Understanding the current role of legumes and their significance for Biological Nitrogen Fixation (BNF) in smallholder farming systems of Zimbabwe

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MSc Thesis Plant Production Systems

October, 2011

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PPS 80424

October 2011

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Preface

This research was my major Master thesis and the report is a part of N2 Africa project "Putting nitrogen fixation to work for smallholder farmers in Africa." The project was funded by N2 Africa (Bill and Melinda Gates Foundation). This report was written for Plant Production Systems chair group of Wageningen University, the Netherlands. The field work for this study was carried out in Zimbabwe, in collaboration with TSBF-CIAT- Zimbabwe, in Mudzi and Murehwa districts from February-May 2011.

Acknowledgements

I would like to thank everyone who contributed through one way or another for this work to be a success. Field work would not have been successful without the help of TSBF-CIAT, and the extension officers. Many thanks go to SPRL for the analysis of my soil and plant samples, and to Mazvita Murwira in particular for the cooperation when things seemed challenging. I greatly acknowledge my supervisor Franke Linus for the insightful advice he gave me. I am indebted to him for his academic input. Many thanks also to Ken Giller for the constructive ideas and reading materials. My sincere thanks go to people at the Plant Production Systems Group, Wageningen University for the support in my work. I would not have made it without the love and support from my family and friends. Thanks so much mum for the prayers and to Charity for being a pillar all the way. Finally I would like to thank God for seeing me through.

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Abstract

One of the major challenges faced by small holder farmers in Southern Africa and Zimbabwe in particular is poor soil fertility. Use of synthetic fertilizers is limited due to its high costs and this has led to a drastic decrease in productivity. Alternatively, farmers can incorporate legumes in their cropping systems thus improving soil fertility through biological nitrogen fixation. However, legumes are still grown at a very low scale. In order to understand the cropping patterns of legumes relative to cereals a study was carried out in Murehwa and Mudzi districts. The two areas are located in two contrasting agro ecological regions. In each district, twenty farmers were selected and based on their resource endowment, they were divided into four resource groups (RG); RG1 being the richest and RG4 being the poorest farmers. Data was collected through structured questionnaires. Comparisons of legume productivity in the different resource groups were made by evaluating areas under legumes and yields attained. These results were compared with those for maize, the major cereal crop in Zimbabwe. Constraints faced by farmers in legume production were also evaluated. In the research, analysis was also made of the agronomic practices used by farmers in different RGs to grow legumes compared to maize. The agronomic practices included labour and input allocation to different fields within the farms and legume residue use. Soil structure and fertility status for the different fields of the target farmers were determined. Total nitrogen content in different legumes was also analyzed. The marketing of the different legumes was evaluated. Results indicated that groundnut, cowpea and Bambara nut were commonly grown in the two districts while common bean and soybean were exclusively grown in Murehwa. Larger proportions of land, fertilizers and labour were allocated to maize relative to legumes. Mudzi had average areas of 0.89 ha per farm under maize, 0.09 ha per farm under Bambara nut and 0.25 ha per farm under groundnut while Murehwa had on average 1.84 ha per farm, 0.19 ha per farm and 0.15 ha per farm under the respective crops. Higher yields of both legumes and cereals were attained in Murehwa compared to Mudzi. Cereals were mostly grown in the fertile home fields while legumes were grown in mid and outfields by most farmers. The majority of the farmers applied more fertilizers to the home fields while outfields are given less attention. There were no significant differences in the quantities of fertilizers used by farmers in different resource groups in both districts. Farmers indicated that they get more profits from selling legumes than from cereals. There were no significant differences in soil structure among the different farms in the different resource groups within each district. There were no significant differences in pH, soil available N, Ca, organic carbon between the different plot types. However, the proportions of most cations decreased in the pattern; Plot type 1 >Plot type 2 > Plot type 3. There is need to promote optimal agronomic practices so as increase productivity of legumes by smallholder farmers in the two districts. Differences in input resource management on the various fields within a farm result in variation in fertility and hence differences in productivity within the fields.

Key words: Legume, cereals, productivity, smallholder farmers, soil fertility

1. Introduction

1.1 Background

Poor soil fertility is a major constraint in crop production by smallholder farmers in Zimbabwe. Most smallholder farmers are located in marginalized areas, where soils are barely productive. There is need to improve soil fertility to ensure food security. Soil fertility improvement can be achieved by using synthetic fertilizers. However, these are expensive and many farmers cannot afford to purchase them in the right quantities to meet plant nutrient demand. For the farmers who can afford to buy the fertilizers, it may be difficult to access the fertilizers in good time and transportation can be very expensive.

Alternative nutrient sources available in Zimbabwe include: cattle manure, crop residues, termitarium soil and leaf litter. However, these contain low nitrogen (N) and phosphorus (P) concentrations and are usually applied at rates far short of meeting crop requirements (Mapfumo and Giller, 2001). The majority of smallholder farmers own few cattle, hence cannot get enough animal manure to improve soil fertility. Use of termitarium soil as an ameliorant is difficult due to the fact that digging out and incorporating termitarium in soil is labour intensive and not feasible for the resource constrained farmers. For leaf litter to be used as a soil ameliorant, large quantities of the leaf litter should be available. However due to marked deforestation it is a challenge to gather enough leaf litter to meet plant nutrient demand. Labour is an important constraint which limits productivity by smallholder farmers (Ncube et al., 2007; Zingore et al., 2009).

Given this background, use of legumes as an alternative nitrogen source is potentially a good option. A number of studies have been carried out in Zimbabwe showing the benefits of incorporating legumes in agricultural cropping systems by improving soil fertility through biological nitrogen fixation (Nezumba et al., 2010; Tauro et al., 2010). Legumes contribute to nutrient cycling and nutrient enrichment in smallholder systems. Legumes intensify productivity and interaction of the soil, crop, livestock, and people, and they are considered as drivers of sustainable farming in certain cases (Amede, 2002). Grain legumes such as soybean, groundnut and pigeon pea, and fodder legumes like lucerne, red clover and white clover are important livestock feed. Grain legumes grown in Zimbabwe include soybean, groundnut, common bean, Bambara nut and pigeon pea. These play a pivotal role as protein sources in smallholder households as well as cash crops. Legumes can be intercropped with cereals and besides adding nitrogen to the soil, intercropping also helps in weed suppression and breaking of disease cycles.

Different legumes have different net contributions to nitrogen fixation in the soil. Soybean (*Glycine max* L.) for example, is efficient at translocating nitrogen into the grain. When residues are returned to the soil and grains are removed, there can still be a net removal of nitrogen from the fields (Giller et al., 1997). Leafier soybean varieties have greater potential to add nitrogen to the soil (Mpepereki et al., 1996). There are differences in C: N ratio in the residues of different legumes. A high C:N ratio can result in the immobilization of nitrogen thus making it less available on the short term to the subsequent crops. For example the residues of soybean have C:N ratio of around 45:1 and this tends to immobilize nitrogen. Other legume residues are less lignified, for example groundnut (*Arachis hypogaea* (L.)), which is rich in nitrogen as the crop is harvested while still green. The longer duration legumes contribute more nitrogen to the soil as more leaves fall before harvest, for example pigeon pea (*Cajanas cajan* (L.)) (Giller and Cadisch, 1995). Some grain legumes have a low nitrogen harvest index and relatively large proportions of the fixed nitrogen remains in the field. Relative to grain legumes, herbaceous legumes grown as green manures contribute more to soil fertility through nitrogen fixation (Giller et al., 1997). This is because for the herbaceous legumes, no grains are harvested and high amounts of nitrogen are added to the soil when the whole plants are incorporated in the soil.

Despite the benefits of legumes in farming systems, it has been noted that little success has been achieved in adopting legumes in Zimbabwe (Giller 2001). According to Sumberg (2002), adoption of legumes as food, feed or cover crops has been affected by three major factors, which are socio-cultural, economic and political, agro-ecological and management at farm level. Most smallholder farmers in

Zimbabwe own only small pieces of land and they prioritize growing maize, which is the staple crop, instead of legumes. The majority of these farmers consider legume production as labour intensive and are not attracted to growing them. In addition, legumes like groundnuts are not well adopted in the rotation systems because of the small benefits of the subsequent cereal yields. Usually both the grains and haulms are removed on harvesting and burnt, leaving little residual material. This practice thus contributes little or no nitrogen to the next cereal crop. Furthermore, a lot of labour is required for groundnut production per ton of produce (Waddington and Karigwindi, 2001), making it a challenge for the already labour constrained smallholder farmers.

It has been noted that productivity of legumes is low also due to poor agronomic practices such as use of less vigorous retained seeds, late planting, late weeding and growing legumes on nutrient deficient soils (Allen et al., 1989). An additional reason for preferring cereals to legume production is related to the small pieces of land owned by the farmers. They optimise in growing maize that is a staple crop to ensure food security. Legumes are mostly grown in the low potential fields with known history of outbreaks of pests and diseases (Sumberg, 2002), hence they do not perform optimally. Lack of markets for the grain legumes has also been noted as a constraint to the adoption of legumes. Knowledge of how farmers can utilize and process legumes to make market-oriented products is also limited (Amede, 2002). A notable challenge has been to identify high yielding, drought tolerant legume species that are well adapted to low rainfall, drought prone areas.

Different farmers manage organic and mineral nutrient resources differently within their farms and this has consequences on soil resource base, cropping patterns and crop yields. It is essential to understand how farmers use their resources over time and space and this serves as a basis for designing relevant and sustainable interventions to improve resource use efficiency at farm level (Zingore et al., 2007). In this research, the aim is to understand the interaction between household characteristics, legume and non-legume crops, soils and livestock, hence determine resource and nutrient flows. Different legume crops perform in dissimilar ways in varied climatic conditions. Evaluating on-farm, the role of different legumes in areas of Zimbabwe with different agro-ecological potentials will help to gain understanding of the role legumes play in smallholder farming systems. The research helps to identify challenges being faced in legume production by smallholder farmers and from these, practical solutions are suggested to help improve legume productivity and consequently, soil fertility improvement through biological nitrogen fixation. The specific objectives of the study were:

1) To characterise farms on the basis of resource endowment and biophysical factors, and then to characterise fields within selected farms based on their productivity potential;
2) To quantify the current legume productivity trends in the selected farms (considering grain yields, total areas under different legumes and amounts of N_2 fixed) relative to maize;
3) To understand the variability of production practices used in grain legume production within farms, between farms and between regions; and
4) To identify potential biophysical niches for legume expansion in crop systems.

This study was conducted within the framework of a larger project called N_2Africa, which is currently working in eight African countries: Kenya, Rwanda, DRC, Ghana, Nigeria, Malawi, Mozambique and Zimbabwe. The N_2Africa project has a mandate of promoting legume adoption by smallholder farmers in the selected countries and to enhance Biological Nitrogen Fixation.

2. Methodology

2.1 Study sites

The study was carried out in Zimbabwe, in two districts Murehwa and Mudzi which are located in contrasting agro ecological regions II and IV respectively (Fig. 1).

