizes do significantly influence the OM fractions of the soil with its attendant consequences on crop yield.

The result also showed the difference in response of different crops to different residue management practices and strong relationship between OM fractions in various residue particles which in turn responded differently to different management techniques. It is thus necessary to understand this rather intricate yet important relationships between residue management and soil properties influencing crop production and its implications on production of different crops. The specific research domains could thus be:

- Identify compatible crops, that may have similar response to a particular residue management technique;

- Determine both long and short term impact of the various residue management techniques on both soil physical and chemical properties, as it affects productivity of various crops;

- Assess the social and economic implications of the various residue management techniques and their potential adoption;

- Assess short and long term effect of different intensities of burning of slashed vegetation (currently used by the farmers) on crop yield and soil properties (IITA scientists are addressing part of this subject);

- Screen species and rank for plant biomass decomposition rate and nutrient release;

- Identify type and frequency of nutrient requirement of the common crops in the region with a view to selecting shrub species with appropriate biomass decomposition rate and nutrient release for intercropping or relay cropping.

■ Quantify and/or identify artificial or biological technique to influence (hasten and slow) biomass decomposition rate of selected shrubs with a view to synchronizing nutrient release from residues and nutrient up-take by the crops.

General comments and suggestions on improved fallow

Current studies on improved fallow, both in humid lowlands of Cameroon and the Southern Africa AFRENA, has demonstrated the potential of the technology in improving soil fertility and crop yield. The issue of adoptability of the technology is however far from being resolved.

Where perennial shrubs like Sesbania are raised in the nurseries, transplanted and tended until it was ready to use the biomass, the high establishment cost involved is still a major constraint to the adoption of the technology.

In humid lowlands, where annual or bi-annual shrubs are used, how and when to integrate the technology into the existing practice is a major constraints to its potential for adoption.

When justifying the positive role of agroforestry in soil fertility improvement, two words frequently appear "improve/ ameliorate" and "sustain". Whether it is possible to achieve these or not, two cases become critical regarding where the technology should be first introduced.

1. On degraded land for fertility amelioration and if possible sustainable productivity;

2. On a land relatively fertile to ensure sustainable production or maintenance of soil fertility.

Considering case "1", it is obvious that the shrubs also require some degree of soil fertility for initial establishment. Moreover, it is not certain that the farmers are willing to work on the land they have just decided to let it fallow. The research priority for this situation could thus be:

(a) Screen shrub species adaptable to degraded or poor fertility situation (is there any?).

(b) Conduct "fertilizer test" to ensure establishment of potentially useful shrub species (is it economically viable?).

(c) Identify compatible shrub/crop combination (legume and non legume, use of inoculum) for intercropping with a view to ensuring cost effective and successful establishment of the shrub species on degraded land.

(d) Study the social and economic implication of promoting the technology for the purpose of ameliorating degraded land.

Referring to case "2", establishing the shrubs, in terms of soil fertility requirement may not be a major problem. On a newly cleared land, the farmers plant over seven different types of crops of different growth cycles in a non defined orientation. This is a factor that is likely to affect the shrub establishment.

The IRA/ICRAF project conducted several short term trials both on-station and on-farm to successfully establish the shrubs during the cropping phase without altering the farmers cropping pattern or crop components. At one point, attempts were even made to prune cassava (which is not a typical farmers practice) to ensure early establishment of the introduced shrubs such as C. cajan. None of the methods tried seems to ensure establishing the shrubs without altering the existing cropping practice.

If the system is intended to maintain the fertility of an already productive land, then establishing the shrubs during the cropping phase becomes necessary. Therefore the following topics could be considered in future research efforts.

(a) Assess the social and economic cost to the farmers and the farmers response to possible altering of their traditional cropping practice with a view to facilitating establishment of the shrubs at cropping phase.

(b) Assess the effect of different combinations and different densities of crops on shrub establishment with a view to identifying appropriate shrub/crop combination that ensures cost effective and adoptable shrub establishment.

(d) Screen shrub species and/or provenance for shade tolerance.

(e) Continue with the screening of shrubs with potential for soil fertility under relay cropping.

SCATTERED TREES ON FARMS

EXPERIMENT 11. COCOA BASE CROPPING SYSTEM

Background: At the end of the early planning phase of the IRA/ICRAF project, it was decided that the cocoa research unit of IRA takes the responsibility of developing agroforestry technology for the cocoa based cropping system. Should the unit fail to do so during the first five years, it was recommended that the project considers addressing the issue. The first cocoa cropping system based trial was thus initiated in 1992.

Objectives: During the D & D exercise, the major constraint identified was declining productivity of cocoa owing to poor soil fertility, poor shade quality, labour shortage, lack of capital for high energy input and pest and disease.

Over the last five years however, the situation has changed. At present, the major problem is rather the declining market for the cocoa beans. Most farmers have been forced to abandon their cocoa farms in favour of increased involvement in food crop production for cash income.

The objectives of the current trial is therefore, first to identify appropriate cocoa spacing that would allow intercropping of food crops with a view to diversifying the production base of the system. After five years, the trial will be modified to test effect of selected legume tree species on soil fertility and cocoa yield as soil ameliorating agent as well as providing shade for the cocoa trees.

