Productivity of Maize (*Zea mays* L.) and Mung bean (*Vigna radiate* L. Wikzek) in Homegardens and Cropping Fields under Subsistence Conditions

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ABSTRACT. *Low sustainability is an inherent character of tropical smallholder farming systems. These systems can be developed through sustainable agricultural practices such as inclusion of green manure (eg: <u>Gliricidia</u> <u>sepium</u>). Field experiments were conducted using three treatments (T_1- NPK + 3 t/ha Gliricidia, T_2- Zero fertilizer + 3 t/ha Gliricidia and T_3 – zero fertilizer + zero Gliricidia) to assess the productivity of maize (<u>Zea</u> <u>mays</u> L.) and mung bean (<u>Vigna</u> <u>radiate</u> L. Wikzek) in homegardens and extensive cropping fields in the 2007/8 maha and 2008 yala seasons located on three elevation categories [flat (slope < 10%), moderate (slope 10 - 30%) and steep (slope > 30%)] in the Meegahakiula region of Sri Lanka. The study included 30 homegardens and adjacent cropping fields to represent different elevation categories. Soil samples were obtained initially by considering the rooting depth of maize at 10 cm intervals up to a 60 cm depth to determine changes in fertility. Plant samples were obtained at full crop maturity to quantify biomass production and seed yields. Incorporation of green manure improved the soil properties of homegardens significantly when compared to cropping fields, although the impact declined with increasing inclination and the soil depth. The decline in soil properties was greater in fields than in homegardens. The greatest yield improvement of maize and mung bean in terms of total biomass and seed was observed in homegardens in the flat and moderate elevation categories. However, the yields of steep fields were better than that of homegardens in the same elevation class, which indicate the significance of fallowing. The higher productivity of homegardens under subsistence conditions was clearly observed in this field study.*

INTRODUCTION

Degradation of natural resources is most serious in many developing countries (Cairns and Garrity, 1999). Poor soil fertility is widely accepted as a major factor limiting productivity of smallholder farms in Asia. Inability to access required amount of mineral fertilizer, causes an exhaustion of soil fertility with frequent cropping (Ayoub, 1999). In the past, land fallowing was a method used widely for rehabilitation of soil fertility (Beets, 1990).

The Meegahakiula region of Sri Lanka is a typical example of tropical smallholder upland farming systems, which are associated with soil degradation, low productivity and poor livelihoods (Fox *et al.*, 2000). The region is characterized by high gradient slopes ranging

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from 40 – 80%. In this region, two systems of farming were identified as homegardens and cropping fields. Intensive nutrient management strategies (e.g: inclusion of green manure, organic matter *etc.*) are adopted in homeghardens while the cropping fields had been managed as shifting cultivations with annual food crops and tobacco for many years. With successive reduction of the yields and government policies, the tobacco cultivation shifted from this site to other locations and people in this area were left with barren landscape and poor soils. Since the vegetation cover was lost, the land was subjected to severe erosion aggravating the condition. As a solution, *Gliricidia sepium* (Jacq.) Walp, a leguminous green manure was introduced in 2001 to this region and was integrated to farming systems. Green Manure (GM) was used primarily as a soil amendment and a nutrient source for subsequent crops and could provide an alternative source of fertilizers. Many studies on the impact of trees on field crop productivity of smallholder units have been carried out in Africa, with special emphasis on alley cropping (Vanlauwe *et al*., 2005). In South Asia, such studies are seldomly reported although over 30% of the world's population live in this region. The use of green manures, especially *G. sepium* in homegardens for maintaining productivity over time has not been clearly defined as most studies highlight its use in alley cropping or extensive field conditions. The hypothesis of this study was that the productivity of homegardens is greater than that of fields since the abundance of *G. sepium* is high in the experimental region. Similarly, it was assumed that the productivity of both farming systems (homegardens and fields) declines with increasing gradient and that decreasing rate is greater in cropping fields than in homegardens. Based on these assumptions, a study was carried out to assess the productivity of maize and mung bean in homegardens and cropping fields under subsistence conditions, in the two cultivation seasons of *maha* and *yala* respectively.