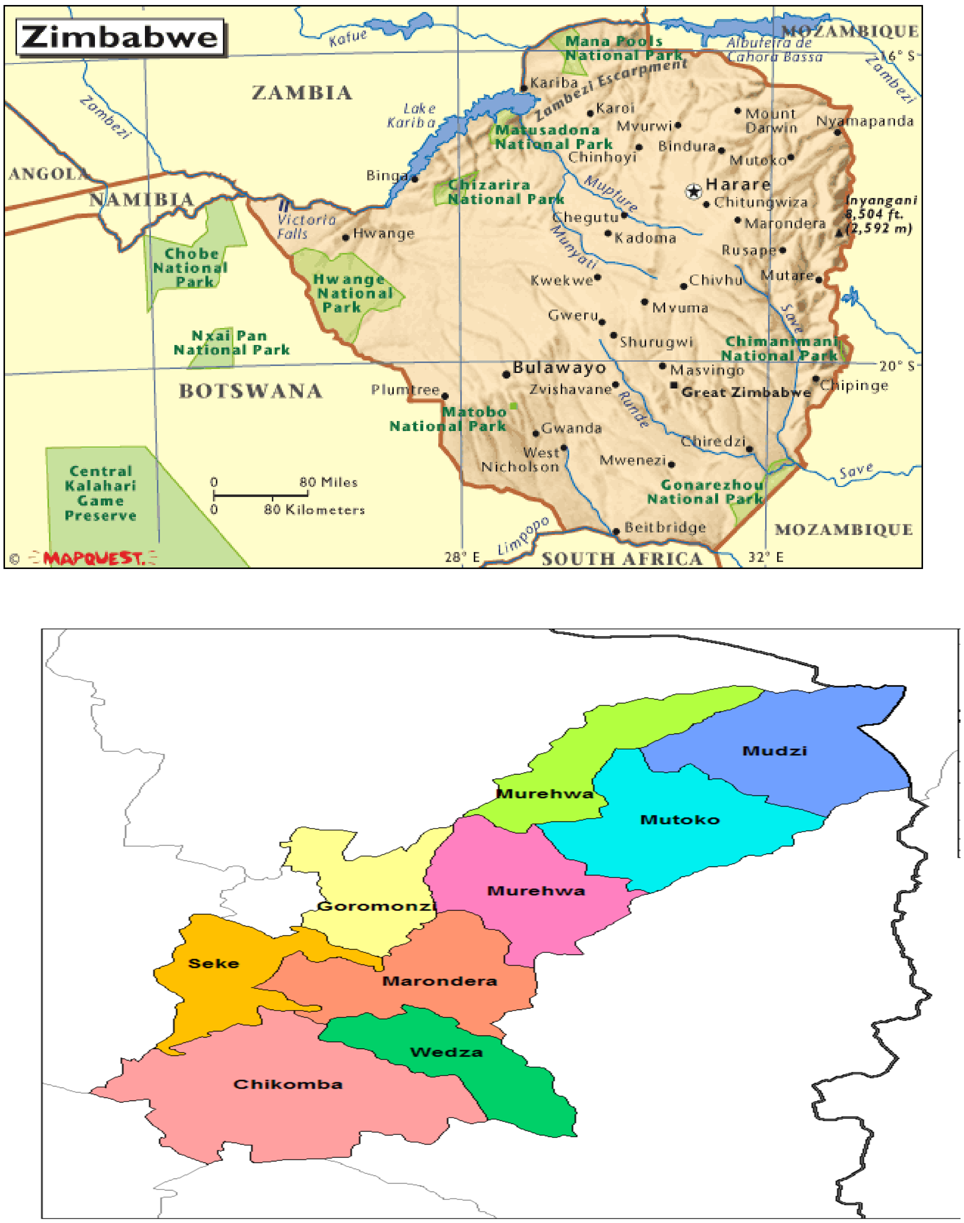

Figure 1. Study areas where the research was carried out

2.2 Farm and plot characterization (Objective 1)

2.2.1 Development of farm typology

Seventy five farmers were randomly selected from ward 12 of Mudzi district and wards 12 and 13 of Murehwa district, by using a recorded list of farmers from the extension officers. With the help of the village heads and local extension officers, farmers were categorized into four wealth classes, based on their resource endowment, their capacity to hire labour and capacity to purchase inorganic fertilizers (Table 1). The wealth classes were named as resource group (RG) 1, RG2, RG3, RG4; with RG1 being the wealthiest and RG4 being the poorest farmer. In each of the identified resource groups, a subset of 5 farms was selected based on the following elements; distance from the main roads or from the market, whether the farm is located on a hill or in a valley, to capture any possible factors that might influence productivity within a resource group. In total, forty farms were selected and these were then closely monitored.

Table 1. Wealth indicators and the characteristics of the different groups (adapted from Zingore, 2006)

Indicators	*Resource group 1 (better off)*	*Resource group 2 (average)*	*Resource group 3 (poor)*	*Resource group 4 (very poor)*
Livestock ownership	Own more than 10 cattle	Own less than 10 cattle	Do not own cattle, have goats and chickens	Do not own cattle, have goats and chickens
Draught power (oxen)	Own draught power	Own draught power	No draught power	No draught power
Hire or sell labour	Afford to hire labour	Do not regularly hire labour	Cannot afford to hire labour	Sell labour locally
Mineral fertilizer	Use large amounts of mineral fertilizers (about 10 bags	Mineral fertilizers used (< 10 bags AN)	Mineral fertilizers (< 10 bags AN)	Do not regularly use fertilizers

use	AN)

*One bag of fertilizer weighs 50 Kg

2.2.2 Development of field typology

In order to characterize fields, the different fields in which legumes and non-legume crops are grown within the selected farms were categorized based on their productivity potentials as viewed by the farmer; distance from the homestead and farmer's priority to allocate resources. Fields within the selected farms were demarcated into three different plot types (PTs) and these were described as; PT1- Best, PT2- average and PT3- worst fields (Table 2).

Table 2. Characteristics of the different plot types for Mudzi and Murehwa

	Plot type 1	***Plot type 2***	***Plot type 3***
Past records of yield potential	Very high	Average	Poor
Distance from homesteads	Closest to homesteads	Further away than home fields	Furthest away from homesteads
Organic and inorganic fertilizer application	The highest amounts are applied	Small amounts applied occasionally	Very small amounts to none

2.2.3 Soil sample analysis

Soils (0-20cm depth) were sampled in the plots identified at different distances from homesteads. Sub plots (10 m x 10 m) were randomly selected in each plot within each subplot. Ten to fifteen random samples were collected and bulked together to form one composite sample. This procedure was repeated in the fields representing the 3 plot types (PT1, PT2, and PT3), therefore three fields were sampled per farm. The three composite samples from each farm were air dried and sieved (< 2 mm) and then taken to the laboratory for analysis. Areas of discontinuity such as termite mounds and areas under trees which constituted just small areas under cultivation were avoided. The parameters analyzed at the laboratory do include; particle size distribution (hydrometer method), soil organic carbon (Walkley-Black) total N (semi micro-Kjeldahl), available P (Olsen), cation exchange capacity (in ammonium acetate) (Anderson and Ingram, 1993), pH (0.01M calcium chloride method) and cations Mg, Ca and K (Ammonium acetate extraction method). The percent soil sand, clay and silt were determined using the Bouyoucus method. The analysis was done at Soil Productivity Research Laboratory (SPRL) in Zimbabwe.

2.3 Quantifying legume productivity trends (Objective 2)

After carrying out the field typology and identifying different fields falling under the best, average and worst fields, the current productivity of legumes in these fields was then quantified. To meet this objective the following activities were carried out.

2.3.1 Yield and farm area measurements.

Yields of legumes and maize (*Zea mays L.*) were measured on a whole farm level at the end of the growing season using a measuring balance. Some farmers harvested their produce earlier before we could weigh them so we used the farmers yield records. Total area occupied by different legume crops and maize per farm was determined by physically measuring using a tape measure.

2.3.2 Legume-total nitrogen analysis

Samples of the legumes Bambara nut (*Vigna subterranea*), cowpea (*Vigna unguiculata*), soybean (*Glycine max*) and common bean (*Phaseolus vulgaris*) were taken from farmers from each resource group in the two study areas. These were analyzed for total N. The plant samples were obtained when the crop had reached physiological maturity. Relative proportions of stems and leaves or stems, leaves and immature pods in a representative subsample were taken. The selected samples were then oven dried. The plant samples were then ground into powder and packed in sample bags before they were taken for total N analysis at the laboratory. At harvest time, grain samples were taken for the different legumes. These were dried also and then ground into powder and packed separately before they were analyzed for N using the semi micro Kjeldahl method at SPRL laboratory.

2.4 Agronomic practices (Objective 3)

To achieve the third specific objective of the study, surveys were carried out and crop management data was collected on individual farms. Data were collected, on the different plot types with regard to how the legume crops were managed, labour allocation and nutrient management. Data were also noted on how farmers managed home fields, mid fields and out fields. Data on how the legume residues are used were noted (i.e. whether the residues are incorporated into the soil, fed to livestock, exported to other farms or are burnt). A comparison was made of legume crop management relative to cereal crop management.

2.4.1 Nutrient management

Quantities of the major nutrients N and P in kg^{-1} ha^{-1} yr were determined by firstly determining the total amounts of both organic and inorganic fertilizers applied in the different plot types by farmers in different resource groups. The fertilizers commonly used were Compound D with N.P.K ratio of (7:14:7), Ammonium nitrate (34% N) , animal manure and other ameliorants such as leaf litter, composts, termitarium soil The organic inputs mentioned above had an average N.P ratio of (2:0.47). The ratios were used to then determine the actual N and P quantities applied.

2.5 Identification of opportunities for legume expansion (Objective 4)

The information found from the above activities was integrated and used to achieve Objective 4. An evaluation of the performance of the different legumes was made under different climatic and agronomic conditions to determine the suitability of legumes in terms of biophysical and socio economic environment, and ways of improving their productivity.

2.6 Data collection sheets

Data were collected through surveys, in order to address the four specific objectives of the study. Structured questions were asked to the farmers, extension officers and key informants. The farmers were asked questions on the agronomic practices they carried out on cereals as well as legumes, that is: the time of planting, the type and amounts of fertilizers they applied, the type of seed, used the number of times they weeded and a comparison was made between the legume and cereal crops. Questions were also asked on the benefits that farmers derived from legumes, and their order of preference to different legumes. Farmers were also asked on the different challenges and constraints they faced in growing and marketing legumes. Questions were also asked on the farmers' perceptions of the significance of intercropping and rotation of legumes with cereals. The different ways in which farmers use their legume residues were also noted. The farmers were also asked how they managed their home fields, mid fields and outfields.

2.7 Statistical analysis

Statistical analysis was done using GENSTAT Version 13. Analysis of variance (ANOVA) was used to determine treatment differences with respect to legume yields, areas under legumes and cereals and organic and inorganic fertilizer application rates. The two districts Mudzi and Murehwa were analysed separately with resource groups being taken as factors while parameters such as areas under maize and legumes, yields of maize and legumes, amounts of organic and inorganic fertilizers applied were treated as the variables. Analysis of variance (ANOVA) tables were also generated for soil nutrient status across the four resource groups and between plot types using GENSTAT 13 to test for significant differences at $P < 0.05$.

3. Results

3.1 Study sites

The study was carried out in Zimbabwe, on smallholder farms in Wards 12 and 13 of Murehwa and Ward 12 of Mudzi. Murehwa is located about 80 km east of Harare. It lies between 17° South and 31° East, on an altitude of about 1100 - 1500 m above sea level. The area has a sub-tropical climate and is characterized in Zimbabwe as having a high potential for crop production. Murehwa is in agro ecological Zone of Natural region II, receives 750 - 1090 mm rainfall annually, distributed in a unimodal pattern (December to April). The soils are predominantly granitic sandy (Nyamapfene, 1991).

Mudzi is a low potential area and it is in Agro ecological zone of Natural region 1V, receiving mean annual rainfall of less than 600 mm. It lies between 17° South and 32° East on an altitude of 1210m. The area is characterized by high likelihood of severe mid-season dry spells during the rainy season, and droughts, which occurs every 3 or 4 years. Zimbabwe is divided into five agro ecological regions known as Natural Regions I to V. Natural regions I and II receive the highest rainfall (at least 750 mm year^{-1}) and are suitable for intensive farming. Natural region III receives moderate rainfall (650 - 800 mm year^{-1}) and Natural regions IV and V have fairly low annual rainfall (450 - 650 mm year^{-1}) and are suitable for extensive farming (Vincent and Thomas, 1960).

