Vulnerability and Resilience of Social and Ecological Systems Project Progress Report for Theme I: Petauke Research Site, Eastern Zambia

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1. Introduction

The Vulnerability and Resilience of social and ecological systems in Zambia are being studied in the context of climate change as it affects both the social and ecological factors in a given local environment. Vulnerability and resilience research studies with themes I, II, III and IV aim to serve to develop a comprehensive methodology for assessing social-ecological resilience. Theme I main focus is on soils and forest resources to analyze ecological resilience.

In the Agro-Ecological Region II (medium rainfall zone) of Zambia this is being conducted as part of the ecological resilience and sustainable productivity agriculture demonstration in a *Miombo* woodland ecological system at Mwelwa village in Chief Sandwe's area, Petauke District, in the Eastern Province.

Whilst the theme II focus is to conduct intensive interviews with village farm households and communities to identify factors of social resilience, historical, land tenure systems, government policy change effects on a natural environment and socio-political factors constitute subjects for focus in theme III, as theme IV deals with the use of statistics and remote sensing data to help trace long term changes in soils, forests, and analyze climatic data like rainfall, temperature, wind direction and speed including measurement of sunshine hour periods, through the establishment of Automatic Weather Stations in selected research sites.

The objective for this report is to present the progress of the activities of the ecological studies of the programme being conducted by research scientists from the Zambia Agriculture Research Institute Department of the Ministry of Agriculture and Co-operatives, over the period from April 2007, to November 2008, with the main focus on the theme I. The programme activities are being carried out in eastern Zambia located within the village of Headman Mwelwa, Chief Sandwe, Petauke District.

2. Materials and Methods

To effectively implement and undertake the Vulnerability and Resilience Research Project in Zambia, three main methodological approaches were adopted. For the Themes I and II, the Research Institute for Humanity and Nature (RIHN) of Japan in conjunction with other collaborative institutions such as Kyoto University, Ministry of Agriculture, Fisheries and Forestry (MAFF) in Japan, and others, together with the Zambia Agriculture Research Institute (ZARI) Department of the Ministry of Agriculture and Co-operatives (MACO) of Zambia and other partners, such as the University of Zambia (UNZA), Survey Department, Central Statistical Office, (CSO) undertook to establish respective memoranda of understanding (MoUs) to facilitate

carry out the various activities of the Vulnerability and Resilience Research studies in Zambia.

Out of three main target study areas of the Social and ecological Resilience, one is the soils and forest ecological research at the Petauke site area in the Eastern Province of Zambia, and will be the subject of this report.

2.1 Soil and Ecological Research at Petauke, Eastern Province

In collaboration with the RIHN Resilience Research Project, the ZARI Department researchers commenced to conduct experiments and demonstrations for soil fertility restoration and sustainable agriculture at Mwelwa village, Chief Sandwe, in Petauke, Eastern Province.

The studies are aimed to use agro-forestry and green manure plant cultivation in an integrated soil fertility management agricultural system introduction to benefit local farmers, the ecology and soil resources, at the same time help promote both social and ecological resilience through increased soil and land resources productivity, without impairing the ecological environment nature.

2.1.1 Location and Site Characterization

The research site in Mwelwa village is located some 38 Km north-east of the Petauke township, along the Sandwe-Ukwimi Settlement scheme road, with geographical co-ordinate location at approximately 14^0 55' S and 31^0 25' E at an elevation about 980 m above mean sea level. The area falls within the Agro-Ecological Region IIa, (Veldkamp et al., 1984), which is characterized by medium rainfall precipitation of about 900 mm in an average year. Like most of Zambia the area falls in a sub continental and subtropical savanna climatic, and vegetation conditions, respectively.

The main local vegetation comprises the *Miombo* woodland (Forestry Department, 1974), dominated by the *Brachystegia* genera trees and *Hyperhania* grass species. The geology in the area lies within the Mvuvye Paragneis and Minga Granites rock formations. These consist of a variable sequence of biotite-gneisses and granulites. One of the commonest rock types is medium grained mafic gneiss composed of quartz, sodic plagioclase and biotite (Drysdall, 1960). The soils in the area have been generally described as to include very deep to deep, well drained, strong brown to red, friable, moderately leached fine loamy to clay, classified as *Chromi-haplic* LIXISOLS (Soil Survey Unit, 1991).

Prior to establishment of the research plots detailed site characterization were conducted including the determination of soil spatial variability, topographical and botanical spatial variability assessments (Noro, 2007). The main soil types were classified as *Typic Plinthustalfs*.

