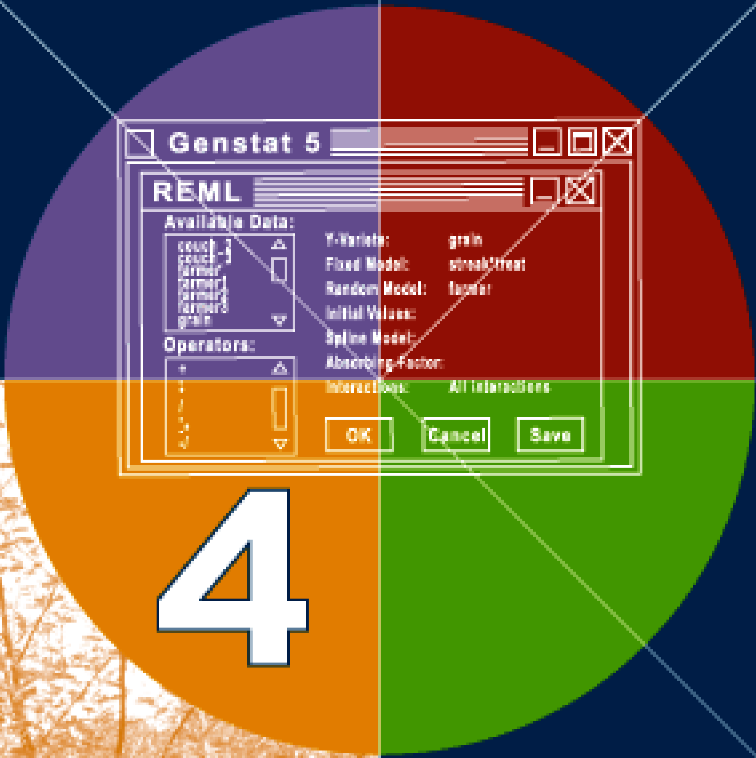
Data analysis of agroforestry experiments



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Experiments portfolio

World Agroforestry Centre

TRANSFORMING LIVES AND LANDSCAPES

Data analysis of agroforestry experiments

4

Experiments portfolio

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The World Agroforestry Centre (ICRAF) is the international leader in Agroforestry – the science and practice of integrating 'working trees' on smallholder farms and in rural landscapes. Agroforestry is an effective and innovative means to reduce poverty, create food security, and improve the environment. The Centre and its many partners provide improved, high quality tree seeds and seedlings, and the knowledge needed to use them effectively. We combine excellence in scientific research and development to address poverty, hunger and environmental needs through collaborative programs and partnerships that transform lives and landscapes, both locally and globally.

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Protocols and datasets

Introduction

Following are brief protocols for each of the examples referred to in the training course notes and practicals. Each protocol refers to the Excel data file that contains the data . The Excel data files are included on the CD.

The protocols have been provided solely for the purpose of describing the data, so that a sensible statistical analysis can be done. They are not a complete record of the trial, and only describe the details that are needed for the analysis of the data provided.

The data files have been provided to give realistic examples for use in training. They are not complete sets of data from the trials. In a few cases some details may have been altered in order to make a training point. Therefore the results of the analysis should be used to understand statistical methods, but not to reach conclusions about agroforestry practices.

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Protocols and datasets

Relay planting of *Sesbania sesban* and maize

Data file name

Relay planting.xls

Trial Location

Makoka, Malawi

Principal investigator

Prof. J. Maghembe, ICRAF-Malawi

Starting date

12/1988

Justification

Two *Sesbania sesban* provenances, *S. sesban* (ex Jamhuri, Ngong, Kenya) and *S. sesban* (ex Kakamega, Kenya) grow fast and have shown high biomass production in the unimodal upland plateau ecozone of Southern Africa. In the first year of growth, these *Sesbania sesban* provenances have attained 4 m in height in a 3-4 month time period, and showed remarkable production of phytomass in the same period, of 4-3 $tonha^{-1}$, dry weight. In addition, they are highly nodulated by local Rhizobia strains and they can easily be grown from nursery seedlings and by direct seeding. These characteristics of *S. sesban* make them ideal candidates for use in the improvement of infertile soils.

Within the Southern Africa Miombo ecozone, *S. sesban* has been used to enhance soil fertility in improved fallows, and alley cropping at Chipata and Chalimbana in Zambia. Initial results from these experiments are presented in the 1989 progress reports for Chipata and Chalimbana (Kwesiga, 1989; Kamara, 1989). In general, the prospect of developing viable technologies for improving soil conditions using these benefits will depend on existing land use constraints and the biology of the trees.

The small land holdings, 0.1 - 0.2 ha/family (Minae and Msuku, 1988), in the Shire highlands and the Lilongwe land use systems in Malawi, preclude the wide use of fallows. The small farm sizes also limit the utilization of agroforestry technologies in which trees occupy a substantial portion of the land.

We propose to test an agroforestry arrangement, which strives to maintain the recommended population of maize plants/ha while utilizing the soil improving capability of the sesbanias.

Objectives

1. Determine the soil improving potential of *S. sesban* grown in relay with maize and left to occupy the field for the dry season after maize harvesting.
2. Determine how the yield of maize is modified by relay planting with *S. sesban.*
3. Determine a good time for planting *S. sesban* in relay with maize.
4. Determine the interaction between *Sesbania* and fertilizer applied to the maize.

Treatments

Two factors will be used in a 4 x 3 factorial design. The factors constitute the following treatments:

1. Four *Sesbania sesban* planting times;
   - at maize sowing, P1,
   - at the period of rapid maize stem elongation, i.e. at node formation, P2,
   - during tasselling of maize, P3,
   - at maize growth maturity, P4.

2. Three N and P fertilizer levels;
   - no fertilizer applied, F0,
   - 50% of the recommended dose of Nitrogen and Phosphorus fertilizer, F50,
   - 100% of the recommended dose of Nitrogen and Phosphorus fertilizer, F100.

In addition there will be three control treatments of the maize without trees but with each of the three fertilizer levels.

A total of 15 treatments.

Replicates

Three or six. The original design included a third factor (*Sesbania* provenance) which has now been dropped.

Field layout

There were 27 plots in each of three blocks. The blocks coincided with bench terraces. Blocks 1 and 2 had all 27 plots laid out in a single line, the position indicated in the data file. In Block 3 the plots were arranged in two lines with a break between them; the positions again indicated in the data file.

Measurements

Many tree and crop growth and soil variables were measured for a number of seasons. Here just maize grain yield for one 'typical' season in which the rainfall was good is presented.

Field Layout:

Distance from left-hand side	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Terrace Boundary																																
Rep 1 (Terrace)		P4 F50	P4 F0	P3 F50	Control F100	P4 F100	P3 F0	P2 F0	P4 F50	P4 F0	Control F0	P3 F100	P3 F100	P2 F50	P1 F50	P2 F100	P4 F100	P2 F50	P2 F0	P1 F100	P1 F0	P2 F100	P1 F0	P1 F50	Control F50	P3 F0						
Rep 2				P3 F100	P2 F50	P2 F50	P2 F0	P4 F50	P3 F50	P4 F0	P1 F0	P2 F100	P1 F100	P3 F50	P4 F100	P3 F100	P3 F0	P1 F100	P2 F0	P1 F50	P4 F0	P1 F0	P4 F100	Control F50	P3 F0	P2 F100	P4 F50	Control F100	P1 F50	Control F0		
Rep 3															P2 F100	P1 F50	P3 F50	P4 F50	P3 F0	P1 F0	P2 F0	P4 F0	P1 F0	P2 F50	Control F100	P3 F100	P1 F100	P1 F100	P4 F50	P3 F50	P4 F0	P3 F100
	Control F50	P1 F50	P2 F50	P2 F0	P4 F100	P3 F0	Control F0	P2 F100	P4 F100																							

***Sesbania* Planting time:** P1 = maize sowing, P2 = node formation, P3 = tasselling, P4 = maize maturity, Control = no *Sesbania*

Fertilizer (% of recommended): F0 = No fertilizer, F50 = 50% of recommended, F100 = 100% of recommended

Effect of *Tithonia diversifolia* and *Lantana camara* mulches on crop yields in farmers fields

Data file name

Onfarm tithonia and lantana mulches.xls

Location

West and Central Bunyore, Vihiga District, Kenya

Start Date

01/09/95

Justification

Traditional hedges in internal and external boundaries for demarcation, protection and production functions constitute one of the most popular agroforestry practices found in most land use systems in the Eastern and Central Africa highlands (Hoekstra, 1988). Those hedges comprised generally *Lantana camara*, *Tithonia diversifolia* and other species and produce a large quantity of biomass, which is not fully utilized. Results from trials established in September 1994, comparing the effect of 6 different mulch species from existing hedges on maize fields have shown very promising results with *Lantana camara* and *Tithonia diversifolia*. These results were confirmed with another trial established in March 1995. Yield of maize is increased considerably if 5 t ha^{-1} of *Lantana* or *Tithonia* are applied. It is therefore important to find out how these two mulch species perform on farmers' fields and under farmers' management conditions.