3.2 Wealth classes and farm characterisation

Farmers in both Mudzi and Murehwa were characterised into four groups which were RG1- very rich, RG2- rich, RG3- poor and RG4- very poor depending on their differences in resource endowment, most importantly considering cattle ownership, then farm assets such as ploughs, Scotch carts, cultivators, wheelbarrows and other farming implements, ability to hire or sell labour and use of mineral fertilizers (Table 1). For the seventy five farmers used in the initial random sampling in each of the two districts, different proportions of farms fell under different farm types. The majority of the farms (41%) in Mudzi fell under RG3 while in Murehwa the majority fell under RG2 (34%) (Table 3).

Table 3. Distribution of farms in the different RGs in ward 12 of Mudzi and wards 12 and 13 of Murehwa

	Farm type	***No. of farms***	***% of farms***
Mudzi	RG1	8	11
	RG2	14	19
	RG3	31	41
	RG4	22	29
Murehwa	RG1	12	16
	RG2	26	34
	RG3	20	27
	RG4	17	23

RG1- Resource group 1, RG2- Resource group 2, RG3- Resource group 3, RG4- Resource group 4

Farmers in Murehwa under RG1 owned an average of 14 cattle while those in Mudzi had an average of 10 cattle. The resource endowed farmers in both Murehwa and Mudzi could afford to purchase mineral fertilizers, to hire labour for ploughing, weeding and harvesting and they had large amounts of manure to apply to crops. On the other hand, resource constrained farmers in RG3 and RG4 lacked draught power and could not afford to buy sufficient mineral fertilizers. In both Mudzi and Murehwa, farmers in RG3 and 4 did not hire labour, rather, they depended completely on family labour to work on their fields and had to often sell their labour locally.

The criteria for characterising the plot types into PT1, PT2 and PT3 were applicable to all resource groups in both districts. All RGs had the three plot types although PT1and PT2 were most common for farmers in RG1 and RG2 while the majority of the fields for farmers in RG3 and RG4 were of plot type 3.

Table 4. Annual organic and inorganic fertilizers (kg ha^{-1} yr^{-1}) applied to maize in different plot types by farmers in different resource groups

(A)

Farm	*Plot type*	*Compound D*	*AN*	*Animal manure*	**Other*
RG1	PT1	80	75	2000	-
	PT2	35	40	1000	-
	PT3	10	11	588	-
RG2	PT1	40	70	900	-
	PT2	15	23	600	-
	PT3	-	-	300	-
RG3	PT1	9	18	1200	1200
	PT2	-	-	511	850
	PT3	-	-	-	642
RG4	PT1	22	70	1800	600
	PT2	10	47	417	400
	PT3	-			199

(B)

Farm	*Plot type*	*Compound D*	*AN*	*Animal manure*	**Other*
RG1	PT1	40	50	1500	500
	PT2	26	48	1000	220
	PT3	-	-	455	-
RG2	PT1	90	100	2300	-
	PT2	50	56	1800	-
	PT3	22	-	745	-
RG3	PT1	44	100	1150	510
	PT2	-	44	400	300
	PT3	-	-	300	-
RG4	PT1	45	81	667	1800
	PT2	-	-	-	1124
	PT3	-	-	-	-

*Other- soil ameliorants including composts, leaf litter, termitarium soil.

The area under study in Mudzi was generally characterised by lighter sandy soils while that in Murehwa had slightly heavier, sandy loam soils. Farmers in RG3 and RG4 for both Mudzi and Murehwa did not apply inorganic fertilizers in PT3 while those in RG2 and RG1 applied small amounts of either organic or inorganic fertilizers (Table 4a and 4b). It was noted that the farmers applied these different amounts of fertilizers particularly to maize crop in the different plot types and not to legumes and other crops such as sweet potatoes, millet and sunflower. Only a few farmers applied small amounts of fertilizer to legumes in home fields.

3.3.1 Comparison of productivity between Mudzi and Murehwa

There was a significant difference ($P < 0.05$) in the mean area under maize, Bambara nut and groundnut between Mudzi and Murehwa districts. Murehwa had a larger mean maize area of 1.84 ha per farmer while Mudzi had an average of 0.89 ha under maize. Murehwa also had a larger Bambara nut area mean of 0.19 ha per farmer while Mudzi had 0.09 ha on average. Mudzi had a larger mean area under groundnut of 0.25 ha while Murehwa had a mean of 0.15 ha under the legume (Table 5).

There was no significant difference ($P > 0.05$) in the mean yields of Bambara nut between Mudzi and Murehwa districts. Significant differences ($P < 0.05$) were noted in the mean yields of groundnut and maize between the two districts, Mudzi and Murehwa. For these two crops, Murehwa had higher yields than Mudzi (Table 5).

Table 5. Areas and yields of maize and different legumes in the study areas

	Mudzi	***Murehwa***	***SED***	***P values***
Mean area *(ha per farm)*				
Maize	0.89	1.84	0.311	<0.01
Bambara nut	0.09	0.19	0.0273	<0.001
Groundnut	0.25	0.15	0.0313	<0.002
Mean yield (t/ha)				
Maize	1.06	1.99	0.206	<0.01
Bambara nut	0.92	1.03	0.1498	<0.473

Groundnut	1.81	2.42	0.248	0.021

*The yields are for shelled grain

3.3.2 Maize and legume productivity in Mudzi

The crops that were commonly grown in Mudzi and Murehwa were maize, groundnut and Bambara nut. Results from statistical analysis showed that there were no significant differences ($P > 0.05$) in the area of land that was cultivated under maize, groundnut and Bambara nut between the farmers in the four resource groups in Mudzi. Bambara nut had the lowest grand mean area of 0.09 ha while maize had the highest mean area of 0.89 ha (Fig. 2). For groundnut and maize the high resource endowed farmers had the largest areas under these crops and the areas decreased following the pattern RG1>RG2>RG3>RG4.

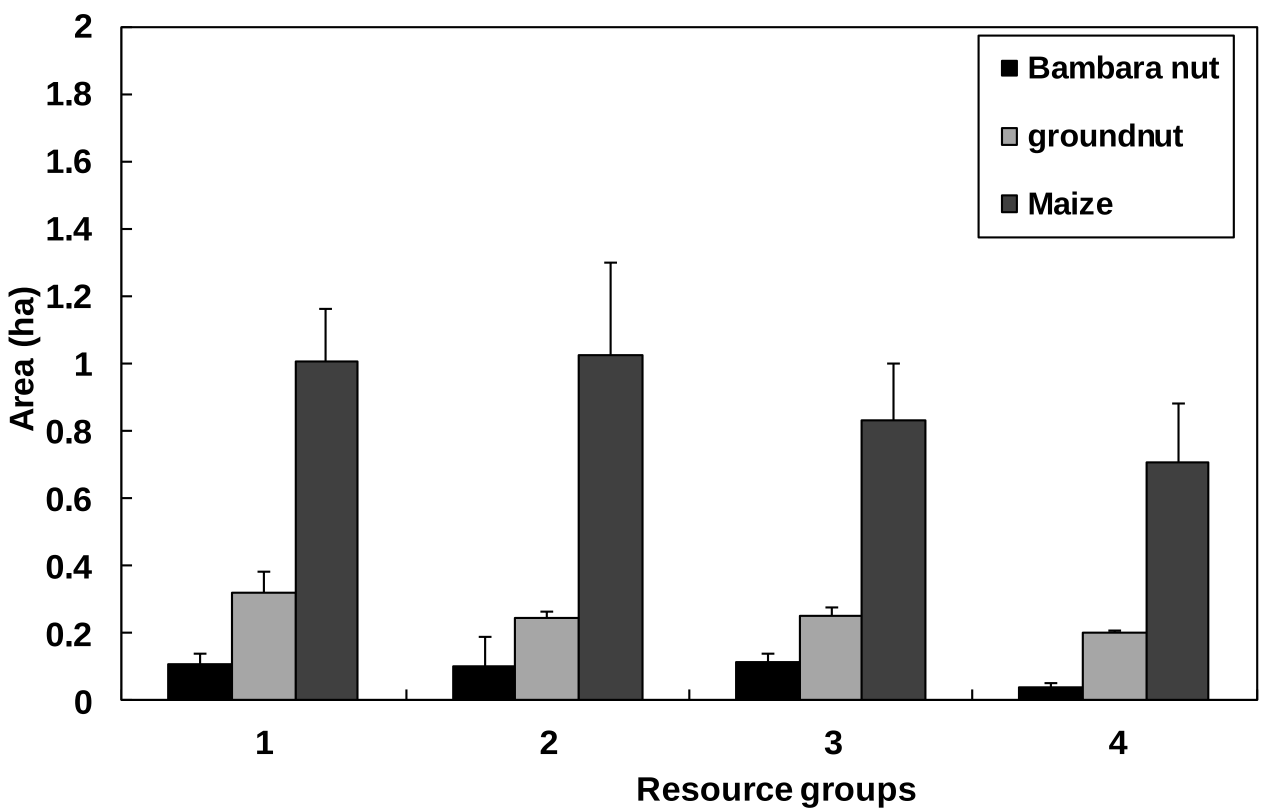

Figure 2. Mean areas of maize, groundnut and Bambara nut for the different RGs in Mudzi. Bars show standard error of means.

There was a significant difference ($P < 0.05$) in the yield of Bambara nut and groundnuts attained by farmers in the different RGs in Mudzi district. Of the three crops, groundnut recorded the highest mean yield of 1.81 t/ha. Farmers in RG1 had the highest groundnut yields (2.49 t/ha) while those in RG4 had the least (1.26 t/ha). Farmers in RG 1 also had the highest Bambara nut yield of 1.50 t/ha (Fig. 3). There was no significant difference ($P > 0.05$) in the yields of maize attained by farmers in the four RGs. The grand mean was 1.06 t/ha and the yield range was 0.82 to 1.20 t/ha.

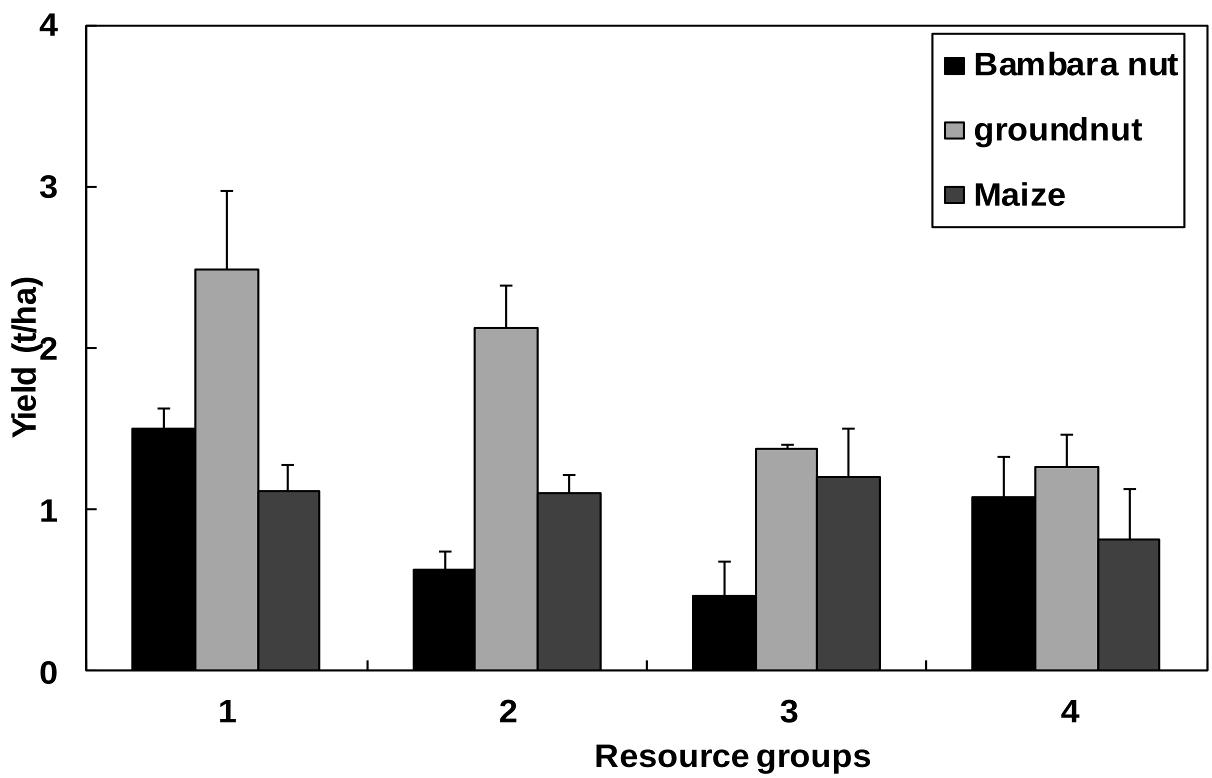

Figure 3. Mean grain yields of maize, groundnut and Bambara nut of farmers in different RGs in Mudzi. Bars show standard error of means.