2.1.2 Evaluation of Agro-Forestry Plants for Soil Fertility Restoration and Enhancement of Sustainable Agriculture

The ZARI Department researchers selected two fast growing agroforestry plant species, namely; *Grilicidia sepium* (Grilicidia) and *Cajanus cajan* (Pigeon pea) and two green manure plants represented by *Mucuna repensis* (Velvet bean) and *Chlotolaria juncea* (a Sunnhemp) to

undergo experimentation and demonstrations to evaluate their effectiveness in enhancing soil ecology resilience as measured by their efficacy in soil fertility restoration for enhancement of sustainable agricultural practices. Three specific objectives were to be investigated

1) To demonstrate the named plant species in soil fertility improvements for improved short fallow agricultural technology practices,
2) To measure soil properties dynamics and characteristics that occur as a result of defined practices in land use and imposed field practices and
3) To assess any socio-economic impact of (long-term) benefit achieved on adoption of the technologies by various households and community, thereby re-enforcing social and ecological resilience concept and principles.

2.1.3Experimental Design

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

Figure 1: ZARI Research Plot Layout, Mwelwa Village

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

R O A D

N

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

2.1.4 Experiment Treatments

The following treatments were imposed:

A *Grilicidia sepium* fallow (GSF)
B Maize continuous fertilizer (MCF)
C Native Forest fallow (NFF)
D Maize, no Fertilizer (M0F)
E Green Manure fallow (GMF *Mucuna* and *Chrotolaria*)
F *Cajanus cajan* fallow (CCF)

Notes:

a) At the time of implementation each sub plot measuring 20 x 20 m^2 was 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 split by planting one half with Velvet bean and the other with Sunnhemp. These are considered to give similar effects and were also introduced for seed multiplication purposes and comparison for soil vulnerability and resilience factors.

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.

g) After planting crop performance monitoring activities were instituted 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 yield performance. Pigeon pea seed was harvested from dry pods later in the dry season at the time when fields were being protected from fire by clearing the fire breaks around all trial plots.

3. Results and Discussion

In the current results presentation no attempt has been made at any statistical data analyses, since this first progress report mainly serves as a record of raw data observed and collected during the course of and after year 1 of the implementation of the experiment and demonstration activities. The study is scheduled to last for at least four years at the end of which a final report will be compiled. However, from year 2 more comprehensive data generation is expected, and then the results are to be treated with appropriate analytical tools.

3.1 Soil and Ecological Resilience Studies, at Petauke

Progress monitoring and evaluation on the ZARI plots was carried out early in March and the following field observations were made.

1. Between mid-December, 2007 and the end of February, 2008 most of the experimental plots suffered from incidences of attacks by pigs, goats and cattle from surrounding villages (Table 1)

Table1: Incidence of Pigs, Goats, Cattle and Wild Rabbit (Hare) attack on experimental crops at Mwelwa Village Research Site, Petauke.

Animal	Pigs	Goats	Cattle	Hare
Incidence of attack (%)	40	25	18	17

2. Crop performance observations were related to general crop stand, vigour, pest, disease and/or observed nutrient deficiency (Table 2).

Table 2: Observed Crop Performance, Petauke Research Site, 2007/08

	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	Goats 70% Pigs 5% Mice 20% Cattle 5%	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 (M0F)	Generally small, stunted;; nothing to small cobs	Goats 60% Pigs 20% Cattle 10%	GLS mild Necrosis	Widespread N -*Chlorosis*; Few signs of P Deficiency	As above
3.	Grilicidia (GS)	Good survival rate (90%)	Very slight black aphids -	Not observed	Not observed	Resilient to pest damage once established
4.	Pigeon pea (CC)	Very good, survival rate (98%)	Goats Cattle Hare Pig	Not observed	Not observed	Very good establishment
5.	Velvet bean (V VB)	Medium good cover and growth	Non observed	Non observed	Slight yellowing	Yet to fully establish; planting was late
6.	Sunnhemp (SNH)	Good establishment, severely attacked	Severe by Goats, Hare/rabbits and other rodents (> 90% wiped out)	Not observed	Not observed	Very vulnerable to attack due to good palatability for goats and Hares
7.	Native fallow (NC)	Bush fallow	N/A	N/A	N/A	Some mushrooms growing in association with rotten woody materials

Notes

1. It was noted that continuous heavy rainfall in January soon after top dressing in maize may have induced loss of nitrogen (N) in the MCF treatment.