Objectives

The overall objective of this trial is to find out if the good results obtained on-station with *T. diversifolia* and *L. camara* will be confirmed in farmers' fields and conditions.

In order to do this we need to:

1. Determine the effect of *Tithonia* and *Lantana* mulch on maize yield.
2. Investigate any problems associated with biomass transfer technology.
3. Measure the effect of different management practices, disease and weed problems on the performance of the mulches.
4. Assess the farmers views, opinions on the process, on implementing the technology and the effect of mulch application on crops, weed etc.

Treatments

It was proposed that each farmer could have two or three treatments replicated once, with control (farmers usual practice) being one of the treatments in each farm. The other treatments comprise of:

+ *T. diversifolia*

+ *L. camara*

Each farmer was allowed to apply any quantity of the mulches, provided (s)he records the quantity applied and tries to use the same amount of both *Lantana* and *Tithonia.* It was recommended to use 100 kg per plot.

If a farmer uses animal manure, he was asked to use the same amount in all the treatments. Mulches can be applied before sowing or on existing crop, and the following application methods could be used:

- Spreading all over the plot.
- Point placement.
- Any other, provided the farmer states the method used.

Farmer selection

Collaborating farmers are those who have shown interest during field visits organized in Ebukanga and Ochinga. Meeting of farmers and researchers were organized. During the meeting, the researchers discussed with the farmers the proposed research and questions arising about species, treatments, research protocols and modality of operations. Responsibilities of each of the partners were clearly explained and answered. It was emphasized to the farmers that the research was wholly under their management.

It was agreed that if the control performed better than the other two treatments, the farmers would be compensated for the difference. Harvesting the required amount of biomass, the application and incorporation are the responsibility of the farmers.

Screening of suitable species for three-year fallow

Data file name

Fallow N.xls

Location

Chipata, Zambia

Investigators

Dr F. Kwesiga, Dr E. Barrios, ICRAF

Start Date

01/12/91

Justification

Farmers in Eastern province complain that crop yields, especially maize, continue to decline year after year if inorganic fertilizers are not applied. This was confirmed during micro D and D in Chipata and Katete Districts (Ngugi, 1988). The problem is largely attributed to the low fertility status of the soil. To increase crop yields, farmers have adopted several strategies including use of chemical fertilizers, crop rotation with legumes and leaving land to rest (fallow) for a few years. The fertilizer strategy has become less reliable because the government subsidy has been removed. The economic price of these fertilizers is very high and most of the small-scale farmers cannot afford to buy them. In addition, the majority of these small-scale farmers are not eligible to bank loans which are offered over a short period at very high interest rates, presently at 45% per annum.

The cheaper options still available to these farmers are; (i) to continue using legumes in crop rotation, (ii) to apply scientific principles to improve the efficiency of traditional fallows.

It is now well established that legumes (groundnuts, soya beans or pigeon peas) can contribute at least 30kg N ha^{-1}/year and this is about 25% of the total N requirement of maize in Zambia. Besides being low, it is not known whether this N is in the available form for crop utilization at peak-time.

As for the fallows, there are still challenges which have to be overcome before this strategy can be of wide use.

1. Increasing population pressure on the land (the present growth rate in Zambia is 3.5% per annum) means that long fallow periods are not possible in most of the settled areas. In Eastern province, fallow periods of 1-5 years are very common on the plateau and are still declining (Kwesiga and Chisumpa, 1989).

2. There are studies in which some tree and shrub species have been shown to improve fallow period and increase subsequent crop yields (Kwesiga and Coe 1991, Adejuwon and Adesina1990, NCSU 1990, Palm et al., 1988, Saleen and Otsyina 1986). Such species improve the physical and chemical conditions of the soil in a short period when planted as improved fallows compared to natural vegetation which takes longer to reach the peak of biological productivity. Obviously, there are many fast growing trees and shrubs, which have not yet been evaluated in fallow improvement.

In order to improve on the efficiency of the natural fallow, there is need to screen appropriate trees that may have relevance in soil fertility regeneration within permissible fallow periods in Eastern Zambia.

Understanding the mechanism of improved fallow effects on crop yields in relation to rooting depth of tree and crop species, and the interaction with moisture uptake (including effects of litter on the enhancement or inhibition of inorganic decomposition and nutrient availability) is essential.

Objectives

1. To screen species that might be suitable for 3-year fallows.
2. To study the impact of such fallows on soil changes and crop yields.
3. To evaluate the consequences of improved fallow on nutrient and water uptake of the crop.

Treatments

T1 *Sesbania sesban* three-year fallow followed by maize
T2 *Gliricidia sepium* three-year fallow followed by maize
T3 *Leucaena leucocephala* three-year fallow followed by maize
T4 *Flemingia congesta* three-year fallow followed by maize
T5 *Cassia siamea* three-year fallow followed by maize

T6 Groundnuts in one-year rotation with maize

T7 Natural fallow for 3 years, followed by maize

T8 Continuous maize without fertilizer

T9 Continuous maize grown with 120 Kg N ha^{-1}

T10 *Calliandra calothyrusus* three -ear fallow followed by maize

Statistical Design

Randomized complete block, 4 replicates.

The whole experiment was repeated starting one year later, on an adjacent site.

Measurements

These include soil nitrogen analyses at the end of the fallow period, and before the start of the first crop, together with the crop yield that year.

Publication

Barrios E, Kwesiga, F, Buresh RJ, Sprent JI and Coe R (1998). Relating preseason soil nitrogen to maize yield in tree legume-maize rotations. Soil Science Society of America Journal 62: 1604-1609.

Field Layout

Experiment 1 (91)

Block 1	T3	T7	T4	T10	T1
	T8	T5	T9	T6	T2
Block 2	T4	T10	T2	T5	T8
	T6	T9	T1	T7	T3
Block 3	T8	T3	T2	T9	T5
	T6	T4	T10	T7	T1
Block 4	T10	T3	T9	T5	T7
	T8	T4	T1	T6	T2

Experiment 2 (92)

Block 1	T7	T8	T3	T9	T2
	T6	T1	T5	T4	T10
Block 2	T6	T3	T9	T1	T8
	T4	T10	T5	T2	T7
Block 3	T1	T5	T10	T9	T4
	T6	T2	T7	T8	T3
Block 4	T3	T6	T9	T2	T4
	T1	T5	T1	T8	T10

Gross Plot: 10m × 10m

Upperstorey/understorey tree management trial

Data file name

Upper under storey.xls

Location

Kabanyolo, Uganda

Investigators

Nelson Wajja-Musukwe, NARO and Don Pedon, ICRAF

Starting date

11/88

Justification

While numerous upperstorey tree species and provenances are being evaluated for their suitability in agroforestry in the bimodal highlands of East and Central Africa, some were already well known. Two of these, *Grevillea robusta* and *Casuarina equisetifolia*, were chosen for management studies intended to evaluate less known management factors that might influence their performance. Two factors identified for study are optimal intra-row spacing of upperstorey trees on farmland, and the compatibility of these upperstorey trees when interplanted with understorey species such as *Pennisetum purpureum* (Napier, elephant grass) and *Calliandra calothyrsus*. Interplanting with understorey species is of great importance especially in sloping land where they may serve to control soil erosion and run-off. Other potential benefits from upperstorey / understorey combinations include production of fuel wood, green mulch, fodder, stakes for climbing beans, and stabilization of the terrace structures.