3.3.3 Maize and legume productivity in Murehwa

There was a significant difference ($P < 0.05$) in the area of land under Bambara nut, groundnut and maize, for the farmers in the different resource groups in Murehwa. Maize occupied the largest area with a grand mean of 1.84 ha while groundnut had the least area with grand mean of 0.15 ha. Farmers in RG 1 had the highest mean areas under groundnut (3.35 ha) and Bambara nut (2.43 ha) and the least areas were recorded for RG4 farmers (Fig. 4).

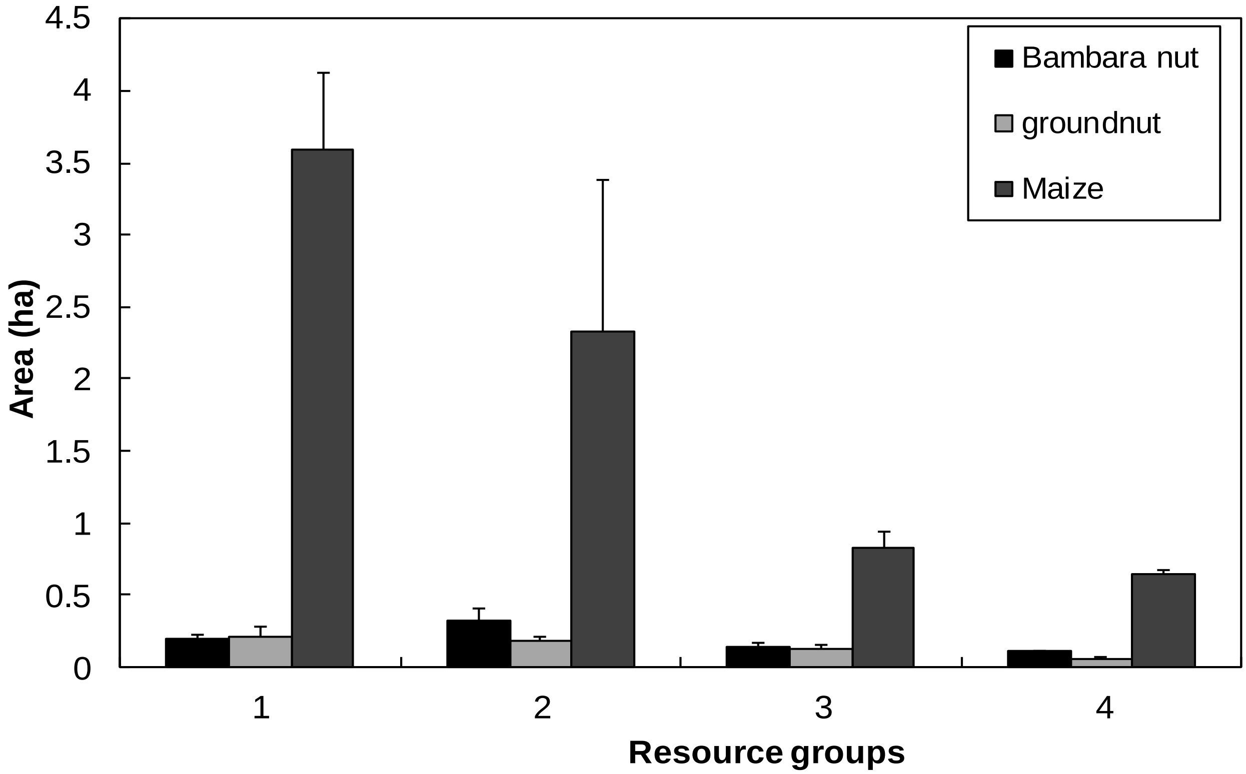

Figure 4. Mean areas (ha) of maize, groundnut and Bambara nut for the different RGs in Murehwa. Bars show standard error of means.

There was a significant difference ($p < 0.05$) in the average yield of Bambara nut and maize among the farmers in the four RGs in Murehwa district. Farmers in RG1 had the highest mean Bambara nut yield (2.43 t/ha) and the yields decreased in the pattern RG1>RG2>RG3>RG4. For maize RG2 farmers had the highest mean yield of 2.83 t/ha while RG4 had the least. There was no significant difference in the yields of groundnut attained by farmers in the respective RGs. Compared to common crops, groundnut recorded the highest yields with a grand mean of 1.81 t/ha. Farmers in RG1 had the highest groundnut yields (3.35 t/ha) while those in RG4 had the lowest mean yield (Fig. 5).

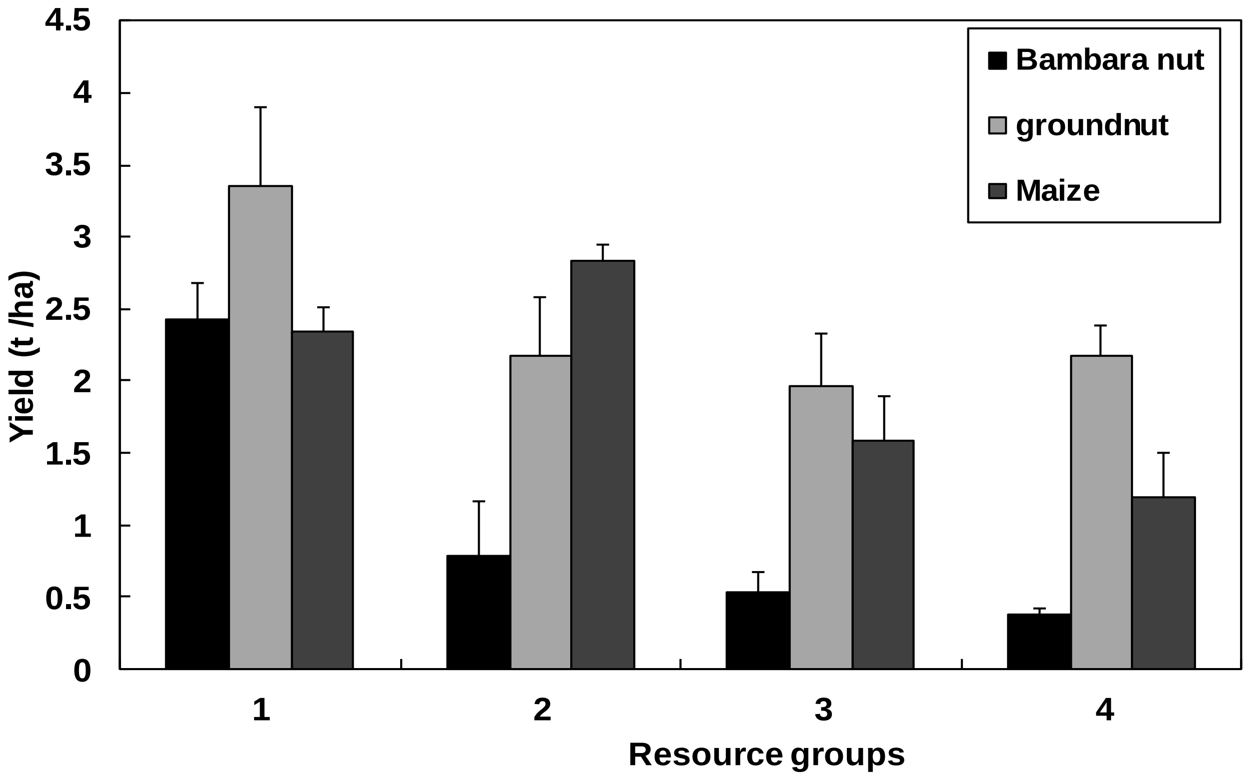

Figure 5. Mean grain yields of maize, groundnut and Bambara nut of farmers in different RGs in Murehwa. Bars show standard error of means

Of the twenty farmers considered for the study in Murehwa, only four grew soybean while seven grew common bean (Table 6). From these results it can be noted that groundnut, and Bambara nut were the most popular legumes while soybean was the least. The overall average area per farmer growing the two legumes in the district was 0.02 ha and 0.13 ha respectively. Common bean had an average yield of 0.94 t/ha while soybean had an average of 0.87 t/ha. In both districts, cowpea was mostly grown as an intercrop at very low plant populations without a defined pattern and this made determination of total area under the legume difficult. It was observed that 35 % of the farmers grew cowpea as a sole crop. The overall average area per farmer growing cowpea as sole crop was 0.07 ha and the yield attained was 0.39 t/ha.

Table 6. Number of farmers in the different resource groups growing legumes

	Mudzi				*Murehwa*			
	RG1	**RG2**	**RG3**	**RG4**	**RG1**	**RG2**	**RG3**	**RG4**
Groundnut	5	5	5	5	5	5	5	5
Bambara nut	5	5	5	5	5	5	5	5
Cowpea	5	4	4	4	5	5	3	3
Soybean	-	-	-	-	3	1	-	-
Common bean	-	-	-	-	4	3	-	-

3.3 Agronomic practices

It was noted that different farmers in different resource groups used varied agronomic practices to grow legumes and cereals. Generally more priority in terms of inputs and labour was awarded to maize at the expense of legumes. There was a disproportion in the allocation of labour by the farmers between the cereal and legume fields. The resource endowed farmers in RG1 and RG2 used both family and hired labour to do operations like land preparation, planting, weeding and harvesting. Priority in weed control was given to cereals where the farmers weeded at least two times while the legume fields were weeded at least once (Table 7). It was noted that some resource constrained farmers did not even control weeds in their legume fields and this resulted in production of a poor crop and low yields. Late harvesting by some of the resource poor farmers resulted in grain shattering of legumes such as cowpea. In some cases Bambara nut and groundnuts were already germinating while still in the fields because of light rains received towards the end of the growing season and this compromised the quality of the yields.

