Evaluation of Agro-forestry Plants for Soil Fertility Restoration and Enhancement of Sustainable Agriculture in Eastern Province, Zambia

-Report for the Period of 2008 - 2009 Crop Season-

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Abstract

A field trial for demonstration and evaluation of agro-forestry plants to restore soil fertility is being conducted at the plots adjacent to the RIHN plots in Eastern Province, Zambia. Good growth of agro-forestry plants were observed and farmers, village headmen, and representative of the Chief invited to the Field Day showed great interest on past achievements.

1. Introduction

Vulnerability and Resilience research work is being undertaken in Zambia to address issues pertaining to social and ecological systems in the context of mitigating adverse effects of climate change in local communities of Zambia. The Zambia Agriculture Research Institute of the Ministry of Agriculture and Co-operatives (ZARI/MACO) in collaboration with the Research Institute for Humanity and Nature of Japan (RIHN/JAPAN) established a research site in Eastern Zambia. Selected agro-forestry and green manure plant species are being demonstrated and evaluated for adaptation by local village farmers in Chief Sandwe's area and other surrounding sites of the District since 2007. An update report is provided each year, and this report highlights the 2008/2009 crop season activities entitled, 'Demonstration and Evaluation of Agro-Forestry Plants for Soil Fertility Restoration to enhance Sustainable Agriculture'.

2. Location and site characterization

The research site at Mwelwa village is located some 38 km north-east of the Petauke main urban centre, with geographical co-ordinate references at approximately 14^0 55' S and 31^0 25' E at an elevation of about 980 m above mean sea level. The area falls within the Agro-Ecological Region IIa, which is characterized by medium rainfall precipitation of about 900 mm in the average year. Like most of Zambia the area enjoys a sub-continental, sub-tropical savanna climatic and vegetation conditions, respectively. The main local vegetation comprises the *Miombo* woodland, dominated by the *Brachystegia* genera trees with *Hyperhania* grass species, as undergrowth.

The area where the demonstration study is situated represents a typical rural Zambia, in which main local socio-economic factors are traditional farming based. The agriculture system practice is the *Nsenga* type cultivation, representing a main local ethnic group, who depend on the hand-hoe, axe, and sometimes the ox-drawn plough. Local seeds of crops are used. It is rare to use modern

fertilizers, but may be applied to maize if available. Land is cleared of trees using the hand axe. The cut trees are chopped down and may be piled to dry and burnt in heaps later when dry. At the onset of the rainy season fields are dug up with hoes in land preparation before planting crops. After harvest domestic stock (cattle, goats, pigs) are left to forage on the previous crop residues. The field is extended in this way each subsequent year. Old opened up fields are cultivated continuously with maize and other local crops including beans, pumpkins, groundnuts and cassava, for four to five years, then abandoned, mainly due to low soil fertility and weeds pressure. It has been observed that this traditional system of cultivation may cause deforestation and general soil and land resources degradation with the long term passage of the time.

The current study seeks to introduce an agro-forestry technology intervention of soil fertility management improvement for sustainable agriculture. Prior to establishment of the research field plots detailed site characterizations were conducted including the determination of spatial soil variability assessments, topographical and botanical plants identifications. The main soil types were classified as *Typic Plinthustalfs*.

The purpose of the work by the ZARI studies is aimed at removing conditions undermining food security and soil ecology quality in the local environment, thereby helping to build both social and ecological resilience in the region. The study serves as a demonstration to evaluate the effectiveness of agro-forestry technologies in enhancing soil health ecology resilience as measured by the efficacy of some selected agro-forestry and green manure plant species in soil fertility restoration for the enhancement of sustainable agriculture.

3. Materials and methods

Established plots were planted with *Grilicidia sepium* (Grilicidia), *Mucuna repensis* (Velvet bean), *Cajanus cajan* (Pigeon pea), in addition a Miombo woodland bush (*Brachystegia-Julbernadia* sp.) native forest fallow, and *Zea mays* (Maize), with and without fertilizer treatments. The above named species were placed under experimentation and demonstration to evaluate their effectiveness in enhancing soil health ecology resilience as measured by soil fertility improvement and restoration for sustainable agriculture.

Overall, the hypothesis that proven agro-forestry technologies help to improve soil fertility conditions would be tested through three outlined aims:

1. To demonstrate the agro-forestry species in soil fertility improvement as improved short fallow agricultural technology practices
2. To measure soil property dynamics and characteristics that occur resulting from defined practices in land use and imposed field practices
3. To asses any socio-economic impact of (long-term) benefit achieved on adoption of the technologies by various households in communities, thereby re-enforcing social and ecological resilience concepts and principles.