Objectives

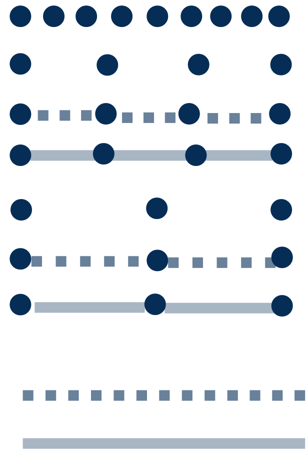
The objectives of the management trial are:

1. To determine the production potential of the upperstorey trees grown at different intra-row spacing and in association with Napier grass and *Calliandra* as understorey hedgerows.
2. To determine the effect of the upperstorey trees and understorey species on adjacent crops.
3. To determine the effect of the upperstorey and understorey species on each other.

Treatments

Combinations of upperstorey tree spacing and type of understorey used in management trial at Kabanyolo.

Intra-row spacing of upperstorey trees (m)	Understorey type
1	None
3	None
3	Napier
3	*Calliandra*
5	None
5	Napier
5	*Calliandra*
C	None
C	Napier
C	*Calliandra*

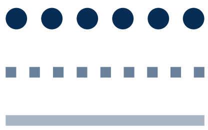


'C' indicates infinite intra-row spacing (i.e. Control)

Grevillea Tree

Napier strip

Calliandra strip



Statistical design

Randomized complete block design, 3 replicates.

Field layout

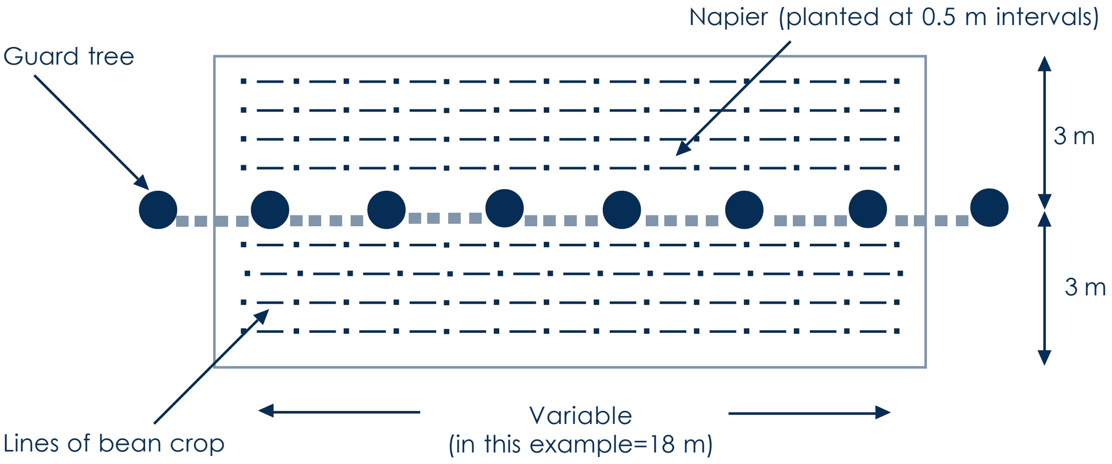
A plot consists of either a control without upperstorey trees or a single row of trees spaced at 1, 3 or 5 m intervals. Plot lengths vary according to the spacing of the trees, with 6 trees in each plot. The control (no tree) plot was 15 m long. Width of each plot is 6 m, with 3 m on either side of the tree row. Adjacent to the tree rows, on either side, a crop is raised. One guard tree is provided at each end of the plot. The understories, Napier grass and *Calliandra calothyrsus*, were planted in the same row as the trees at intervals of 0.5 m.

Measurements

The upperstorey trees, understorey shrubs and adjacent crops were measured at regular intervals. In the data file we present crop yield for one season and several measures of upper storey tree size measured at the same time.

Plot Design

Example Plot (Tree spacing 3metres, Napier hedgerow)



Field Layout

Rep 1

6	4	8	2	9	10	1	3	5	7

Rep 2

10	3	2	6	7	4	8	9	1	5

Rep 3

4	7	8	2	3	10	5	9	1	6

Leucaena trichandra seed production trial

Data file name

Leucaena family trial.xls

Location

Muguga, Kenya

Investigators

James Were, Tony Simons, ICRAF

Start Date

01/05/96

Justification

Timely availability of adequate quantities of high-quality tree seed is vital for the success of any tree planting activity, agroforestry included. *Leucaena* spp have been used in a wide variety of agroforestry activities, although the germplasm used has been mainly of the fast growing *Leucaena leucocephala*. With the recent *Leucaena* psyllid problem in many parts of the world, there is need to diversify and use other leucaenas in place of the susceptible *L. leucocephala*. There is a need to produce seed of suitable provenances and optimize methods for this production.

Objectives

1. To determine intra-provenance variation in survival, establishment and early growth of *Leucaena trichandra* (syn. *L. diversifolia ssp stenocarpa*).
2. To develop protocols for *Leucaena* spp. seed stand planting and management.
3. To produce seed of a superior provenance of *Leucaena trichandra*.

Treatments

1. Twenty families representing a single provenance of *Leucaena trichandra*.

   Two other factors will be introduced at a later date:
2. Coppicing vs no coppicing.
3. Systematic vs selective thinning.

Statistical Design

Incomplete block design. The 20 plots in one row (a complete replicate) made up 5 small blocks (each with 4 treatments). 20 replicates. Line plots of 4 trees each, no guards. 1m spacing with rows, 4 m between rows.

Field Layout: arrangement of plots in field

Replicate	Block 1				Block 2				Block 3				Block 4				Block 5			
1	20	18	9	10	2	16	13	5	4	6	3	19	12	15	8	14	1	11	7	17
2	12	1	13	6	10	3	8	5	2	11	20	4	7	14	18	16	17	9	15	19
3	5	18	1	19	11	16	15	3	12	4	10	7	2	6	14	9	20	17	8	13
4	10	16	17	6	18	15	4	13	5	11	12	9	14	20	3	1	7	8	19	2
5	20	10	9	18	7	11	17	1	8	12	15	14	5	13	2	16	4	3	6	19
6	11	8	18	6	1	10	15	2	14	5	17	4	19	20	12	16	3	7	9	13
7	18	13	4	15	7	8	2	19	9	5	12	11	6	10	17	16	20	1	14	3
8	8	17	13	20	3	11	16	15	7	10	4	12	14	9	6	2	1	19	5	18
9	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
10																				
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20																				

Arrangement of trees (X) within plots

Fruit tree survival

Data file name

Fruit tree survival.xls

Location

Yucatan, Mexico

Scientist responsible

Jeremy Haggar, ICRAF-Mexico

Justification

Farmers in the region are keen to increase the range and number of fruit trees on their farms. However they have problems establishing the trees.

Objective

To determine the extent to which soil depth affects early survival of fruit trees, and whether this can be improved with use of manure.

Design

On-farm trial involving five farmers. Potential planting niches of shallow and deep soil, were identified and trees planted in June 1997. The trees were of four species. In August 1997 chicken manure was applied to some of the trees.

Measurements

The number of trees planted in June 1997 was recorded. The number surviving in August 97, March 98 and October 98 was recorded for each niche-type, manure treatment, species and farmer.

On farm cropping with Sesbania and Gliricidia

Data file name

Onfarm gliricidia and sesbania.xls

Location

Makoka area, Malawi

Investigators

Prof J. Maghembe, G. Kooi, ICRAF

Start Date

01/11/94

Justification

After several years of on-station experimentation, relay cropping of maize with *Sesbania sesban* and mixed intercropping of maize with *Gliricidia sepium* shows promising results. These results should be verified under farmers' conditions.

Objectives

1. To collect biophysical data to assess the effect of relay cropped *Sesbania sesban* and intercropped *Gliricidia sepium* on maize yield, and determine their potential in increasing maize yields.
2. To determine farmers assessments of these technologies.

Treatments

1. Relay cropping maize with *Sesbania sesban.*
2. Intercropping maize and *Gliricidia sepium.*
3. Maize only control.

Statistical Design

One replicate per farm. Some farmers have only one of treatments 2 and 3. A total of 42 farms, plus two farmer training centres.