MATERIALS AND METHODS

Location

The study, which was carried out for one year spanning two planting seasons (2007/8 *maha* and 2008 *yala*), was sited in the Wallapane valley of the Meegahakiula region of Sri Lanka ($81^002.740^1$E, $7^007.485^1$N) (IM_{1c} agro ecological zone). The landscape of the study region is rolling and hilly type with slopes ranging from 40 – 80% (elevation – 327 m above MSL). According to the General Soil Map of Sri Lanka, the test site is located in a region where Red-Yellow Podzolic Soils (Mahawalatenna Series; USDA: Ultisols - Udults - Rodudults, Tropudults) and Mountain Regosols predominate (Panabokke, 1996). The average rainfall of the region is greater than 1300 mm per annum at 75% probability level (Punyawardena *et al*., 2003). The mean temperature is 28 ^{o}C. The major season (*maha*) begins in October and lasts until the end of January. The area receives 78% of the total rainfall, thus farmers grow crops such as maize during this season. The minor season begins in April and lasts until the middle of June. During the minor season of the year the study area receives only 22% of the total rainfall. Therefore, farmers grow short duration crops such as legumes in this season. The area experiences drought from June to September.

Selection of farming systems

Within the test site, three slope categories were identified as flat (gradient < 10%), moderate (gradient 10 – 30%) and steep (gradient > 30%). Ten homegardens and adjacent fields were selected from each elevation category, in order to have an equal representation from each slope category. Thus, 30 homegardens and 30 farming fields were selected on the basis of 10 per land class. The selected number of homegardens represents approximately 40% of the total homegardens available in the region.

Field planting – major season (2007/8 *maha*)

Selected homegardens and adjacent cropping fields were planted with maize (*Zea mays* L.) (variety Ruwan, an open pollinated variety - OPV) during the 2007/08 *maha* season (spacing 60 x 30 cm). An experimental plot of 30 m x 30 m was marked in each selected site and it was divided into 3 equal parts to accommodate treatments (T_1- NPK + 3 t/ha *Gliricidia*, T_2- Zero fertilizer + 3 t/ha *Gliricidia* and T_3 – zero fertilizer + zero *Gliricidia*) which were distributed randomly. Management practices and the fertilizer application (Basal -N- 23 kg / ha, P_2O_5- 46 kg/ha, K_2O- 36 kg/ha and top dressing N-23 kg/ha) were based on the recommendation of the Department of Agriculture, Sri Lanka. (DOA, 1997)**.** Plant samples were obtained at crop maturity to quantify total biomass and seed yields using 5 randomly selected plants per subplot. The plant samples were oven dried at 60 ^{0}C for 48 hours and the total biomass yield was calculated for each treatment per unit area (t/ha). The maize cobs of the sub samples were weighed before shelling and the grain yield was weighed after shelling for each treatment. Soil samples were obtained at the beginning of the *maha* season before the planting of maize by considering the rooting depth of it at 10 cm intervals up to a 60 cm depth (0 - 10, 10 - 20, 20 - 30 and 30 - 60 cm) (three replicates per depth). Soil samples were oven dried and were analyzed for five chemical parameters: soil pH (pH meter), organic matter (Walkley and black method (van Ranst *et al.*, 1999)), total N (Kjeldahl (van Ranst *et al.*, 1999)), available P (Olsen and Sommers, 1982)), and exchangeable K (Knudsen *et al.*, 1982).

Field planting - minor season (2008 *yala*)

The selected homegardens and cropping fields were planted with mung bean (variety – MI 6) during the minor season on plots at equal spacing of 15 cm along the rows and 45 cm apart in the rows. The size of an experimental plot was 5 x 5 m and it was divided into 3 equal parts to accommodate three treatments (T_1- NPK + 3 t/ha *Gliricidia*, T_2- Zero fertilizer + 3 t/ha *Gliricidia* and T_3 – zero fertilizer + zero *Gliricidia*) which were distributed randomly. Management practices and the fertilizer application (Basal -N- 16 kg/ha, P_2O_5- 70 kg/ha, K_2O- 45 kg/ha and top dressing N-14 kg/ha) were based on the recommendation of the Department of Agriculture, Sri Lanka (DOA, 1997)**.** Plant samples were obtained at crop maturity to quantify total biomass and seed yields.