Table 7. Labour allocation between cereals and legumes by farmers in different resource groups

	Land preparation		*Planting*		*Weeding*		*Harvesting*	
	Cereal	**Legumes**	**Cereal**	**Legumes**	**Cereal**	**Legumes**	**Cereal**	**Legumes**
RG1	*Family + hire	Family	Family +hire	Family + hire	Family + hire (2-3 times)	Family (1-2 times)	Family +hire	Family and hire
RG2	Family + hire	Family	Family + hire	Family	Family + hire (2-3 times)	Family (1-2 times)	Family + hire	Family
RG3	*Family	Family	Family	Family	Family (2 times)	Family (none - once)	Family	Family
RG4	Family	Family	Family	Family	Family (2 times)	Family (none-once)	Family	Family

*Type of labour used- family labour or hired labour. Figures in parenthesis denote the frequency of weeding

3.3.1 Soil fertility management

Farmers in both Mudzi and Murehwa applied varied amounts of fertilizers to the different plot types and these fertilizers were particularly directed to maize crop. For the two districts, the resource poor farmers in RG3 and RG4 got inorganic fertilizers for free from some charity organisation so they managed to apply significant amounts in their fields. This season was an exception since the farmers do not regularly get the fertilizer allowances. These resource-constrained farmers also got animal manure from neighbours in exchange for labour. It was noted that about 75% of farmers in RG1 and 40% of those in RG2 in the two districts applied relatively lower quantities of cattle manure in their fields, than they applied in the previous season since they had applied larger quantities the previous season. In this instance the crops would therefore benefit from the residual fertility. There was no significant difference ($P > 0.05$) in the quantities of Ammonium nitrate (34% N), animal manure and Compound

D (with N: P: K composition of 7:14:7), that was applied by farmers in the four resource groups in Mudzi per hectare. There was a significant difference ($P < 0.05$) in the amounts of ameliorants such as composts, leaf litter, anthill soil used by farmers. Of the farmers interviewed, those in resource groups 1 and 2 did not use soil ameliorants while the farmers in RG 3 and 4 did. Farmers in RG3 had the highest quantity of ameliorants (2690 kg/ ha).

It was noted that most organic fertilizers contain about 2% N and the N:P ratio is approximately 4.3. Considering these ratios, the proportion of P in these organic ameliorants would be 0.47. In terms of quantities (kg ha^{-1} yr^{-1}) of nitrogen and phosphorus added to the fields, for Mudzi, farmers in RG 3 used the highest amounts organic N and P inputs while those in RG 1 used the highest inorganic N and P fertilizers (Table 8a). For Murehwa, farmers in RG2 applied the highest amounts of inorganic and organic N and P inputs (Table 8 b).

There were no significant differences ($P > 0.05$) in the amounts of organic and inorganic fertilizers applied per hectare by farmers in the four resource groups in Murehwa. Farmers in RG2 used the largest amounts of AN, Compound D and manure per hectare while those in RG4 used the highest quantities of ameliorants such as leaf litter, composts and anthill soil. On average farmers in Murehwa used more fertilizers compared to those in Mudzi. For both districts it was noted that home fields received the largest quantities of fertilizers, followed by midfields and then outfields (Tables 8 a and b).

Table 8. Quantities of organic and inorganic N and P (kg ha^{-1} yr^{-1}) applied to maize in the different plot types by farmers in different RGs in (A) Mudzi and (B) Murehwa

(A)

	Plot type	Compound D		AN	Animal manure		Other	
		N	P	N	N	P	N	P
RG1	1	5.60	11.20	25.50	40.00	9.40	-	-
	2	2.45	4.90	13.60	20.00	4.70	-	-
	3	0.70	1.40	3.74	11.76	2.76	-	-
RG2	1	2.80	5.60	23.80	18.00	4.23	-	-
	2	1.05	2.10	7.82	12.00	2.82	-	-
	3	0.00	0.00	0.00	6.00	1.41	-	-
RG3	1	0.63	1.26	6.12	24.00	5.64	24.00	5.64
	2	0.00	0.00	0.00	10.22	2.40	17.00	3.99
	3	0.00	0.00	0.00	-	-	12.84	3.02
RG4	1	1.54	3.08	23.80	-	-	12.00	2.82
	2	0.70	1.40	15.98	-	-	8.00	1.88
	3	0.00	0.00	0.00	-	-	3.98	0.94

(B)

	Plot type	Compound D		AN	Animal manure		Other	
		N	P	N	N	P	N	P
RG1	1	2.80	5.60	17.00	30.00	7.05	10.00	2.35
	2	1.82	3.64	16.32	20.00	4.70	4.40	1.034
	3	0.00	0.00	0.00	9.10	2.14	-	-
RG2	1	6.30	12.60	34.00	46.00	10.81	-	-

	2	3.50	7.00	19.04	36.00	8.46	-	-
	3	1.54	3.08	0.00	14.90	3.50	-	-
RG3	1	3.08	6.16	34.00	23.00	5.41	10.20	2.40
	2	0.00	0.00	14.96	8.00	1.88	6.00	1.41
	3	0.00	0.00	0.00	6.00	1.41	0	0.00
RG4	1	3.15	6.30	27.54	13.34	3.13	36.00	8.46
	2	0.00	0.00	0.00	0.00	0.00	22.48	5.28
	3	0.00	0.00	0.00	0.00	0.00	0	0.00

*Organic fertilizers include animal manure, composts, leaf litter and termitarium soil

**Inorganic fertilizers include Compound D and Ammonium nitrate

3.3.2 Crop allocation

On average farmers in the different resource endowment levels allocated a greater proportion of their fields to maize relative to legumes. The better endowed farmers in RG 1 and RG2 allocated relatively larger proportions of land to legumes in all plot types compared to farmers in RG3 and RG4 (Fig 6). The home fields for the farmers in RG3 and 4 were predominantly under maize. Land allocation to sweet potato and sunflower varied among the farmers in the different resource groups.

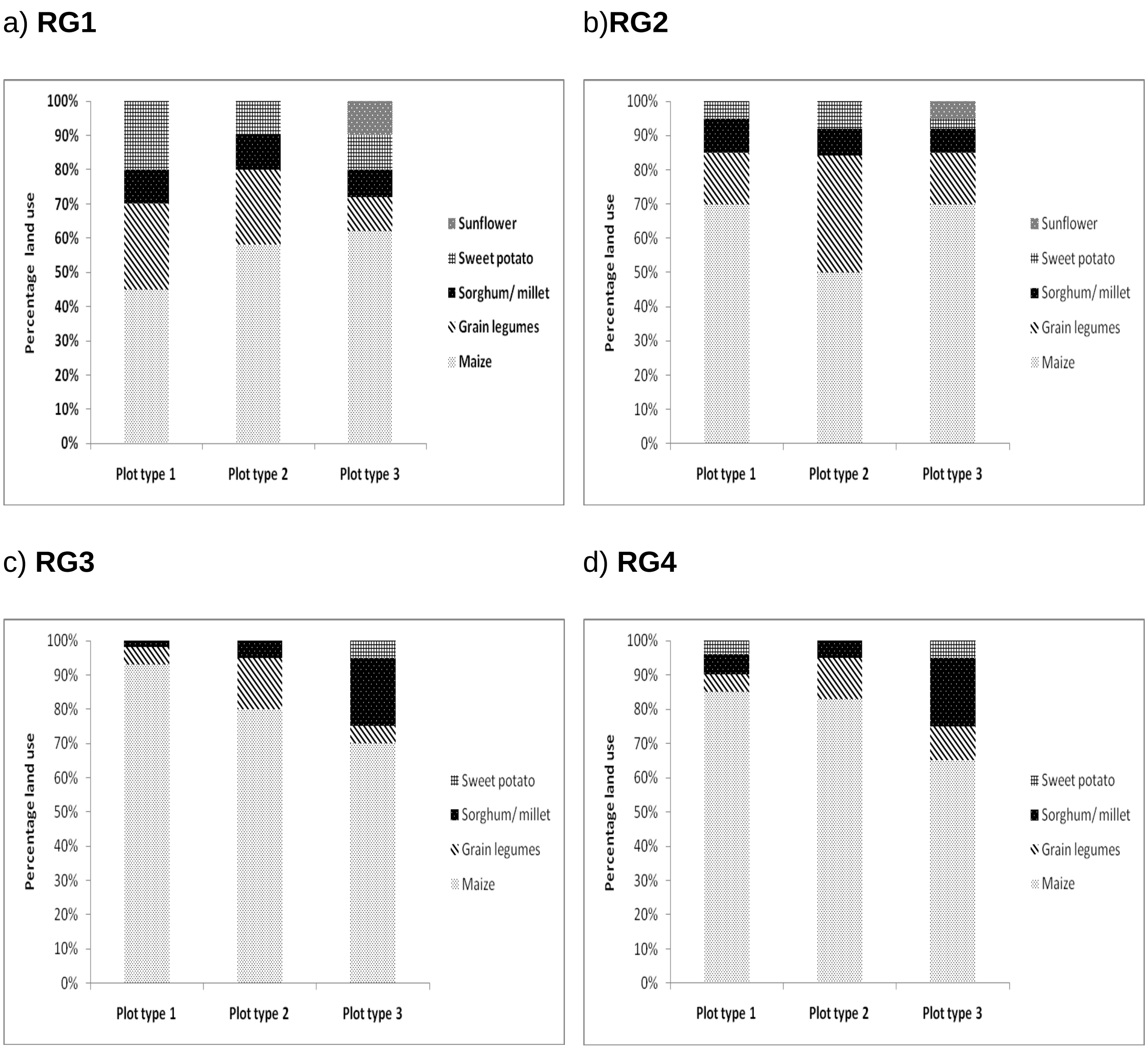

Figure 6. Allocation of different crops by farmers in different resource groups

3.3.3 Use of legume residues

It was noted that farmers from the different resource groups in Mudzi and Murehwa districts used the legume residues differently upon harvesting their legumes. Farmers showed some appreciation of the significance of the legume residues in improving soil fertility. In the two districts 100% of the farmers in RG 1 and 2 devoted most of their legume residues to livestock feed (Table 9). Most farmers in RG 3 and RG4 resorted to incorporating most of their residues in the fields or making composts. The farmers incorporated legume residues in the fields soon after harvesting their crops as the soils still had some moisture and thus they were relatively easy to work on. A small proportion of farmers burnt the residues in Mudzi (10% and 30% of the farmers in RG3 and RG4 respectively). For both Mudzi and Murehwa, farmers in RG 1 and RG2 did not leave legume residues fallow. On the other hand 60% and 50% of RG4 farmers in Mudzi and Murehwa respectively, left legume residues on the fields.

Table 9. Different ways of using groundnut, Bambara nut and cowpea residues (% farmers)

Use	***Mudzi***				***Murehwa***			
	RG1	**RG2**	**RG3**	**RG4**	**RG1**	**RG2**	**RG3**	**RG4**
Incorporated into field	40	40	20	20	40	30	20	10
Made composts	20	30	60	60	20	40	40	50
Fed to livestock	100	100	20	0	100	100	20	0
Left on the field	0	0	20	60	0	0	60	50
Burned	0	0	10	30	0	0	0	0

3.3.4 Cropping patterns

Based on the cropping history, it was noted that all legumes are preferentially grown as sole crops in both districts, except for cowpea which was mostly intercropped with cereals. Farmers in the different resource groups practised cereal/ legume rotation in varied ways. The majority of farmers in RG3 and RG4 in both Murehwa and Mudzi districts practised monocropping of maize in the fertile PT1 and PT2 fields and they had cereal/ legume rotations in the least fertile PT3 fields. On average 70% of the fields for the resource constrained farmers were under monocropping while 30% were under rotation. Farmers in RG1 and RG2 rotated cereals and legumes in PT2 and PT3 while fields under PT1 were mostly devoted to maize monocropping. On average 75% of the fields for the better resource endowed farmers were under rotation while 25% of the fields were under monocropping. The majority of farmers in both districts (80% and 97% respectively) perceived that cereal / legume rotation improved soil fertility more than intercropping. The farmers indicated that when cereals are intercropped with legumes, operations such as weed control are difficult to carry out.

3.3.5 Sources of legume seed

Majority of the farmers in the two districts used retained seed from their previous harvests for the legume crops such as groundnut, Bambara nut. All RG3 and RG4 farmers in both districts used retained seed which was either from their previous harvests or which they got from neighbours. In Mudzi 25% of the farmers in RG1 and 15% in RG2 purchased groundnut seed (Table 10). In Murehwa 30% of RG1 farmers and 15% in RG2 purchased seed. Farmers who grew soybean and common bean used certified seed while Bambara nut and cowpea seeds were retained. A few of the farmers used purchased groundnut seeds. The common groundnut varieties used by farmers are Valencia, Nyanda and Makulu Red.