Trial design

The field experiment was laid out in a Completely Randomized Block Design (CRBD) with three replications (Figure 1) at a sub-plot size of 20 x 20 m^2.

F 13	D 14	A 15	C 16	B 17	E 18
A 12	C 11	D 10	E 9	B 8	F 7
B 1	E 2	C 3	F 4	D 5	A 6

N

Note: A = Treatment; 1 = Sub-plot No. 1

Figure 1: ZARI Plot Layout, Mwelwa Village sketch

Treatments

A *Grilicidia sepium* fallow (GSF)
B Maize continuous fertilizer (MCF)
C Native Forest fallow (NFF)
D Maize, no Fertilizer (MoF)
E Green Manure fallow (GMF *Mucuna*)
F *Cajanus cajan* fallow (CCF)

Notes:

a) At the time of implementation each sub plot measuring 20 x 20 m^2 was composite soil sampled at two depths, the top soil at 0 – 20 cm and the subsoil at 40 – 60 cm depths, respectively. Each soil sample was taken for soil laboratory analyses for pH, Bases, CEC Organic Carbon, total Nitrogen, available Phosphate and Particle Size Distribution (PSD).

b) *Gliricidia* was initially raised in nursery beds, and later planted into the field from potted seedlings at the spacing of 1 x 1 m^2. The spacing for Pigeon pea in the field was the same as for *Gliricidia*, but the crop was direct planted in the field by seed.

c) A Hybrid maize variety MM 604 was used as a test crop and planted at the spacing of 90 cm between rows and 25 cm between stations within the rows. Fertilizer application rate followed the LIMA recommendation of 4 x 50 Kg/ha Compound D (10N, 20 P_2O_5, 10K_2O 4 – 6 S), and the same rate for Urea (46% N) as top dressing in the continuous maize with fertilizer treatment. (MCF).

d) The Native Forest fallow was left without carrying out any land clearing or preparation. The bush was left in the virgin state as it was found before implementation of the experiment.

e) The green manure plot was planted with Velvet bean (*Mucuna*).

f) On all the cultivated plots land preparation consisted of cutting down and stumping all trees, followed by digging with hand hoes well before the onset of the rainy season in October. Soil samples were taken before planting.

g) After planting crop performance monitoring activities were conducted and included replanting, weeding and scoring for disease, pests, etc.

Grain yield and stover were harvested in maize plots and measured by weight to determine the biomass yield. Pigeon pea and velvet beans were harvested from dry pods. All fields were protected from fire by clearing fire breaks around all trials plots.

3. Results and discussion

Soil properties

In general the soils were low to medium in soil fertility status for plant growth and soil reaction conditions were of strong to medium acidity (pH$CaCl_2$ 5.1 – 5.7) (Table 1). Besides having low organic C content (<2.0 %), soils showed low N and P content, with the base saturation percentage being low to medium. It was observed that initially, there was no significant difference in the soil fertility status between the native forest plot and the Maize with continuous fertilizer application. The trend was similar across all the other treatments.

Table 1 Critical values of soil fertility (standard value below which fertility level is regarded low) and analytical results from maize plot with continuous fertilizer (MCF) and native fallow forest.

		Treatment MCF		Native fallow forest	
Parameter	Critical value	Top soil	Sub soil	Topsoil	Subsoil
Ca ($cmol_c$/kg)	1.0	2.7	1.9	1.6	2.07
Mg ($cmol_c$/kg)	0.2	0.63	0.47	0.63	0.57
K ($cmol_c$/kg)	0.07	0.63	0.83	0.68	0.71
Na ($cmol_c$/kg)	NA	0.62	0.46	0.24	0.52
N (%)	NA	0.07	0.05	0.08	0.04
P	7.0	nd	nd	na	na
pH	4.5	5.4	5.6	5.4	5.5
C (%)	1.0	1.04	0.42	1.37	0.38

Biomass estimation in agro-forestry and native forest plots

Above ground plant biomass in the agro-forestry and native fallow plots was estimated by measuring plant height and stem girth (diameter) at ground level. By estimating canopy cover by plants an assessment of ‘volume mass’ may be achieved. A simplified way was to compare tree height and stem thickness at collar (ground) level.