2. Replanting was necessary for all maize plots due to mice rodents attack at germination. In Grilicidia it was necessary to replant to gap for failure of initial establishment due to dry weather experienced at the time of transplanting in late November to early December 2007.
3. A serious source of concern was the high incidence of domestic stock attack, despite employing two full time guards for the security of the crop and the experiments in general.
4. The following interim recommendation was made to be observed in the meantime to the time the crop was to be safely harvested and all the necessary data collected by researchers.
   a) The need to slash around all the trial plots for crop hygiene
   b) To clearly label all treatments with bill boards for identification of experiment treatments and for the work to be informative.
   c) The need to protect all the experimental plots from roaming, or stray livestock (and possible theft by people). It may be necessary to re-enforce a mesh wire fence barrier to stop/prevent access by pigs, goats and cattle to trial fields, or otherwise, boost security patrol intensity by employing more guards.
   d) Fire breaks must be established early. Ox-ploughing along the experimental site perimeter up to five (5) metres wide should be established. At the same time all subplots must be protected from fire, especially during the dry season, after the crop is harvested. This was to be done soon after harvesting in May-June, 2008.
   e) The vulnerability of sunnhemp by animals was a source of concern in the introduction of the green manures technology. The Velvet bean should be evaluated more closely in this context as it seemed to provide greater resilience potential than Sunnhemp, and a decision should be made to remove it all together from the trial, so that the Velvet bean can cover the entire plot as the sole green manure demonstration.

3.2 Soil Laboratory Analytical Results

Composite soil samples were taken from all the experimental plots at topsoil (0-20 cm), subsoil (40-60) depths. Exchangeable bases (Ca, Mg, K, Na), soil pH ($CaCl_2$), Organic Carbon (C), Nitrogen (N) and Cation Exchange Capacity (CEC) including Phosphate are the soil properties to be used as estimation measurements for the soil fertility status (Table 4). The current results were taken prior to planting the trial, representing the virgin state of soil fertility of the land.

At the tome of reporting the soil laboratories were yet to analyse for available Phosphate (P_2O_5) by the Bray 1 procedure. Similarly, the soil Cation Exchange Capacity (CEC) results had not been received. However in terms of soil chemical properties, the soil reaction condition may be described as strongly to medium acid (pH 5.1 – 5.7), with a medium exchangeable Bases content, but low in soil organic matter content and low total soil Nitrogen (N) composition. General indications are that the soils at the research site may be characterized as of low-medium soil fertility status.

Table 4: Soil laboratory analytical results

Plot	Treatment	Depth	Exchangeable Bases					CEC	Org.C	Total N	Avail. P
Units		(cm)	Ca	Mg	K	Na	pH ($CaCl_2$)	(cmol Kg^{-1})	%	%	(ppm)
1	MCF	0-20	2.0	0.4	0.56	0.52	5.3		0.87	0.06	
		40-60	1.5	0.6	0.90	0.22	5.9		0.17	0.02	
2	VGF	0-20	2.9	0.5	0.72	1.22	5.3		0.53	0.05	
		40-60	2.2	0.8	1.01	0.35	5.5		0.10	0.02	
3	NFF	0-20	2.0	0.7	0.72	0.01	5.3		0.88	0.07	
		40-60	1.4	0.7	0.89	0.01	5.1		0.21	0.02	
4	CCF	0-20	1.9	0.6	0.64	0.01	5.3		0.48	0.04	
		40-60	0.9	0.4	0.49	0.01	5.2		0.18	0.01	
5	M0F	0-20	2.3	1.2	0.77	0.04	5.2		1.14	0.10	
		40-60	1.8	0.7	0.90	0.01	5.3		0.54	0.04	
6	GSF	0-20	2.7	0.5	0.66	0.04	5.1		1.08	0.08	
		40-60	2.5	0.6	0.77	0.04	5.4		0.61	0.05	
7	CCF	0-20	2.6	0.6	0.61	0.13	5.1		1.21	0.10	
		40-60	2.5	0.7	0.74	0.30	5.5		0.54	0.05	
8	MCF	0-20	1.6	0.5	0.59	0.09	5.3		1.04	0.08	
		40-60	1.9	0.4	0.59	0.52	5.4		0.66	0.05	
9	VGF	0-20	2.1	0.7	0.49	0.17	5.6		1.33	0.11	
		40-60	1.6	0.5	0.74	0.22	5.4		0.77	0.06	
10	M0F	0-20	1.4	0.6	0.74	0.17	5.3		1.48	0.09	
		40-60	2.6	0.4	0.90	0.65	5.3		0.55	0.05	
11	NFF	0-20	1.2	0.5	0.59	0.66	5.3		1.09	0.08	
		40-60	2.5	0.6	0.59	1.13	5.7		0.41	0.04	
12	GSF	0-20	1.5	0.6	0.82	0.22	5.2		1.21	0.09	
		40-60	1.7	0.5	0.82	0.13	5.4		0.66	0.05	
13	CCF	0-20	1.3	0.7	0.74	0.53	5.3		1.49	0.11	
		40-60	1.8	0.5	0.90	0.43	5.3		0.54	0.05	
14	M0F	0-20	1.5	0.6	0.64	1.00	5.2		1.31	0.10	
		40-60	3.1	0.7	0.77	0.43	5.2		0.67	0.05	
15	GSF	0-20	2.4	0.8	1.00	0.70	5.2		1.33	0.09	
		40-60	2.1	0.8	0.99	0.61	5.5		0.66	0.05	
16	NFF	0-20	1.6	0.7	0.74	0.04	5.5		1.23	0.10	