Table 10: Sources of ground nut seed (% farmers)

Seed	***Mudzi***				***Murehwa***			
	RG1	**RG2**	**RG3**	**RG4**	**RG1**	**RG2**	**RG3**	**RG4**
Retained	75	85	100	100	70	85	100	100
Purchased	25	15	0	0	30	15	0	0

3.3.6 Constraints faced in legume production

Farmers faced similar challenges in legume production. From interviews conducted, the percentages of the interviewed farmers who considered the identified constraints (Table 11) were noted. The constraints for production of groundnut and Bambara nut, which are the major legumes produced in both Mudzi and Murehwa, which most farmers indicated, in order of importance, include, insufficient fertilizers > unavailability of quality seed > limited land > lack of inoculants > lack of markets > limited labour > lack of technical know- how > pests and diseases. It was observed that pests and diseases were not regarded as a significant constraint. All the farmers in RG 3 and RG4 in the two study areas indicated that labour was a significant constraint as they are solely dependent on family labour.

Table 11: Constraints faced by farmers in legume* production (% farmers)

	Unavailability of quality seed	Insufficient fertilizers	Pests and diseases	Limited land	Limited labour	Lack of technical know-how	Lack of inoculants	Lack of mar kets
Murehwa								
RG1	60	80	10	20	20	20	40	60
RG2	60	100	10	60	40	20	40	80
RG3	100	100	20	100	80	20	100	80
RG4	100	100	20	100	100	40	100	80
Mudzi								
RG1	80	100	20	40	20	20	40	60
RG2	100	100	20	60	20	40	60	80
RG3	100	100	40	100	100	60	100	80
RG4	100	100	40	100	100	60	100	80

*The legumes considered are groundnut and Bambara nut.

3.4 Legumes marketing

Farmers in Mudzi and Murehwa used their legume produce mainly for family consumption and they sold any surplus either to the local market, middle men or to larger urban markets. Farmers in RG1 and RG2 for both districts had higher yields and sold a larger proportion of their produce to local and urban markets, while those in RG3 and RG4 sold smaller proportions. Two farmers in RG1 in Murehwa indicated they sold their groundnut produce to Harare, which is the capital city, located 80 km away. Other farmers sold their produce locally and to middlemen since they could not afford transport costs to ferry their produce to the cities. It was noted that most of the farmers sold their legume produce soon after harvesting and at this time the market would be flooded and they are forced to sell at low prices. There was no structured marketing system in both Mudzi and Murehwa districts. The majority of farmers interviewed were exclusively reliant on farming so they depended on selling their produce for livelihood. Some farmers practised batter trade (exchange of produce for items of similar value) while others sold their produce for cash. The soybean and common bean grown by farmers in Murehwa was solely for family consumption; farmers would retain some grain as seed for the next season. Groundnut was the most commonly sold legume followed by Bambara nut (Table 12). Maize was grown mainly for family consumption by farmers in RG3 and RG4. The better resource endowed farmers sold their maize produce locally.

Table 12: Percentages of legume and maize yields use by farmers in the four RGs in Mudzi and Murehwa

	Groundnut	**Cow pea**	**Bambara nut**	**Soybean**	**Common bean**	**Maize**
***Not sold**						
RG1	20	80	60	100	100	30
RG2	20	100	80	100	100	30
RG3	50	100	100	-	100	60
RG4	70	100	100	-	100	80
Sold						
RG1	80	20	40	-	-	70
RG2	80	-	20	-	-	70
RG3	50	-	-	-	-	40
RG4	30	-	-	-	-	20

*The legumes that were not sold were used for family consumption

Most farmers in RG3 and RG4 in both Mudzi and Murehwa sold groundnuts as grain. Approximately 30% of farmers in RG1 and RG2 in the two districts processed the groundnut into peanut butter and realised higher profits. On average, 20 kg of unshelled groundnut was sold for US $ 4.00. However when the same amount of groundnut was shelled and processed into peanut butter, farmers would get an average of US $ 7.50. Farmers however preferred selling raw produce since the manual processing is labourious and time consuming and hiring a processing machine incurs costs.

3.5.1 Soil fertility status in Mudzi

There was no significant difference ($P > 0.05$) in the total soil N in the different plot types and across the resource groups in Mudzi. There was a significant difference in the pH of soils across the different plot types in Mudzi. Soil pH was highest in the home fields (PT1) and the least was recorded for mid fields (PT2). On average the pH of soils was 6.3. There was however no significant difference in the soil pH across the resource groups. There was a significant difference ($P < 0.05$) in the soil P across the plot types. For the four resource groups home fields had the highest P while midfields had the least P (Table 13a). There was no significant difference in the soil P across the resource groups. There was also no significant difference in the soil Mg among the different plot types and across the four resource groups. However home fields had the highest amounts of soil Mg and the quantities decreased with plot type; home fields >midfields >outfields. There was a significant difference in the soil Ca in the different plot types. Home fields had the highest amount of Ca while midfields recorded the least. Significant differences ($P < 0.05$) were also noted in the soil K among the different plot types in Mudzi. Home fields had the highest soil K while outfields recorded the least. There was no significant difference in the available K across the wealth classes. However the highly resource endowed farmers (RG1) had the highest soil K while RG3 farmers recorded the least (Table 13a). There was no significant difference in the proportions of organic carbon available in the soils in the different plot types and across the different resource groups. Home fields had the highest proportion of organic carbon (0.56%) while outfields had the least (0.42%). the C: N ratios ranged from 6.2 to 11.7.

3.5.2 Soil fertility status in Murehwa

There was no significant difference ($P > 0.05$) in the total soil N for the different plot types and across the four resource groups in Murehwa. However home fields had the highest % N while outfields had the least. Farmers in RG1 had largely the highest soil N. Significant differences ($P < 0.05$) were noted in the soil pH among the different plot types. The home fields were more alkaline while outfields were more acidic. There was a significant difference in the soil P among the three plot types. Home fields had the highest soil P followed by mid fields, outfields had the least. There was no significant difference in the soil P across the four resource groups. However the resource constrained farmers (RG4) recorded the highest soil P while RG3 farmers had the least (Table 13b). There was no significant difference in the soil Mg for the different plot types and across the wealth classes. On average RG4 had the highest soil Mg while RG2 farmers had the least. There was a significant difference in the soil Ca across the three plot types. Home fields had the highest soil Ca concentration while outfields had the least. There was no significant difference in the soil Ca across the wealth classes. Significant differences were also noted on the soil K among the different plot types. Home fields had the highest concentrations of soil K while outfields had the least. There was however no significant difference in the soil K across the wealth classes. The resource endowed farmers (RG1) had the highest amounts of soil K. There was no significant difference in the organic carbon proportions for the different plot types across the four resource groups. Although not statistically significant, differences were there in the organic carbon percentages across the plot types. The home fields had the highest proportion (0.63%) while the out fields had the least (0.52%). The C: N ratio ranged from 8.6 to 13.3. Results indicate a higher content of Mg relative to Ca in the plot type 3 of RG4 farmers; this is an indication that there is a problem. Higher levels of Mg relative to Ca result in soils having less oxygen, drainage will be slow and organic matter will break down poorly. There was a general trend of decrease in soil N, P, Ca, K and organic carbon from home fields>midfields>outfields this same pattern can also he noted with the amounts of fertilizers applied. Home fields received the highest amounts of nutrients while outfields received the least (Table 8). Farmers indicated that for any type of crop grown, they get the highest yields from the home fields while the least is attained in the outfields.

Table 13. Soil attribute characteristics in the different plot types for the farmers in different resource groups in (a) Mudzi and (b) Murehwa

(A)

		Soil attribute							
Farm type		**pH ($CaCl_2$) (0.58)**	**Organic C (%) (0.18)**	**Total N (%) (0.01)**	**C:N**	**Available P (ppm) (11.83)***	**Ca (cmol kg^{-1}) (464.3)**	**K (cmolkg^1) (55.71)**	**Mg (cmol kg^1) (38.93)**
RG1	**PT1**	6.50	0.56	0.06	9.3	41	4.45	0.45	0.95
	PT2	6.03	0.54	0.05	10.8	23	3.21	0.26	0.67
	PT3	6.23	0.58	0.06	9.7	33	3.88	0.28	0.89
RG2	**PT1**	6.75	0.53	0.06	8.8	51	5.25	0.39	0.87
	PT2	5.64	0.43	0.05	8.6	17	2.98	0.25	0.85
	PT3	5.65	0.32	0.04	8.0	21	2.78	0.26	0.71
RG3	**PT1**	7.38	0.40	0.05	8.0	30	4.72	0.29	0.75
	PT2	5.79	0.41	0.05	8.2	19	2.61	0.19	0.71
	PT3	6.13	0.42	0.04	10.5	25	3.87	0.22	0.67
RG4	**PT1**	6.60	0.70	0.06	11.7	43	6.69	0.34	0.83
	PT2	6.17	0.46	0.06	7.7	31	3.53	0.31	0.88
	PT3	6.31	0.37	0.06	6.2	33	3.54	0.25	0.82

(B)

Farm type		Soil attribute							
		pH ($CaCl_2$) (0.90)	Organic C (%) (0.23)	Total N (%) (0.0098)	C:N	Available P (ppm) (14.6)*	Ca (cmol kg^{-1}) (363)	K (cmol kg^{1}) (19.8)	Mg (cmol kg^{-1}) (46.1)
RG1	**PT1**	6.03	0.60	0.05	12	57.01	2.78	0.16	0.33
	PT2	5.00	0.54	0.05	10.8	24.72	1.28	0.09	0.18
	PT3	5.02	0.54	0.05	10.8	26.42	1.75	0.13	0.36
RG2	**PT1**	5.46	0.63	0.05	12.6	48.20	2.27	0.14	0.34
	PT2	4.40	0.48	0.04	12	42.33	0.62	0.08	0.22
	PT3	4.24	0.53	0.04	13.3	26.42	0.62	0.08	0.12
RG3	**PT1**	6.20	0.62	0.06	10.3	30.75	2.45	0.11	0.29
	PT2	5.25	0.61	0.05	12.2	23.64	1.97	0.12	0.30
	PT3	5.09	0.53	0.05	10.6	21.48	1.50	0.09	0.23
RG4	**PT1**	5.51	0.68	0.06	11.3	64.74	3.46	0.14	0.33
	PT2	4.82	0.43	0.05	8.6	33.84	1.54	0.14	0.20
	PT3	4.29	0.45	0.04	11.3	30.44	0.54	0.08	0.71

* Numbers in parentheses denote SED

3.6 Soil texture

Results from the Bouyoucos analysis showed that there was no significant difference in the proportions of sand, silt and clay in the different plot types across the different resource groups in Mudzi. On average, the soils had a higher sand content with a grand mean of 89.6%, relative to clay (6.3%) and silt (4.1%) (Table 14). Similarly for Murehwa there was no significant difference in the proportions of sand, silt and clay in the different plot types across the different resource groups. The grand means were, sand 88.1%, silt 5.3% and clay 6.5%.

Table 14: Proportions (%) of (a) clay (b) silt and (c) sand in the different plot types in (i) Mudzi and (ii) Murehwa districts.