Table 2 Performance of the Native Forest, Cajanus cajan and Gliricidia sepium trees

FIELD MEASUREMENTS IN EVERY 5 METRES						
	Native Forest - Plot 3		*Cajanus cajan* - Plot 4		*Gliricidia sepium* - Plot 6	
Serial No.	Average Height (m)	Average Girth (mm)	Average Height (m)	Average Girth (mm)	Average Height (m)	Average Girth (mm)
1	2.4	36.4	3.4	37.1	2.1	41.6
2	4.2	74.2	4.2	40.1	2	44.1
3	2.2	35.4	3.5	50	1.9	45.3
4	2.9	60.2	3.7	50.7	1.9	40.4
5	3.6	52.7	3.5	39.8	2.3	47.1
Av.	**3.06**	**51.78**	**3.66**	**43.54**	**2.04**	**43.7**

Table 3 Summary of performance by treatments.

a) Agroforestry and Native forest trees

Plant sp.	***C. cajan***	***G.sepium***	**N.forest**
Height (m)	3.66	2.04	3.06
Girth (mm)	43.54	43.7	51.78

b) Maize performance

Treatment.	**Cobs No.**	**Cobs Wt.(Kg)**	**Stover Wt (Kg)**	**Diseased Cobs (Fusarium)**
Plot 1 Maize with fertilizer **MCF**.	74	10.58	19.26	9
Plot 17 Maize with fertilizer **MCF**	72	7.06	18.26	16
Plot 8 Maize with fertilizer **MCF**.	81	7.54	20.7	15
Plot 14 Maize without fertilizer **M0F**	73	2.42	2.88	1.6
Plot 5 Maize without fertilizer **M0F**.	78	2.8	4.26	9
Plot 10 Maize without fertilizer **M0F**	82	3.18	4.42	4

NB: Number of cobs (5*5 m^2)

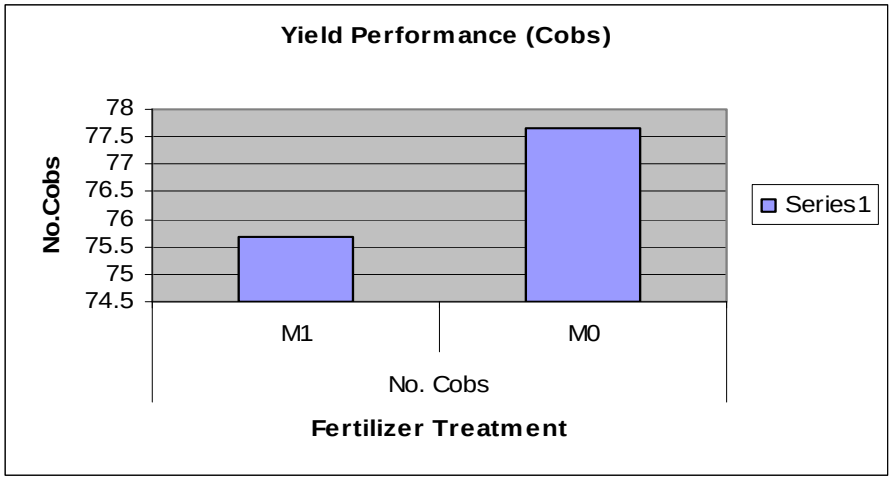
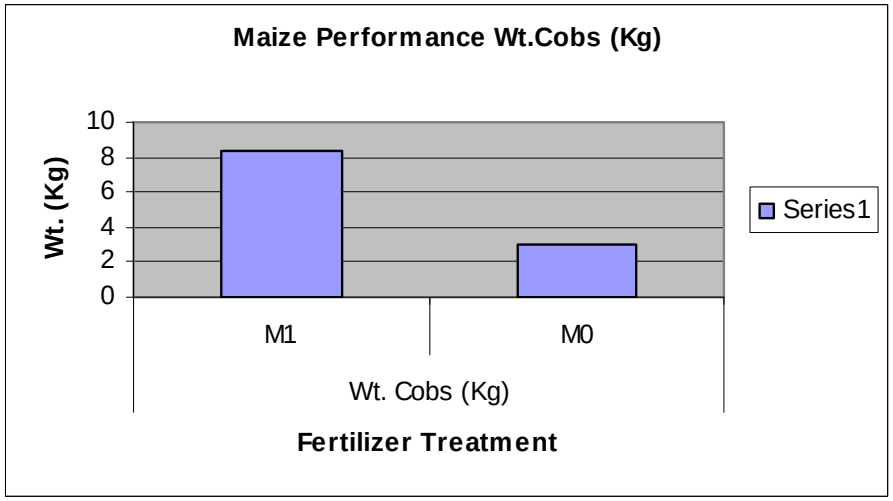
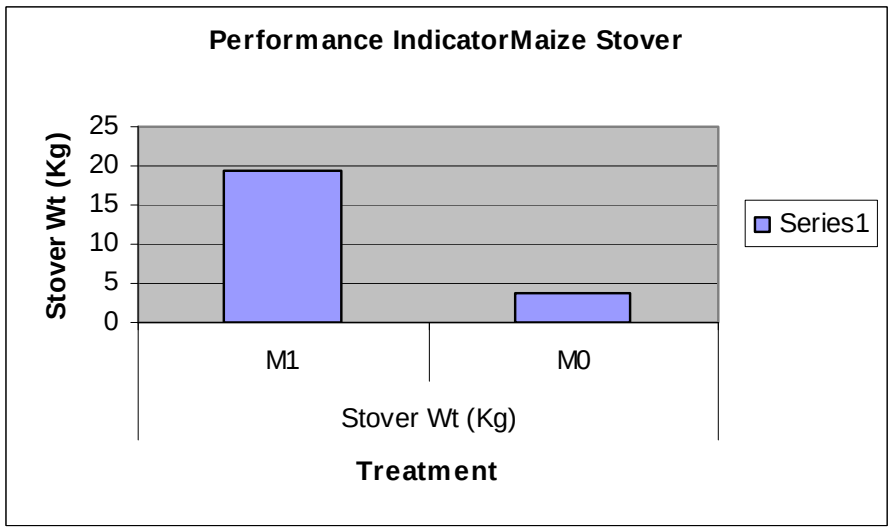