The cocoa spacing being compared are: (1) 3 m x 3 m (control); (2) 4 m x 4 m; (3) 5 m x 5 m. Crops to be intercropped are; (1) Maize + cassava + plantain + natural fallow; (2) Maize + cassava + plantain + Cajanus fallow and (3) Cocoa mono crop.

The design of the experiment is split plot, with the cocoa spacing as main plot and intercropping as sub-plot treatments. Each treatment was replicated three times. The fourth replicate is planned to be added in 1993.

Traditionally, cocoa is planted under retained natural trees with the aim to provide shade for the seedlings.

However, the current trial being designated to evaluate effect of planting density (shade effect), the trees on the experimental plot were deliberately cleared at establishment.

The cocoa was established in August 1992. Due to the short rainy season (Sept-Nov), and absence of shade trees on the farm, large proportion of the cocoa seedlings died during the long dry period. Currently, the dead seedlings are being replaced.

PART III. HUMAN RESOURCES DEVELOPMENT

INTRODUCTION

One of the IRA/ICRAF objectives was to institutionalize agroforestry research within the national research set up. The strategy adopted to achieve this objective was to (a) assist the national programme in upgrading its infrastructure for the use of agroforestry research; (b) promote inter-institutional collaboration as multidisciplinary approach is a prerequisite for agroforestry research; (c) upgrade the skill of national scientists in agroforestry research and (d) train young national scientists in agroforestry research.

Unless it was proved impossible, the project strongly emphasized the need to utilize existing resources, thus ensuring the commitment of the national programme towards building a viable agroforestry research unit. In this respect, the entire project staff would like to extend their sincere thanks and appreciation to the management of the entire Ministry in general and that of IRA in particular for ensuring that our requests were adequately met when and where possible.

The major activities carried out and achievements made are reported below.

ACTIVITIES

The human resources development was implemented at various categories. These include:

1. Insuring that national scientists, directly hired by the national institute, were attached to the project on full time basis and participate in planning and implementation of the project activities;

2. Organizing group training on different aspects of agroforestry research principles and methods locally or sponsoring national scientists to attend such meetings organized at ICRAF HQ or elsewhere;

3. Providing necessary research facilities and supervising special projects of graduate and postgraduate students in agroforestry research;

4. Provide consultancy service to NGO's, farmers' groups, national institutions and international organizations involved in agroforestry research and development.

Achievements: (See Table 40).

Table 40: Statistics of the IRA/ICRAF training output (1986-1992).

Category	Years/sessions							
	1986	1987	1988	1989	1990	1991	1992	TOTAL*
In service training	7	1	1	3	3	3	3	7
Group training	-	-	-	25	1	1	44	71
Vacation Res. Scholars	-	3	3	5	2	3	3	19
Research scholars	-	-	-	2	-	1	1	3
Research fellow	-	-	-	1	-	-	1	1

* Refers to individuals and for some groups is not necessarily the sum of number indicted for various years which varied according to the duration of the different training activities.

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APPENDIX 2

Scientists who joined in discussions with the
review team during their visit

Name	Organization	Position
Mapongmetsem P. M.	University of Yaoundé	Student
Jacob M. Ngeye	IRA/CNRCIP, Nkolbisson	Breeder Root crops Research
Kouonmenioc	IRZV - Nkolbisson	Agro-zoologist
Fondoun J. Marie	IRA/Plant Genetic Resources	Currator
Gwangwa Anthony	IRA/NCRE (TLU)	Technician
Ngeh C. Pauliaus	FMRP (Mbalmayo)	Research
Kaho François	IRA/NCRE, Yaoundé	Agronomist
Kalto-Same	CRA/IRA	Soil Scientist
Stan Claasen	IITA	Farm Manager, Mbalmayo
Stephan Hauser	IITA	Soil Physicist
Stephan Weise	IITA	Weed Scientist
Jacqueline Henrot	IITA	Soil Biologist
Graham Mclaren	ODA	Biometrician

APPENDIX 3

INTERNAL INTERPROGRAMME REVIEW OF ICRAF/IRA PROJECT, CAMEROON JUNE 13-20TH 1993 EXPERIMENTAL CHECK LIST

- Trial Title and Number..
- Date Start..................................... Date Completion.......................
- Trial Objective..

- For on farm research what is rational
  - (a) Lack of land on-station
  - (b) Need to obtain farmers reaction/constraints
  - (c) Need to sample wider biophysical environment
  - (d) Other
- Falls within objectives of which ICRAF Project.....................................
- Does trial meet major IRA/ICRAF project objective/priority Yes/No
- Major findings of trial

- Has all data collected been analysed. If so, timetable for reporting.

- Are trial design and management satisfactory? If not what are principle concerns.

- If design faults exist, should a re-designed trial be initiated. Yes/No

- Should trial be continued? Yes/No
  If yes (1) should management be modified (2) How long should trial continue?

- Are all current measurements necessary. Yes/No
  If No to above, which should be discontinued

- **Should additional measurements be made within trial. If so, what?**

- **What are existing/potential/desirable links with other ICRAF Projects, and what activity should be involved.**

  Activity

  Project...
  Project...
  Project...
  Project...
  Project...

- **Are the various components and management requirements of technology compatible with farmers needs and constraints?** **Yes/No**

  If no, what are likely constraints to adoption

  1. **4.**

  2. **5.**

  3.

- **Implication of above for trial design and/or modification, or new trial.**