In both seasons, *Gliricidia sepium* was added two weeks prior to the planting of maize and mung bean to facilitate decomposition. Application of *G. sepium* green leaf manure was based on the fresh weight (FW) and the application rate was 3 t/ha. Since the homegardens cannot be replicated, the experimental set-up was a randomized complete block design with one replicate per site. Analysis of Variance (ANOVA) was performed on the data to determine significant differences in soil properties and yield of these two crops in homegardens and cropping fields in three elevation categories. The LSD (p = 0.05) test was used to determine significant differences among means. All the data were subjected to General Linear Model (GLM) and the SAS (SAS Institute Inc, 1999) programme was used to analyze the data.

RESULTS AND DISCUSSION

Soil properties in homegardens and cropping fields

The soil organic matter content (%) at each depth differed significantly ($p<0.05$) along the gradient of the study region in both farming systems (Table 1). Furthermore, mean organic

matter (%) content declined significantly (p<0.0001) with increasing slope in both farming systems. Surface soil layers (0 - 10 cm) in both farming systems at each slope category contained relatively high amount of organic matter. However, the soil organic matter content in fields at each elevation class of the study region decreased significantly with increasing soil depth (p<0.05). This was not significant in homegardens of the flat (p = 0.34) and moderate (p = 0.82) slope categories (Table 1). In contrast, organic matter content of homegardens in the steep elevation class decreased significantly (p<0.01) with increasing soil depth. The total nitrogen content (mg N g^{-1} soil) of the soil followed the same pattern as that of organic matter. The total N content at each soil depth differed significantly (p<0.05) along the gradient in the study region (Table 2). In addition, the mean total N (mg N g^{-1} soil) content declined with increasing slope significantly (p<0.05) in both farming systems. The decline of soil N content was not significant (p>0.05), down to 30 cm depth and beyond 30 cm depth, the N content decreased significantly in all three elevation classes for both farming systems (Table 2).

Table 1. Variation in organic matter content (%) in homegardens and cropping fields at different soil depths in three elevation categories (flat, moderate and steep).

Farming system	Soil depth (cm)	Gradient category			p**
		Flat	Moderate	Steep	
Homegarden	0 - 10	$1.99^{ax} \pm 0.52$	$1.82^{ay} \pm 0.66$	$1.37^{az} \pm 0.35$	*0.061*
	10 - 20	$1.85^{ax} \pm 0.37$	$1.75^{ax} \pm 0.56$	$1.16^{aby} \pm 0.22$	*0.002*
	20 - 30	$1.77^{ax} \pm 0.50$	$1.68^{ax} \pm 0.36$	$0.98^{bcy} \pm 0.24$	*0.0003*
	30 - 60	$1.57^{ax} \pm 0.52$	$1.60^{ax} \pm 0.72$	$0.78^{cy} \pm 0.20$	*0.0039*
	p*	*0.34*	*0.82*	*0.0004*	
Fields	0 - 10	$1.84^{ax} \pm 0.51$	$1.74^{ax} \pm 0.37$	$1.08^{ay} \pm 0.19$	*<0.0001*
	10 - 20	$1.83^{ax} \pm 0.50$	$1.72^{ax} \pm 0.37$	$1.09^{ay} \pm 0.20$	*<0.0001*
	20 - 30	$1.70^{ax} \pm 0.49$	$1.54^{bx} \pm 0.44$	$0.95^{ay} \pm 0.29$	*0.0001*
	30 - 60	$1.42^{bx} \pm 0.55$	$1.56^{bx} \pm 0.47$	$0.73^{by} \pm 0.11$	*0.0003*
	p*	*<0.0001*	*<0.0001*	*<0.0001*	

Means with same letters are not significantly different according to the LSD test (*p* = 0.05).
[a,b,c] indicates the difference between soil depths
[x,y,z] indicates the difference between gradient categories
p** indicates the probability values for the three gradient categories
p* indicates the probability values for the different soil depths

The variation of other soil properties (soil P, soil K and pH) followed a similar pattern as that of soil N and soil organic matter. However, fields had significantly lower pH values when compared to the homegardens in all three land categories. The mean soil pH was lowest in the fields of the steep slope category (mean = 5.98). Fallowing of fields either for a short period (for one season) or for a longer period is confined to moderate and steep slope categories in the study region. Johnston (2004), reported that soil pH was reduced significantly in a short fallow, which could be attributed to the organic acids released during decomposition of succulent organic matter.