Roots and Competition (RAC)

Data file name

Roots and competition.xls

Location

Machakos, Kenya

Start Date

10/1/93

Justification

When crops and trees are grown together under semi-arid conditions, there is increasing evidence that competition for soil moisture is mostly responsible for the observed reduction in crop yields (Ong et al, 1991; ICRAF, 1992). Measurements of root distribution have shown that dense and superficial tree roots, such as exhibited by *Leucaena leucocephala*, can explain intense competition with crops. However, we still lack a clear relationship between tree root structure and competition with crops, Therefore we need to check the hypothesis that root density and distribution of a tree determines competitiveness with crops. In addition, it is not well known how tree management (e.g. pruning) can modify the tree root system and hence influence competition with crops.

In order to answer the above questions, this experiment uses a range of tree species with expected different rooting patterns, as well as contrasted management for some species. In order to correlate tree-crop competition with root distribution only, it is important to uncouple different possible interference between trees and crops. This is achieved by the canopy manipulation of the trees (pruning) according to the monitoring of transpiration rates and light interception, so that different tree species have similar water uptake and above-ground interactions with crops. Competition for nutrients is not expected since the site was previously under fallow and a cover crop assessment before the experiment did not show any sign of nutrient deficiency. Both N-fixing and non N-fixing species are nevertheless included in the experiment, since Nitrogen fixation may be a major determinant of competition with crops. This experiment is ICRAF's flagship initiative on root studies in water limiting conditions and should provide us with a better understanding of the relationships between tree root architecture and the consequences on competition for water with crops. Such information is critical both for the selection of multi-purpose trees and for the design of agroforestry technologies which minimize competition.

Objectives

1. To measure the competition (in terms of reduced crop yield) due to differing tree species and pruning patterns.
2. To characterize important difference in patterns of competition.
3. To test the hypothesis that root structure of a tree determines the characteristics of competitiveness with crops.
4. To test the hypothesis that tree pruning induces changes in root structure, which in turn modify competition with crops.

Treatments

T1. *Senna* spectabilis*, upperstorey tree
T2. *Senna spectabilis*, hedge
T3. *Croton megalocarpus*, upperstorey tree
T4. *Gliricidia sepium*, upperstorey tree
T5. *Gliricidia sepium*, hedge
T6. *Grevillea robusta*, upperstorey tree
T7. *Leucaena collinsii*, upperstorey tree
T8. *Melia volkensii*, upperstorey tree
T9. *Leucaena leucocephala*, upperstorey tree
T10. *Casuarina equisetifolia*, upperstorey tree
T11. Control (crop only).
(* formerly *Cassia*)

The associated cropping pattern is a maize-bean rotation.

Statistical Design

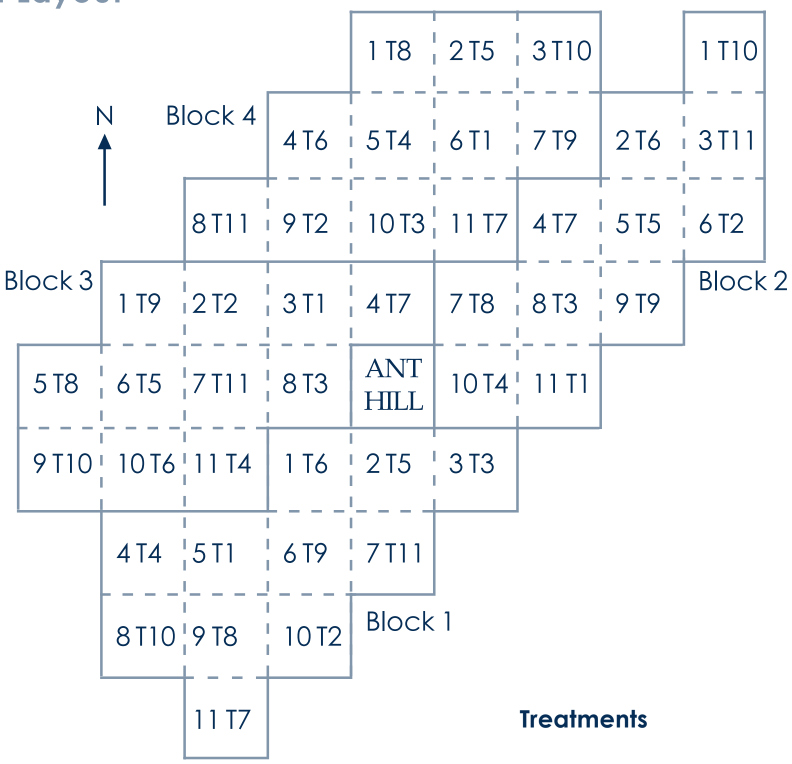
Randomized complete block design. 4 Replicates

Layout

A plot consists of a single line of trees (1 m spacing) with parallel rows of crops on either side. Trees are grown for pole (upperstorey) or mulch (hedge) production, as a single row per plot, with crops on both sides; a simple arrangement which is expected to yield clear results on competition at the tree-crop interface. Blocking was done according to a visual assessment of the land and soil. A maize cover crop grown prior to the experiment showed very uniform yields, with the exception of one ant hill which was avoided. Blocks 1 and 2 are on the upper flat zone, while blocks 3 and 4 are on the slightly sloping area to the West, where the soil is not as dark as in the upper part. Tree rows in plots are East-West oriented, in order to minimize light interference with crops. Plots are sufficiently large (18 m x 18 m) to accommodate repetitive environmental and root measurements as well as possible superimposed studies. Trenches are seasonally dug and refilled in a 2 m-wide border area around all plots to check any root interferences across treatments.

Ong CK, Corlett JE, Singh RP, Black CR. (1991). Above and below ground interactions in agroforestry systems. *Forest Ecology and Management 45: 45-57*.

Field Layout



Treatments

T1 = Senna spectabilis (Upper-storey)

T2 = Senna spectabilis (Hedge)

T3 = Croton megalocarpus (Upper-storey)

T4 = Gliricidia sepium (Upper-storey)

T5 = Gliricidia sepium (Hedge)

T6 = Grevillea robusta (Upper-storey)

T7 = Leucaena collinsii (Upper-storey)

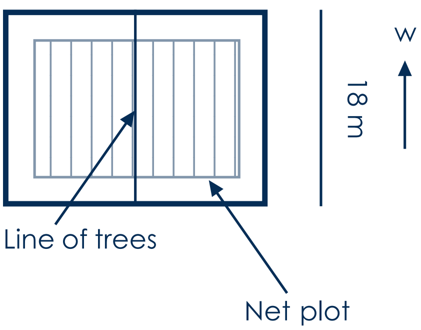
T8 = Melia volkensii (Upper-storey)

T9 = Leucaena leucocephala (Upper-storey)

T10 = Casuarina equisetifolia (Upper-storey)

T11 = Control (Crop only)

Plot Layout



Prototype hedgerow intercropping systems

Data file name

Prototype HI.xls

Location

Machakos, Kenya

Investigators

M.R.Rao, M.N.Mathuva, ICRAF

Starting date

11/1989

Justification

The potential of hedgerow intercropping for sustained crop production has been demonstrated by IITA in the humid to sub-humid lowlands of Africa. But its prospects in semi-arid environments as a means of improving soil fertility and maintaining crop yields, has not been proven conclusively. In these areas the woody perennial may compete with annual crops for soil moisture and the system may not show similar benefits as in high rainfall areas. Nevertheless, on sloping areas the hedges act as barriers and reduce soil erosion, and to that extent the hedgerow intercropping is beneficial even in semi-arid tropics. Hedgerow intercropping demands extra labour for establishment and management of hedges. To what extent the system is economically viable in limited labour areas has not been examined so far.

An alternative approach to the *in situ* incorporation of hedge pruning is to feed the biomass to livestock and return manure to the field for improving the soil fertility. This approach fulfils both soil fertility improvement and livestock production.

An earlier experiment at the Field Station, failed to establish the potential of hedgerow intercropping because of the absence of control treatment and fertilization of annual crops.