(i) Mudzi			
Plot type	**Sand **(2.27)**	**Silt (1.56)**	**Clay (2.14)**
1	89.33	4.56	6.11
2	89.78	3.67	6.56
3	89.58	4.21	6.21
(ii) Murehwa			
Plot type	**Sand (2.77)**	**Silt (2.05)**	**Clay (2.64)**
1	88.20	5.10	6.70
2	88.10	5.30	6.60
3	88.10	5.60	6.30

**** numbers in parentheses denote SED**

3.7 Legume N analysis

In both Mudzi and Murehwa districts it was noted that there was a significant difference in the total N content among the different legumes. Legume samples were taken for analysis while they were still green and had the peak N content. Differences were noted in nitrogen proportions between the legume grain and legume biomass. Overally the legume grains contained more nitrogen than the biomass (leaves and stems). Soybean grain had the highest %N while common bean biomass had the least %N (Table 15).

Table 15. Mean Nitrogen content (%N) for the biomass and grain of different legumes

*Legume	Mudzi	Murehwa
Groundnut biomass	2.2 (1.4 - 3.3)	2.4 (0.9 - 3.6)
Groundnut grain	5.9 (5.4 - 6.7)	5.8 (4.7 - 6.3)
Bambara nut biomass	2.0 (1.3 - 3.0)	2.4 (1.5 - 3.1)
Bambara nut grain	3.2 (2.8 -3.8)	3.1 (2.6 - 3.4)
Cowpea biomass	3.1 (2.4 - 4.1)	3.0 (2.2 - 4.2)
Cowpea grain	4.5 (3.0 - 4.9)	4.4 (4.3 - 4.7)
Common bean biomass	-	1.7 (1.2 - 2.4)
Common bean grain	-	3.4 (2.9 - 4.2)
Soybean biomass	-	2.5 (1.3 - 3.1)
Soybean grain	-	6.7 (6.0 - 7.4)

Figures in parentheses denote minimum and maximum %N in legumes

*Legume samples were taken while they were still green, at physiological maturity

3.8 Nitrogen budget

The nitrogen balances for different legumes on a per hectare and per farm basis, are shown for the farmers in different resource endowment levels in both Mudzi and Murehwa districts, in grain and biomass is shown below (Tables 16a and 16b). If all legume residues will be either incoporated into the fields, fed to livestock, which will then leave some nutrients in their manure, or made into composts which will be added into the legume fields, then the legume fields will benefit from the N in legume residues.

An assumption made in formulating the Nitrogen budgets is that 70% of the total N in the legumes is fixed from the air N and that all grain will be removed from the fields. Incorporation of all legume residues in the fields results in a higher N balance in the soils relative to scenarios when 50% of the residues are incorporated in both districts (Table 16). However if none of the residues are retained to the fields there will be an overall loss of N from the soils, the soils therefore become less fertile than they were previously before the legumes were produced. Results show differences in nitrogen balance for the different farms on a per hectare and per farm basis. For the different legumes the nitrogen balances per farm basis is lower relative to per hectare basis since most farmers grow legumes at a small scale thus farms do not significantly benefit from biological nitrogen fixation.

Table 16. Partial N budget for farms in different resource groups in A) Mudzi and B) Murehwa

(A) i)

	N balance (kg/ha)				N balance (kg/farm)			
Bambara nut	**1** (5)	**2** (5)	**3** (5)	**4** (5)	**1**	**2**	**3**	**4**
N fixed by legume	54.75	23.00	17.18	39.31	3.74	3.60	4.13	1.45
Total N in grain	48.13	20.22	15.10	34.56	3.39	3.26	3.74	1.31
Total N in residues	30.08	12.64	9.44	21.6	1.95	1.88	2.16	0.76
N balance (0% residue incorporated)	-23.46	-9.86	-7.36	-16.85	-1.60	-1.54	-1.77	-0.62
N balance (50% residues incorporated)	-8.42	-3.54	-2.64	-6.05	-0.63	-0.60	-0.69	-0.24
N balance (100% residues incorporated)	6.62	2.78	2.08	4.75	0.35	0.34	0.39	0.14

(ii)

	N balance (kg/ha)				N balance (kg/farm)			
Groundnut	**1** (5)	**2** (5)	**3** (5)	**4** (5)	**1**	**2**	**3**	**4**
N fixed by legume	179.53	153.57	99.50	90.85	22.93	17.66	18.17	14.35
Total N in grain	146.91	125.67	81.42	74.34	18.76	14.46	14.87	11.74
Total N in biomass	109.56	93.72	60.72	55.44	13.99	10.78	11.09	8.76
N balance (0% residues incorporated)	-76.94	-65.82	-42.64	-38.93	-9.83	-7.57	-7.79	-6.15
N balance (50% residues incorporated)	-22.16	-18.96	-12.28	-11.21	-2.83	-2.18	-2.24	-1.77
N balance (100% residue incorporated)	32.62	27.90	18.08	16.51	4.17	3.21	3.30	2.61

**** Numbers in parentheses denote the number of observations**

(B) i)

Bambara nut	N balance (kg/ha)				N balance (kg/farm)			
	1 (5)	2 (5)	3 (5)	4 (5)	1	2	3	4
N fixed by legume	93.56	30.03	20.41	14.63	248.57	161.01	146.17	161.01
Total N in grain	75.33	24.18	16.43	11.78	194.3	125.86	114.26	125.86
Total N in residues	58.32	18.72	12.72	9.12	160.8	104.16	94.56	104.16
N balance (0% residues incorporated)	-40.10	-12.87	-8.75	-6.27	-106.5	-69.01	-62.65	-69.01
N balance (50% residues incorporated)	-10.94	-3.51	-2.39	-1.71	-26.13	-16.93	-15.37	-16.93
N balance (100% residues incorporated)	18.23	5.85	3.98	2.85	54.27	35.15	31.91	35.15

(ii)

Groundnut	N balance (kg/ha)				N balance (kg/farm)			
	1 (5)	2 (5)	3 (5)	4 (5)	1	2	3	4
N fixed by legume	248.57	161.01	146.17	161.01	15.66	13.73	9.72	4.08
Total N in grain	194.3	125.86	114.26	125.86	12.24	10.73	7.60	3.19
Total N in residues	160.8	104.16	94.56	104.16	10.13	8.88	6.29	2.64
N balance (0% residues incorporated)	-106.53	-69.01	-62.65	-69.01	-6.71	-5.88	-4.17	-1.75
N balance (50% residues incorporated)	-26.13	-16.93	-15.37	-16.93	-1.65	-1.44	-1.02	-0.43
N balance (100% residues incorporated)	54.27	35.15	31.91	35.15	3.42	2.99	2.12	0.89

(ii)

Common bean	N balance (kg/ha)				N balance (kg/farm)			
	1 (3)	2 (2)	3 (1)	4 (1)	1	2	3	4
N fixed by legume	0.03	0.029	0.024	0.028	4.49	13.28	0.42	0.00
Total N in grain	0.03	0.028	0.023	0.027	4.39	12.99	0.41	0.00
Total N in residues	0.01	0.014	0.011	0.013	2.02	5.99	0.19	0.00

N balance (0% residues incorporated)	-0.01	-0.012	-0.010	-0.012	-1.92	-5.69	-0.18	0.00
N balance (50% residues incorporated)	-0.005	-0.006	-0.005	-0.005	-0.911	-2.69	-0.085	0.00
N balance (100% residues incorporated)	0.0014	0.0014	0.0011	0.0013	0.099	0.29	0.0093	0.00

(iii)

	N balance (kg/ha)				**N balance (kg/farm)**			
Soybean	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
	(1)	(1)	(1)	(1)				
N fixed by legume	39.31	8.19	44.23	36.04	15.40	25.80	11.47	8.68
Total N in grain	32.16	6.70	36.18	29.48	12.60	21.11	9.38	7.10
Total N in residues	24.00	5.00	27.00	22.00	9.40	15.75	7.00	5.30
N balance (0% residues incorporated)	-16.89	-3.51	-18.95	-15.44	-6.60	-11.06	-4.91	-3.72
N balance (50% residues incorporated)	-4.848	-1.01	-5.45	-4.44	-1.90	-3.18	-1.41	-1.07
N balance (100% residues incorporated)	7.15	1.49	8.05	6.56	2.80	4.69	2.09	1.58

(iv)

	N balance (kg/ha)				**N balance (kg/farm)**			
*****Cow pea**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
	(4)							
N fixed by legume (kg/ha)	20.75	0	0	0	3.61	0	0	0
Total N in grain	17.55	0	0	0	3.15	0	0	0
Total N in residues	12.09	0	0	0	2.00	0	0	0
N balance (0% residues incorporated)	-8.89	0	0	0	-1.55	0	0	0
N balance (50% residues incorporated)	-2.85	0	0	0	-0.54	0	0	0
N balance (100% residues incorporated)	3.20	0	0	0	0.46	0	0	0

****Numbers in parentheses denote number of observations**

4. Discussion

4.1 Field and farm characterisation

Characterization of farms was done based mainly on cattle ownership. This is because cattle are socially considered as a source of wealth. They are a capital investment and contribute to food security as a source of meat and milk. They provide draught power and are used in preparation of fields before the growing season. Cattle feed on crop residues and leave behind nutrients in the form of manure thus increasing crop production. Farmers in Murehwa under RG1 owned an average of 14 cattle while those in Mudzi had an average of 10 cattle. The differences in resource endowment between the rich and poor farmers have an impact on the farmers' operations and overall productivity. The criteria used in this research to characterize farmers, indicates that those who are resource endowed have the capacity to purchase mineral fertilizers, to hire labour (for ploughing, weeding and harvesting) and they had manure to apply to crops while the resource constrained farmers are challenged in the respective areas (Table 1). Our findings have shown that resource poor farmers did apply fertilizers on their fields, which they got from charity organizations. They applied animal manure which they got from neighbors in exchange for labour. As a result of this it was noted that there was no significant differences in the amounts of fertilizers used by farmers in the different resource groups (Table 8a and 8b) in both Mudzi and Murehwa. These findings are in contrary to those by Zingore (2006) which showed that the quantities of fertilizers used by smallholder farmers decreased in the pattern RG1> RG2> RG3> RG4. The characterization of fields within the plots was based mainly on the farmers' experience and records of the fields 'performance over the past growing seasons. Results from the analysis of soil texture showed that there was no significant difference in the proportions of silt, sand and clay (Fig. 8) for the different plot types within the farms and among the different farms from the two districts. This confirmation is important as it explains that any difference in soil fertility and productivity among the different plot types is mainly due to differences in management of the fields.

4.2 Productivity trends of legumes relative to maize

As is the trend for most of smallholder farmers in Sub Saharan Africa, including Zimbabwe, the results of the study showed that in both Mudzi and Murehwa communal areas, maize dominated other crops in terms of total area cropped (Table 5). This is because maize is the staple crop in Zimbabwe and it is an important cash crop ensuring food security (Zingore, 2006, Kumwenda, 1998). These results concur with reports by Giller (2001) and Mapfumo (2001) who reported that most smallholder farmers in Sub Saharan Africa, including Zimbabwe prefer growing cereals at the expense of legumes. Since relatively smaller areas compared to maize, were allocated to legume production, very small amounts of legume biomass is produced per farm and this may not contribute significantly to the farm N budget. There will be minimal BNF thus little N is added to the fields. The disproportionality of areas allocated to legumes relative to maize and other cereals makes it difficult to have a systematic cereal/ legume rotation (Chikowo et al. 2006).

In the two sites the average yield of maize outweighed that of other legumes, with the exception of groundnuts, for the four resource groups (Table 5). This was mainly because farmers preferentially applied more manure and fertilizers in homefields and these were largely under maize (Table 8a and 8b). Groundnuts gave higher yields than maize in both districts, recording an average of 2.42 t/ha in Murehwa and 1.81 t/ha in Mudzi. This shows that groundnuts have the potential to perform well even under low moisture conditions as Mudzi is a low rainfall area. Despite the fact that the farmers in both districts did not apply fertilizers to the groundnuts, the legume performed significantly better than maize (Table 5). Relative to maize, groundnuts were grown on smaller land area despite its high yields and this could be attributed to the reason that most farmers still have the mentality of majoring in maize production as it is the staple crop. In the two districts, groundnuts and Bambara nut were mainly grown as sole crops while cowpea was mostly intercropped with maize. Few farmers in Murehwa grew soybean and common bean, while none grew these legumes in

Mudzi. This was due to the low rainfall received in Mudzi which does not favor growth of soybean and common beans.