		40-60	2.3	0.4	0.66	0.43	5.6		0.52	0.05	
17	MCF	0-20	4.5	1.0	0.66	1.26	5.7		1.21	0.08	
		40-60	2.3	0.4	1.00	0.65	5.5		0.44	0.03	
18	VGF	0-20	2.4	0.6	0.72	0.26	5.3		1.10	0.08	
		40-60	2.1	0.5	0.61	0.19	5.2		0.28	0.03	

CCF	Cajanus cajan fallow (Pigeon pea)
GSF	Grilicidis Sepium fallow (Grilicidia)
MCF	Maize with fertilizer continuous

3.3 Crop Performance for Maize

The maize crop was harvested on 27th March 2008. Maize harvest data were measured both in the field to obtain biomass weight, and at the laboratory to estimate the grain yield, and then to compare both parameters for the effects of cultivation without fertilizer and with fertilizer (Table 3)

Table 3a: Maize harvest data biomass (Field) per plot

Plot No	Treatment	# Cobs	Wt. of Cobs (Kg)	Wt Stover (Kg)	Biomass Wt. (Kg)
8	M0F	136	6.6	9.9	16.5
17	M0F	81	5.9	6.4	12.3
1	M0F	121	6.1	6.1	12.2
Av.	M0F	112.7	6.2	7.4	13.7
5	MCF	160	12.2	25.4	37.6
10	MCF	124	6.2	11.8	18.0
14	MCF	138	11.1	11.2	22.3
Av.	MCF	140.7	9.8	16.1	25.9

Table 3b: Maize grain yield data

Plot No	Treatment	Grain Yield Mass (Kg)	Moisture (%)	Grain Yield/Plot	Yield (Kgha-1)
8	M0F	3.852	12.4		
17	M0F	4.297	11.3		
1	M0F	3.403	11.9		
Av.	**M0F**	**3.851**	**11.9**	**3.076**	**769**
5	MCF	5.009	12.6		
10	MCF	4.572	12.0		
14	MCF	4.529	12.2		
Av.	**MCF**	**4.703**	**12.3**	**4.125**	**1031**

Notes:

1. Harvest area: 2x2 M2 x10 = 40 M2
2. MCF = Continuous Maize with Fertilizer
3. M0F = Continuous Maize without Fertilizer

4. Discussion and Recommendation

4.1 Soil Properties

Soil chemical properties represented by soil reaction conditions are strongly to medium acid (pH 5.1 – 5.7), with a medium exchangeable Bases content, but low in soil organic matter content and low total soil Nitrogen (N) composition. General indications are that the soils at the research site may be characterized as of low-medium soil fertility status.

4.2 Maize Crop Performance

In general the maize crop performance appears to have been rather suppressed as observed by *chlorosis* symptoms, indicating low Nitrogen intake during crop plant growth. This may be attributed to high amounts of rainfall received during the season. However in terms of grain yield, the continuous Maize with fertilizer treatment out yielded the one without fertilizer by at least 25 %. The result represents a first season crop and an abnormally higher than usual rainy season.

4.3 Agro-Forestry and Green Manure Technology Demonstration

The establishment for both the Grilicidia and Pigeon pea plots was successful. The pigeon pea plants were able to flower during the dry season (July to September 2008), and a small amount of pulse grain was harvested. Yield quantities will be measured in the second season (Year 2) of plant growth.

Whereas both the green manure plants of Velvet bean and Sunnhemp established successfully, a set back was experienced with the Sunnhemp as it was wiped out from all the plots, having been grazed by wild rabbits (Hare) and other rodents such as mice. Subsequently a decision was reached to phase out the Sunnhmp, and instead to plant all the green manure plots with Velvet bean 100 % in the coming seasons.

The second season (Year 2) trial crop of maize has been planted during the last week of November 2008 as adequate rains for planting were received in the area. The Velvet bean green manure crop was planted at the same time.

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