Objectives

1. To evaluate the potential of hedgerow intercropping in maintaining crop yields in semi-arid conditions.

2. To compare the effects of *in situ* incorporation of hedgerow prunings with recycling of prunings through livestock as manure.
3. To determine the extent to which seasonal rainfall modifies the performance of the systems.

Treatments

1. Annual crop, no fertilizer and crop residues removed.
2. Hedgerow intercropping, no fertilizer and biomass incorporated in alleys.
3. Hedgerow intercropping, no fertilizer, and biomass fed to oxen and manure returned to crops.
4. Annual crop with recommended fertilizer rates and residues taken out.

Statistical design

Randomized block design, 3 replicates. Plot sizes varied in order to fit them into the site. However all were over 500 m^2.

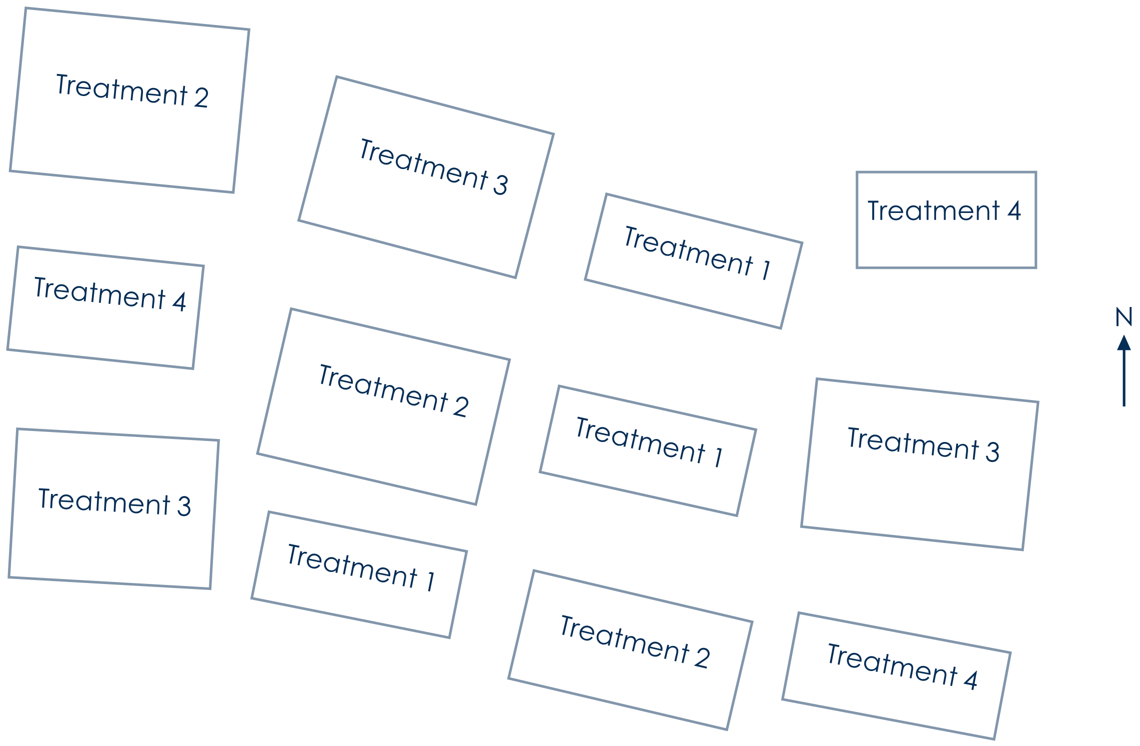
Measurements

These included crop growth and yields, hedge growth and production, nutrient contents of all components, labour inputs and others. Here we present crop yield data for all seasons of the trial.

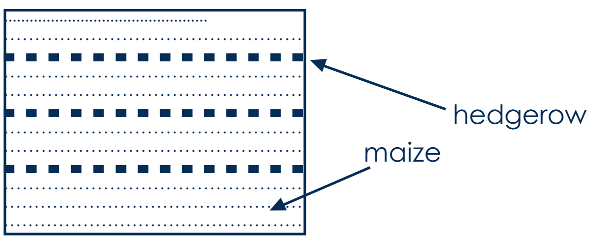
Publication

Mathuva MN, Rao MR, Smithson PC, Coe R (1998). Improving maize yields in semi-arid highlands of Kenya: agroforestry or inorganic fertilizers? Field Crops Research 55: 57-72.

Field layout



Plots of Hedgerow treatments (2 and 3)



(area is approximately 550 m^2)

Fertilizer, *Tithonia* and *Lantana* mulch as sources of phosphorus for maize

Data file name

Organic-inorganic P.xls

Location

Maseno (Ochinga farm), Kenya

Starting date

03/95

Justification

Phosphorus is the limiting nutrient for most of the soils in Western Kenya. Phosphorus application is inevitably required to increase crop production on these soils. Small-scale farmers have insufficient capital to purchase inorganic fertilizers. Consequently there is a great potential in use of organic materials to supply nutrients for crop production. One possible source of this organic materials could be the traditional hedges, used in internal and external farm boundaries for demarcation and production function, which are one of the most popular agroforestry systems found in most of land use systems in Eastern and Central Africa highlands (Hoekstra, 1988). These hedges are comprised generally of *Lantana camara* and *Tithonia diversifolia*. They produce a large quantity of biomass which is not fully utilized and which can be harvested and used as mulch in order to provide nutrients particularly P to the crops.

Objectives

1. To compare effects of *Tithonia diversifolia* and *Lantana camara* mulches and inorganic P at comparable P levels on maize and soil properties, in particular to measure any advantage of using organic sources.
2. To determine and compare the response of maize to different rates of inorganic and organic P inputs.

Treatments

1. Control with no input
2. Inorganic 12.5 kg Pha^{-1} (TSP)
3. Inorganic 25 kg Pha^{-1} (TSP)

4. Inorganic 50 kg Pha^{-1} (TSP)
5. *Lantana* mulch 5 Tha^{-1} (D.M)
6. *Lantana* mulch 10 Tha^{-1} (D.M)
7. *Lantana* mulch 20 Tha^{-1} (D.M)
8. *Tithonia* mulch 5 Tha^{-1} (D.M)
9. *Tithonia* mulch 10 Tha^{-1} (D.M)
10. *Tithonia* mulch 20 Tha^{-1} (D.M)

The quantity of dry matter to apply is based on the estimated P content of *Lantana* and *Tithonia* mulches (0.2% to 0.3%). 5, 10 and 20 tonnes of dry matter will correspond to 10-15, 20-30 and 40-60 kg Pha^{-1} which is equivalent to the quantities of inorganic P applied.

All the fertilizers will be incorporated one day before sowing maize. The fertilizers and mulch will be applied only during the long rainy season and the residual effect will be assessed during the short rainy season.

Statistical design

Blocked design with unequal replication.

Layout

Rep 1

8	2	6	5	3	1
4	1	10	7	9	5

Rep 2

8	10	2	6	5	4
5	9	8	1	3	7

Rep 3

9	3								
7	4	6	2	8	1	5	8	1	10

Calliandra feeding trial

Data file name

Calliandra feeding trial.xls

Location

Embu, Kenya

Justification

Preliminary work has shown that fresh leaves of *Calliandra calothyrsus* provide a fodder supplement for dairy cattle. Nutritional analysis suggests that 3 kg of *Calliandra* should be nutritionally equivalent to 1 kg of concentrate. This trial aims to test that.

Objectives

Determine whether *Calliandra* will substitute (in terms of milk yield) for dairy concentrate at the rate of 3 to 1 when added to the basal diet of cows in Embu.

Treatments

1. Basal diet alone
2. Basal + 3 kg *Calliandra*
3. Basal + 1 kg concentrate
4. Basal + 3 kg *Calliandra* + 1 kg concentrate

Design

Twelve Farmers, each with a lactating cow, are used in the study. Each cow is allocated to a sequence of treatments in which they are on one treatment for a period, and then change to the next. A treatment period is 14 days with milk yield assessed during the second seven only.

Effects of organic and inorganic sources of nutrients on striga, weeds and maize

Data file name

Organic-inorganic-weeds.xls

Location

Maseno, Kenya

Start Date

01/09/95

Justification

Low available soil phosphorus, striga and weeds are the major factors responsible for the low maize yields, which hardly exceed 1 tha^{-1}, in much of western Kenya. Fertilizer trials on farmers fields frequently showed large maize yield responses to phosphorus. However, observations in an on-going trial in Ochinga farm indicate that response to P in striga-infested fields is dependent on how well the striga is controlled.