Figure 4 a) Crop performance as number of cobs, with and without fertilizer



b) Performance of maize by weight of cobs



c) Maize stover weight

It was ascertained that fertilizer application resulted in greater performance in a maize crop by cob and stover weight. However, under stress of low fertility conditions, a greater number of cobs with very low weight were produced by maize (Fig. 4 a).

Monitoring of Crop Performance

Monitoring of crop performance observations were related to general crop stand, vigour, pest, disease and/or observed nutrient deficiency (Table 4).

Table 4 Some monitored crop performance, Petauke Research Site

	Crop	**Establishment, crop stand, vigour**	**Pest type, severity**	**Disease type, severity**	**Nutrient deficiency**	**Other remarks**
1.	Maize with fertilizer (MCF)	Medium; milk stage, small to medium cob size formation	Mice 20%	Necrotic GLS (few) Streak virus (isolated)	Chlorosis, N (yellow) P (purple) Mg (green veins in leaf)	Weed pressure, Too much Rain (January)
2.	Maize without Fertilizer (MoF)	Generally small, stunted;; nothing to small cobs	-	GLS mild Necrosis	Widespread N Chlorosis; Few P Deficiency	
3.	Grilicidia (GS)	Good survival rate (90%)	-	-	-	Resilient to pest damage once established
4.	Pigeon pea (CC)	Very good, survival rate (98%)	-	Few plants infected with fungal infection from the roots.	Not observed	Very good establishment
5.	Velvet bean (VVB)	Good cover and growth	Non observed	Non observed	Non established	Very good establishment
6.	Native fallow (NC)	Bush fallow	N/A	N/A	N/A	Some mushrooms growing in association with rotten woody materials

Field Day

After the maize crop maturity and establishment of the agro-forestry and green manure plants around March/April 2009, a field day was held at the research field plots, where local farming people from nearby communities around Mwelwa village, including His Royal Highness Chief Sandwe, and Petauke District officials from the Ministry of Agriculture, and representatives from schools participated. The purpose of hosting the field day was to demonstrate and begin to disseminate agro-technology information into the local community, and consequently share a platform of understanding and appreciate of both the ZARI and RIHN research activities in the area.

4. Conclusion

It was noted that continuous heavy rainfall in January 2008, soon after top dressing in maize may have induced loss of nitrogen in MCF treatment. Replanting was necessary for all maize plots due to mice attack at germination. Initial soil fertility status is generally low to medium. Maize with fertilizer treatment out yielded the one without fertilizer by at least 25 %. The establishment for both the Grilicidia and Pigeon pea plots was successful. Velvet bean established successfully, having been grazed by wild rabbits.

The field day was highly successful with more than 12 village headmen, and the Chief Sandwe representation in attendance, more than 100 small scale farmers participated.

There was an overwhelming request for distribution of some agro-forestry plant seeds (Pigeon pea) to plant by headmen and the Chief in the coming season.

The crop for the 2009/2010 season was planted on time in 2009 and is presently under field performance monitoring stage.