Productivity of legumes varies markedly with agro-ecological zones (Ojiem, 2006). On average, both maize and legumes performed significantly better in Murehwa than in Mudzi. This was mainly due to differences in rainfall patterns of these two districts as well as differences in soil fertility. Murehwa is a high potential area receiving an average of 750-1090mm rainfall per year and is characterized by rich clayey soils while Mudzi receives an average of 450-650mm per year and has mainly sandy soils with low nutrient content. Soil analysis results showed that soils in Mudzi had higher levels of cations (Mg, K, Ca) while those in Murehwa had lower levels (Table 13). Despite the lower cation levels in Murehwa soils, higher yields of legumes and maize were attained. This could be because the cations are not growth limiting. Murehwa is characterized by better rainfall relative to Mudzi and this leads to higher yields in Murehwa.

On average the resource endowed farmers in Resource groups 1 and 2 in both Mudzi and Murehwa had higher maize and legume yields than the farmers in RG3 and 4 despite the fact that there was no significant difference in the quantities of fertilizers used. This could be attributed to past management of the fields by the farmers. The acquisition of inorganic fertilizers by the farmers in RG 3 and 4 is not regular but the resource endowed farmers used large quantities of fertilizers each season. As it was noted in the study, farmers do not deliberately apply fertilizers to legumes, rather legumes benefit from the residual fertility when legumes are grown in rotation with cereals.

4.3 Agronomic practices adopted by different farmers

From the study it was noted that there were no significant differences in the amounts of both inorganic and organic fertilizers (excluding ameliorants) applied by farmers in the different resource groups in both Murehwa and Mudzi. This is in contrary with those by Zingore (2006) and Zingore et al. (2007) who observed that fertilizer use in smallholder farms decreased in the order RG1>RG2>RG3>RG4. Usually such differences in resource endowment among farmers of the different resource groups would result in marked differences in their productivity potentials with the rich farmers attaining significantly higher yields. It was noted in this study that although farmers in RG3 and RG4 did not own cattle, from which they could get manure, they had to work on the farms of the rich farmers and in exchange for their labour they would be given manure. The resource constrained farmers got mineral fertilizer as special allowance from a charity organisation thus boosting their soil fertility. This is however not sustainable as they do not get these allowances regularly. Most of the RG1 farmers do not apply large quantities of cattle manure each season, rather after an enormous application they leave the manure to accumulate for at least a year before applying large amounts again.

In the two districts it was noted that there was no significant difference ($P > 0.05$) in the total soil macro and micro nutrients across the four resource groups. Significant differences were noted in the proportions of P, Ca and K across plot types in both districts. However there were no significant differences in the total N, Mg and organic carbon in both districts. The proportions of these soil attributes followed a pattern home fields > mid fields > outfields (Table 13). This is as a result of differences in the management of different plot types. Farmers preferentially applied larger quantities of organic and inorganic fertilizers in the home fields than in midfields and outfields (Table 8a and 8b). This confirms reports by Tittonell et al. (2005b), Ojiem (2006), Zingore (2006), Masvaya et al. (2010) and Mtambanengwe and Mapfumo (2009) that there are differences in nutrient resource management strategies by smallholder farmers. The smallholder farmers prefer investing their labour and inputs where returns are already favourable.

In order to determine the N: P ratios of the organic soil ameliorants added to different plot types in both districts (Table 8a and 8b), average ratios were used from previous research (Murwira et al., 2002). It was noted that most organic fertilizers contain about 2% N and the N: P ratio is approximately 4.3. Considering these ratios, the proportion of P in these organic ameliorants would be 0.47. There could be a weakness in considering this as an overall N: P ratio because there is a lot of variability in nutrient levels between different organic fertilizers and even within the same type of ameliorant. According to Giller et al. (1997) there occurs variability in nutrient contents of different cattle manures due to differences in the cattle's diets and also due to difference in the ways that manure is collected and stored. In order to determine the actual amounts of N and P contributed by organic fertilizers we should have analyzed manure samples from the particular farmers under study.

Most of the smallholder farmers indicated that when cereals are intercropped with legumes, it would be difficult to carry out operations such as weeding the legumes which then grow in shady conditions would not perform optimally. There would be competition for moisture and nutrients with the main cereal crop. Given these concerns, there would be need to ensure compatibility between the legume used as an intercrop and the cereal, for example, a variety could be chosen which thrives under low light conditions and which has a rooting system different from that of the cereals such that it can utilize nutrients and moisture from a deeper or lower level than the cereal. According to Nhamo and Mapangwa (2000) the benefits of cereal/ legume intercropping in improving soil fertility may not be realized because of moisture and nutrient constraints. Intercropping ensures optimal land utilization as higher yields will be realized per hectare of land. Results from plant N analysis showed that for all the legumes under study, grain has a higher proportion of N than the biomass (Table 15). For grain legumes, part of the N fixed is exported in the grain and thus this does not contribute to N input of the field. It therefore follows that the benefit of grain legumes to soil fertility largely depends on how their residues are utilized. Grain legumes with large N harvest indices contributed very little N to the soil (Chikowo et al., 2006). Farmers in RG1 and RG2 used most of their residues for livestock feed. The farmers would then benefit from manure produced by the livestock. However quality of manure depends on animal feed as well as where the manure is deposited (Giller et al., 1997) since some nutrients can be lost through volatilization.

In scenarios where the legume residues are to be removed from the fields for making composts or to be used as animal feed, the fields in which they were grown may not necessarily benefit from N enhancement. This is because most of the N will be in the seed and biomass and so there may be an overall mining of N leaving the soils in a worse state.

Most farmers in RG 3 and 4 used their legume residues to make composts since they did not own livestock. Some of these resources poor farmers could not afford to make composts since this is labourious. As a result some resorted to burning while others just left the residues in the fields. The ash from the burned residues was used to fertilize the fields, to control some pests and to lime the soils. However the benefit derived from burning is minimal compared to the loss of nutrients incurred in the process. Part of the residues which were left on the fields would decompose and add fertility to the fields. However most of these residues would be eaten by the cattle and other livestock belonging to the rich farmers as the livestock were allowed to freely graze once crops were harvested from the fields. This results in the exportation of nutrients from the poor farmers to the rich as the cattle will graze and provide manure to the owners. A wider divergence in nutrient gradients is therefore created as the rich farmers will have more nutrients than the resource constrained farmers.

On average, higher yields of legumes were recorded from farmers in RG1 and 2 for both Mudzi and Murehwa districts. As the legumes are grown in rotation with maize, there could be some residual effect from fertilizers and manures applied to the fields in the previous seasons. The farmers in RG1 and RG2 use more organic and inorganic fertilizers compared to those in RG3 and RG4, hence better yields. This concurs with the report by Nhamo and Mupangwa (2000) that grain legumes require nutrients for high yields to be realized.

Most farmers in Mudzi and Murehwa districts indicated that lack of lucrative markets is one of the major constraints in legume production (Table 11). There are no structured marketing channels. As a result the farmers do not have the bargaining power and thus may be forced to just sell their produce at very low prices to the local market as well as some middlemen. Most of the farmers cannot afford to send their produce to the urban markets since transport is expensive. As a consequence of the low returns, farmers are not motivated to invest much in legume production, in terms of purchase of fertilizers, pesticides, inoculants as well as planned agronomic practices such as timely weeding, early planting and use of optimal plant populations. Farmers mainly in RG3 and RG4, were forced to sell their produce at low prices just soon after harvesting since the market would be flooded. The farmers' failure to hold on to their produce was because most of them did not have other forms of livelihood. Instead they depended solely on agriculture for survival. The farmers sold their legume produce to get money for school fees, to pay hospital bills and also that they could buy other food items and clothing. The results also showed that about 70 % of farmers in both Mudzi and Murehwa did not add value to their legume produce, rather they just sold them as grain. About 30 % of the farmers made peanut butter out of groundnuts and sold at higher prices than they would have sold the groundnut as of grain.

Of the legumes produced in both Mudzi and Murehwa, groundnuts was noted to be the most popular crop in terms of yields produced and proportions sold for income (Table 12). Despite the lack of lucrative markets, farmers in the two districts under study fetched higher income through selling groundnuts relative to maize. This shows a great potential in groundnut as an income generating legume. Also results from N analysis showed that groundnut had a relatively higher N content in both grain and biomass. It therefore follows that incorporating the residues back in the fields would help increase soil fertility.

From this study we noted various ways in which farmers used their legume residues (Table 9). However we did not quantify the exact amounts of residues used in these different ways. Having such precise data would help determine the nutrient distribution within the farms. Records of quantities of yields produced and of organic and inorganic fertilizers applied by the different farmers in the respective plots within their farms, was based on what the farmers recalled and not based on written records. This could be a source of error.

4.4 Opportunities to ensure expansion of legume production

From this study a number of opportunities for expansion of legumes can be identified. There is need to increase area under legumes by the smallholder farmers in both districts since at present, legumes are allocated to smaller areas than maize. More nitrogen will thus be fixed through biological nitrogen fixation and this will improve production of the succeeding crops. The legume biomass may also be incoporated back into the fields to add soil fertility. When farmers attain high grain yields, they will get substantial profits on selling the produce.

Priority should be given to legumes in the production practices such as fertilizer application, weeding, use of certified seeds. By practising systematic cereal - legume rotations, cereals will benefit from nitrogen fixed by the legumes. There is need for careful use of the legume residues to ensure that nutrients are retained in the soils. Farmers should apply fertilizers in all fields (home fields, midfields and outfields) in a uniform way so as to enhance soil fertility. From the study it was noted that most farmers apply more fertilizers to the home fields since these have the highest production potential. Results from soil analysis showed that there are no significant differences in the soil texture across plot types for farmers in the different resource groups. This implies that the fields have a potential to give high yields if sufficient amounts of fertilizer are applied uniformly in the different fields within the farms

Markets for legume produce should be promoted so that farmers can send in their produce and sell at lucrative prices. There is need to promote value addition in such legumes as groundnut whereby farmers can make peanut butter and fetch more profits.

The significance of legumes in contributing to soil fertility depends on how the residues are used. Incoporation of large proportions of the legume residues into the soils ensures that nutrients are retained in the fields, however if they are exported, this may result in a net reduction in soil N in the fields were the legumes would have been grown.

5. Conclusion

From this research it can be concluded that:

1. There are differences in the current productivity of grain legumes relative to maize by smallholder farmers in Mudzi and Murehwa; maize is allocated more land and more fertilizers than legumes per farm.

2. Groundnuts performed relatively better than maize, on a per hectare basis, in both Mudzi and Murehwa in terms of yields

3. Groundnut and Bambara nut are commonly grown in both Mudzi and Murehwa while soybean and common bean are grown at very low scale in Murehwa

4. Productivity of legumes differs with agro ecological regions. Mudzi, a low rainfall area had lower legume yields than Murehwa which receives more rainfall.

5. The resource endowed and resource constrained farmers use different quantities of fertilizers and these results in differences in their productivity.

6. Both the rich and poor farmers tend to prioritize applying larger amounts of fertilizers to home fields at the expense of outfields and this creates differences in fertility regimes within farms.

7. There is need to promote optimal agronomic practices and to have organised marketing channels in order to boost legume productivity in Mudzi and Murehwa districts.

8. For farmers to benefit from biological nitrogen fixation there is need to incorporate the legume stover into their fields.

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