Many resource-poor farmers cannot afford to purchase inorganic P fertilizers. An alternative seems to be the use of organic materials already available on the farm. Trials are currently being conducted in Western Kenya to evaluate the organic materials such as *Tithonia diversifolia, Lantana camara* and *Senna* spp. as sources of nutrients. Preliminary results from these on-going trials suggest that the organic materials, besides increasing maize yield, also reduce the detrimental effect of striga on maize growth.

Organic residues are important mostly for the supply of N and P. It is very well known that high N fertility reduces the striga infestation. It raises an important question whether the reduced detrimental effect of striga due to the application of organic residues, was something to do with their capacity to supply N or some other factors. In high rainfall and light soil conditions as prevailing in Western Kenya, N from inorganic fertilizers may quickly leach beyond 30 cm soil depth, where striga is most active. On the contrary, organic residues may release N slowly, depending on the characteristics of the materials and thus may maintain high N status in the top soil over a prolonged period so as to reduce the striga infestation.

A number of research issues emanate from the above background regarding the utilization of organic materials such as: a) the need to evaluate a large number of organic materials to determine their effect on striga, b) the need to determine the effect of organic vs inorganic sources of P and their integrated use (as integration becomes necessary because the amount of material needed to apply adequate quantity of P through organic sources is too large to obtain on-farm), and c) the potential benefits of organic on annual weeds and soil fauna.

Objectives

1. To determine the effects of organic and inorganic sources of P on maize yield in the presence of striga infestation.
2. To assess the effects of different organic materials on striga incidence and in turn its effect on maize yield.
3. To observe the effect of organic materials on changes in soil fauna, particularly plant parasitic nematodes.
4. To examine the effect of organic and inorganic nutrient sources on weed dynamics (species composition and biomass).

Hypotheses

a) Organic P from tree residues of specific characteristics is more efficient in improving maize yield than the inorganic P.

b) Organic sources of N decreases striga infestation, better than inorganic N; the magnitude of the effect being dependent on the decomposition and mineralization rates of the material.

c) *In situ* decomposition of organic residues reduces the detrimental effect of striga; the magnitude of effect being dependent on the secondary compounds present in the material.

d) Organic residues reduce the population of plant parasitic nematodes.

Treatments

1. Fertility treatments applied to main plots

Treatment	Source	Rate of biomass (t ha^{-1})	Nutrient supplied(kg ha^{-1}) N	P	K
1	inorganic		0	150	100
2	inorganic		120	0	100
3	inorganic		120	10	100
4	inorganic		120	25	100
5	inorganic		120	50	100
6	inorganic		120	150	100
7	*Tithonia diversifolia*	5	*	*	100
8	*Lantana camara*	5	*	*	100
9	*Calliandra calothyrsus*	5	*	*	100
10	*Senna spectabilis*	5	*	*	100
11	*Sesbania sesban*	5	*	*	100
12	*Croton megalocarpus*	5	*	*	100

* The amount of N and P added by the organics will depend on the chemical composition, which will be determined every season at the application time.

2. Split-plot treatment of removing striga as it emerges or not

All the selected organic materials contain fairly high N and P but differ in respect of tannins, polyphenols, etc. A 5 tha^{-1} rate was chosen so that all the materials provide a minimum of P and >120 kg Nha^{-1} and their effects are related to characteristics of the material without being confounded by different rates of N.

Statistical Design

Main -plot treatments: organic and inorganic sources of nutrients.
Sub-plot treatments: presence or absence of striga.
Four replicates in complete blocks.

The influence of improved fallows on soil phosphorus fractions; an on-farm trial

Data file name

Phosphorus fallow.xls

Location

Maseno, Western Kenya

Starting date

10/1998

Principal investigator

Roland Buresh, ICRAF-Nairobi

Justification

Improved fallows are a promising intervention for increasing the availability of N to subsequent crops. Improved fallows however, do not recycle sufficient P to overcome P constraints to subsequent maize crops on the severely P-deficient soils, common in Western Kenya. Past work with *Sesbania sesban*, nonetheless, suggests that fallows might at least slightly increase the availability of P to crops by increasing the quantities of P in labile soil pools.

Most past research has been conducted with *Sesbania sesban*, but two other promising species for improved fallows are *Crotalaria grahamiana* and *Tephrosia vogelii*. Most work with fallows in Western Kenya has been on relatively clayey soils with little or no water deficit during the growing season. This research therefore, involves the relatively little studied crotalaria and tephrosia.

Objectives

1. To determine the effect of fallows on soil P fractions.
2. To assess spatial variability associated with measurement of soil P fractions.
3. To measure the N and P contributions of the fallows to growth of a subsequent maize crop.

Experimental design

Initially, a randomized complete block design with four fallow treatments, is replicated on 9 farms. Each farm contains one plot of each of the fallow treatments. After the growth and harvest of the fallow treatments, each plot will be split into two. One half of each plot will receive N fertilizer, the other half will not. The N fertilizer will be applied in the form of a split application of Urea (100 kg Nha^{-1}), 30 kg Nha^{-1} will be broadcast and incorporated immediately before planting, and 70 kg Nha^{-1} will be side dressed.

Final design is therefore split-plot with fallow treatment as main-plot factor, and N application as sub-plot factor.

Treatment combinations are as follows:

Continuous maize ± N
Tithonia fallow ± N
Crotolaria fallow ± N
Tephrosia fallow ± N

Rationale for sub-plots

Both N and P could limit maize growth in the –N sub-plots, whereas N will not limit maize growth in the +N sub-plots. The comparison of +N and –N sub-plots within a main-plot will assess whether the fallows have eliminated N deficiency for maize.

Differences in maize yield among treatments for the +N sub-plot will result from differences in P plus 'fallow benefits' to maize. Differences in maize yield among treatments for the -N sub-plot will result from differences in N plus P plus 'fallow benefits' to maize.

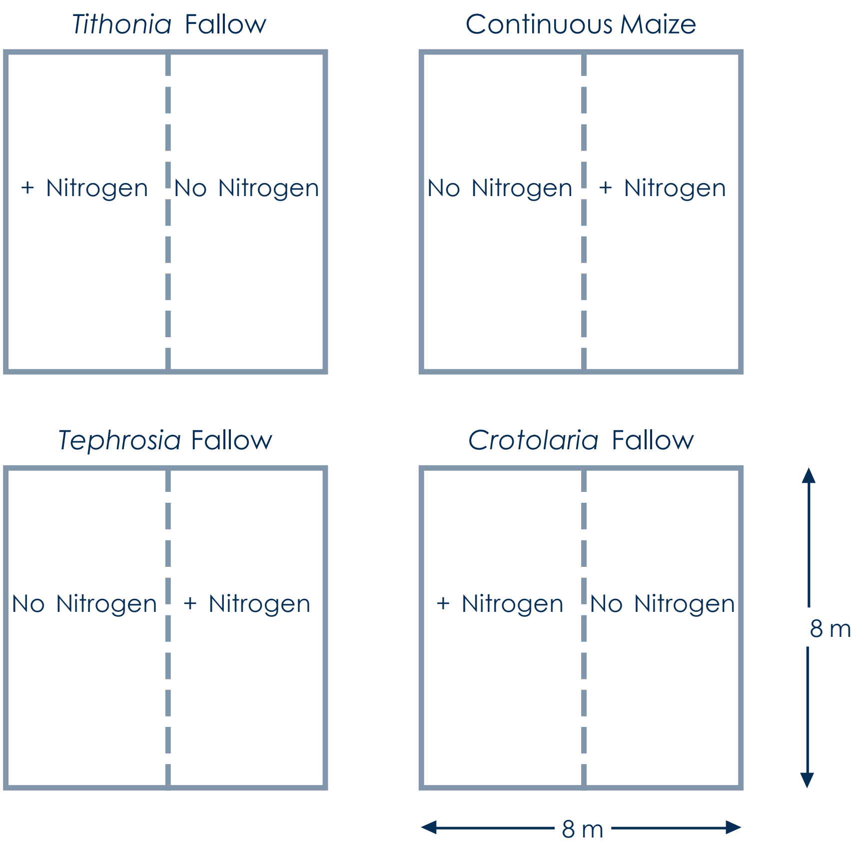
Measurements

Among other measurements:

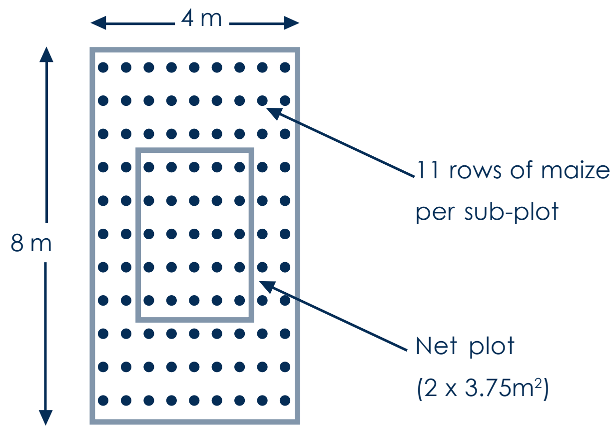
- Striga counts recorded 4 times, beginning after the 1998 short rains and ending before the 1999 long rains.
- Maize grain yield in 1999 long rains.

(Note the soil P data is not provided)

Field Layout (example plan for one farm)



Sub-plot Layout



Improved fallows and rock phosphate: farmers' experiences

Data file name

IF farmers experience - census.xls, IF farmers experience - sample.xls

Location

Vihiga and Siaya District, Western Kenya

Starting date

1/1997

Justification

Fallowing by allowing development of spontaneous vegetation on a field, has always been part of the farming system. Its role is to build up organic matter and nutrients that were depleted during a period of cropping and to interrupt the life cycles of pests associated with the crops. In many places, pressure on land has shortened the period for which fields can be left fallow. Natural fallows can no longer restore soil fertility to the level needed at the beginning of the cropping cycle.

A modification, called 'improved fallows' or 'IF', is to plant trees or shrubs at a high density, instead of letting the spontaneous vegetation develop freely. Desirable characteristics of the planted species include ease of propagation, rapid biomass production, efficient nitrogen fixation, deep rooting and ease of removal. Fallows of this kind should be able to restore soil fertility more rapidly than the traditional ones and hence allow a shortened fallow period. This makes improved fallow an attractive soil management tool in areas with relatively high land pressure.

Experiences with improved fallows in other regions of Africa and in researcher-managed trials in Western Kenya, indicate a possible role of the technology to increase food production of the area. The aims of the project on soil fertility replenishment are to disseminate the technology and then to study how adoption occurs and what impact it has on the livelihoods of the farmer community.

The target area for the project is known to be deficient in phosphorus. Fallowing does not increase P levels in the soil; additional P sources are needed. Researcher controlled trials have shown that the relatively cheap rock phosphate may be effective when used in conjunction with improved fallows. The combination of both technologies might increase their adoption and it is therefore crucial to test both technologies at the same time.

Improved fallows are mainly grown for soil fertility improvement. However, additional benefits are possible. Fuel wood production and the suppression of weeds and pests are some of the known benefits. More unknown benefits could be present.

Not all improved fallow species are equally good in performing these various roles, and their suitability depends on the farming system on a farm. Although some general characteristics of these species are known, some still have to be confirmed and some might still be discovered.

This study builds further on activities that are ongoing in the area. Researcher-controlled experiments with improved fallows created interest of farmers in the neighbourhood. Seed of improved fallow species was made available and many farmers started testing the technology on their own farms. The main objects of investigation are these spontaneously testing farmers.

Primarily this study investigates whether the potential advantages of improved fallows can be realized under farmers' conditions; both the establishment of the species grown as improved fallow and the effect of the fallow on crops, may be dependent on the skills and level of management of the farmer. Secondly, it is to document the experiences of farmers with the technology; especially comparing the different species used to improve the fallows. Thirdly, it aims at establishing whether this spontaneous testing will lead to adoption and which factors might facilitate or constrain this adoption.

Objectives

1. To understand the decision making process on planting fallows (why), the choice of species (which) and niche for fallows (where).
2. To assess the additional labour needed for improved fallow (planting and cutting) and how this fits in the normal farming calendar.
3. To assess the experiences of farmers with the planting and managing of improved fallows.
4. To assess farmers' perception on establishment, growth and biomass production of the various species, as well as their problems of pests, diseases and management.
5. To assess the experiences of farmers with the application of rock phosphate.
6. To assess the experiences of farmers related to crop responses after improved fallow, with or without rock phosphate.
7. To assess preferences of farmers among improved fallow species.
8. To assess major additional benefits of improved fallows, besides soil fertility improvement.
9. To assess farmers' future plans with improved fallows and rock phosphate.
10. To assess if the above topics depend on gender, ethnicity and resources (land, labour, cash).

11. To assess the actual adoption of improved fallows over time and define constraining and facilitating circumstances for this adoption.

Parts of the study

Farmers that were spontaneously testing improved fallow in 1997 were offered the use of rock phosphate, at a time when farmers should have had the chance of completing a rotation cycle fallow-crop; data will be collected on the farmers' reactions.

The information collection consists of three parts:

(1) A general census that covers the entire population of the pilot project area.

(2) A questionnaire with a limited sample (121 farmers) that had experience with improved fallows.

(3) A group discussion with knowledgeable farmers on topics where the questionnaire failed to yield adequate information to be held in 4 areas.

Census

The entire population is covered by a short questionnaire to gather baseline information about household composition, farming system, farm assets and available resources. This will take place once only.

Every year a new inventory is to be conducted to establish which farms have improved fallows, what species are used and how large the area is under improved fallow.

Questionnaire

For more detailed information about experiences with improved fallow and rock phosphate and to compare the benefits of the various fallow species, a study is carried out on the group of farmers that has experience with the technology.

A questionnaire is used to collect the information. It covered all objectives listed, was developed and tested with 5 households that were not part of the sample. It consists of two parts. One contains questions on information at farm level. A second part contains questions about each improved fallow plot that was established on that farm. Additional questions are asked of farmers that had chosen to test more than one species. Bao-games are used to rank species and their benefits.

Group interview

Knowledgeable farmers are invited to a group discussion to cover some aspects in more detail. Farmers are chosen on the basis of interest (either positive or negative) during the individual interviews. Topics to be covered are those needing more clarification after the questionnaire, but certainly include the following;

- Advantages/disadvantages of individual species
- Methods of establishment
- Seed production
- Use of improved fallow wood as firewood
- Methods of cutting and incorporating biomass
- Additional labour requirements
- Application method of rock phosphate
- Negative effects of rock phosphate on crops
- Choice of crop after improved fallow
- Crop performance after improved fallow
- Niche of improved fallow

One session of this group discussion was organized for each of the areas, described in the stratification below.

Stratification and Sample

The entire population in 17 villages, i.e. 2035 households (HH) is monitored for the presence of improved fallow and the basic set of census questions. The villages are grouped in four areas. The Luhya people occupy three of these areas, the Luo people the fourth.

In November 1997, 473 families had improved fallow. This group of families was used as the population to sample the farms visited for the questionnaire. The overview of the sampling frame is given in Table 1. Within each area, households were grouped according to the fallow species they planted to ensure the presence of less-common species in the sample. A random selection of the households took place within these groups. A total of 121 households were interviewed.

Area	Ethnic group	Total number	Total number of HH with improved fallows	Number of HH in sample
Bar Sauri	Luo	747	136	46
Ebukanga	Luhya	546	193	24
Emmbali	Luhya	293	21	20
Essaba	Luhya	467	87	31
Total		2053	437	121

Table 1

Note the number of records in data files may be less than the above due to incomplete information.

On-farm trial with improved fallow and inorganic fertilizer

Data file name

Onfarm IF and P fertilizer.xls

Location

Vihiga and Siaya District, Western Kenya

Starting date

6/1997

End date

12/1998

Justification

Fallowing by allowing development of spontaneous vegetation on a field has always been part of the farming system. Its role is to build up organic matter and nutrients that were depleted after a period of cropping and to interrupt the life cycles of pests associated with the crops. However, pressure on land has in most cases shortened the period of a field being fallow. Natural fallows can no longer restore soil fertility to the level needed at the beginning of the cropping cycle.

A modification, called 'improved fallows' or 'IF' is to plant trees or shrub species at a high density, instead of letting the spontaneous vegetation develop freely. Desirable characteristics of the planted species include ease of propagation, rapid biomass production, efficient nitrogen fixation, deep rooting and ease of removal. Fallows of this kind should be able to restore soil fertility more rapidly than the traditional ones and hence allow a shortened fallow period. This makes improved fallow an attractive soil management tool in areas with relatively high land pressure.

The combination of inorganic fertilizer with improved fallows might bring out their full potential. The combination of both technologies might increase their adoption and it is therefore crucial to test both technologies at the same time.

General objectives

The agronomic potential of improved fallows is to be tested in farmer-managed on-farm trials.

The main aim is to compare improved fallows with traditional fallow and continuous maize cropping. The fallow species used in these trials are mainly *Crotalaria grahamiana* and *Tephrosia vogelii*.

These cropping systems are or are not combined with phosphorus fertilization. Because of the high prevalence of phosphorus deficiencies, which cannot be overcome with the fallow on its own, and the presumption that it would even jeopardize the effectiveness of improved fallows, it was assumed that phosphorus fertilizer is a necessity. The phosphorus is either applied as the standard TSP (Triple Super Phosphate) or as the cheaper, but bulkier and less easily to manipulate rock phosphate. The rate given is either a small dose of 50 kg Pha^{-1} (supposed to be repeated yearly) or a large dose of 250 $kgha^{-1}$ (supposed to build up phosphate levels sufficient for five years). Varying the source and rate of the phosphorus fertilizer is to provide information on efficiency of less costly alternatives (rock phosphate at low dose) compared to what is assumed to be the optimal treatment (TSP at 250 $kgha^{-1}$). The application of 100 kg Kha^{-1} is tested at a high rate of P (150$kgha^{-1}$).

Experimental design

The experiments were conducted in 1997 and 1998 in 17 villages of the project area. The fallow is a one-season short rains fallow.

The experiments take place on-farm, superimposed on improved fallow fields that were planted on farmers' own initiative. Researchers select plots on the basis of a minimum size (to accommodate at least two plots of 8 by 8 m) and a dense (total ground cover) homogenous shrub stand. The owners are proposed to participate in on-farm trials and invited to planning meetings. During the meetings farmers can choose between several sets of simple comparisons (with a maximum of three treatments per farm) or decide not to participate. Farmers linked to one trial then meet to agree on a common set of non-experimental management principles (e.g. planting distances, monocrop – intercrop, varieties, weeding intensity, pest treatment).

Except for the fertilizer, the farmers provide all external inputs and labour, with no compensation promised. Research assistants are present during the cutting-down of the fallow stand (to assess the fallow biomass), casual checks, and the crop harvest (to measure the yields and take samples). Crops are an intercrop of maize and beans. Otherwise farmers are left alone to manage their crops. Commonly, farmers use local varieties of beans and maize, and do not use chemicals to overcome pests and diseases.

Besides yield data, the time needed to carry out certain activities in the IF system, is monitored on several farms. In conjunction with local market prices for the produce and the inputs, these data are used to calculate economic costs and benefits of the IF system. The costs and benefits are combined over four seasons; the cropped season when the fallow is planted, the un-cropped season when the fallow is developing, and two cropping seasons after the fallow. The benefits are based on the maize and bean yields for all these seasons.

After the completing of the cropping cycles, group discussions with the participating farmers are held to elicit experiences.

Experimental treatments

The experimental treatments are the result of a factorial combination between the improved fallow species and the fertilizer treatments.

The improved fallow species is the fallow present on the participating farms. Additional fields will be required to provide the control treatments of 'natural weed fallow' and 'continuous cropping'.

The sets of fertilizer comparison that can be chosen from are:

1. Rates of TSP:
   - 50 kg Pha^{-1}
   - 250 kg Pha^{-1}

2. Comparison of P sources:
   - no fertilizer
   - 250 kg Pha^{-1} as TSP
   - 250 kg Pha^{-1} as RP

3. Effect of potassium:
   - no potassium + 150 kg Pha^{-1} as TSP
   - 100 kg K ha^{-1}+ 150 kg Pha^{-1} as TSP

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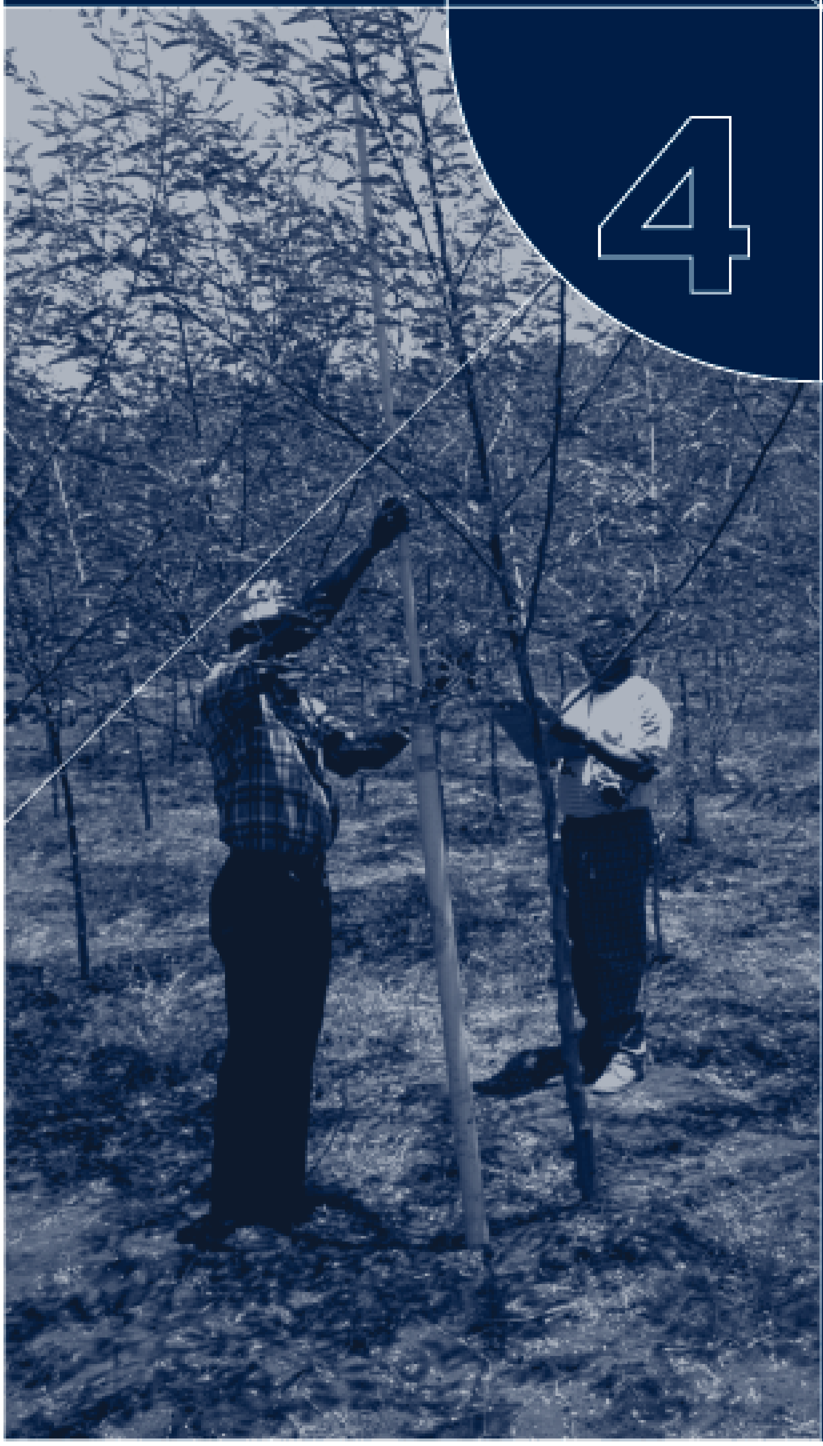

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