In each gradient category, nutrient status of the homegardens was greater than the corresponding fields. Most of the green manures from *G. sepium* and other organic residues were incorporated to homegradens, because trees are integrated within the system. Besides, homegardens are located in close proximity to homesteads and incorporation is easier than into fields located at a distance. In homegradens, frequent lopping enables greater incorporation of green manure, which led to high nutrient status. Even though fields are low

in nutrients, farmers incorporate *G. sepium* once a year before the beginning of the *maha* season. Most of the farmers tend to fallow their cropping fields at least a season or more to replenish the soil before establishing the major crop. These approaches assure enough supply of nutrient for the *maha* season crop with low external inputs. In flat regions, where moisture availability was high, two cropping seasons are possible. However, in the moderate and steep slopes, only rain fed agriculture is possible and the crop management and other aspects of cropping are more or less similar in these two slope categories. Therefore, the nutrient status of these two categories were similar. Furthermore, continuous crop production on these lands has led to impoverishment of soil through continuous export of nutrients as crop yields. Erosion also reduces the organic matter content in the soil (Vlek *et al.*, 1997). Therefore, the lands in the steep elevation class become marginal in the long run due to decline of the soil nutrient status (Table 1). However, adoption of integrated nutrient management practices in homegardens of the flat and moderate slope categories assures efficient nutrient recycling within these units.

Table 2. Variation of soil N content (mg N g^{-1} soil) at different soil depths in homegardens and cropping fields in three elevation categories (flat, moderate and steep).

| Farming system | Soil depth (cm) | Gradient category | | | p** |
		Flat	Moderate	Steep	
Homegarden	0 - 10	1.43[ax] ± 0.36	1.31[ady] ± 0.27	1.02[az] ± 0.21	*0.043*
	10 - 20	1.25[abx] ± 0.21	1.26[ax] ± 0.30	0.98[aby] ± 0.11	*0.032*
	20 - 30	1.33[ax] ± 0.49	1.23[ady] ± 0.29	0.94[aby] ± 0.25	*0.099*
	30 - 60	1.00[bx] ± 0.21	0.94[by] ± 0.20	0.85[by] ± 0.16	*0.24*
	p*	*0.011*	*0.023*	*0.15*	
Fields	0 - 10	1.23[ax] ± 0.21	1.22[ax] ± 0.26	0.94[ay] ± 0.29	*0.012*
	10 - 20	1.19[ax] ± 0.20	1.21[ax] ± 0.27	0.94[ay] ± 0.30	*0.046*
	20 - 30	1.15[ax] ± 0.21	1.15[ax] ± 0.22	0.89[ay] ± 0.27	*0.026*
	30 - 60	0.92[bx] ± 0.34	0.90[bx] ± 0.31	0.51[by] ± 0.25	*0.009*
	p*	*0.0009*	*<0.0001*	*<0.0001*	

Means with the same letters are not significantly different according to the LSD test ($p = 0.05$).
[a,b,c] indicates the difference between soil depths .
[x,y,z] indicates the difference between gradient categories.
p** indicates the probability values for the three gradient categories.
p* indicates the probability values for the different soil depths

Productivity of maize in homegardens and cropping fields

Incorporation of green leaves induce nitrogen availability in the top soil (Barrios *et al.*, 1998; Ikerra *et al.*, 1999). This helps the farmers to reduce the application of synthetic sources. The study clearly showed that there was a significant variation ($p < 0.05$) in biomass production between homegardens and fields in the flat and moderate elevation categories (Fig. 1). Mean biomass production of homegarden growing maize in these two categories was high, especially with the external fertilizer (T1) and sole *Gliricidia* application (T2) treatments when compared with the fields of the same elevation classes.
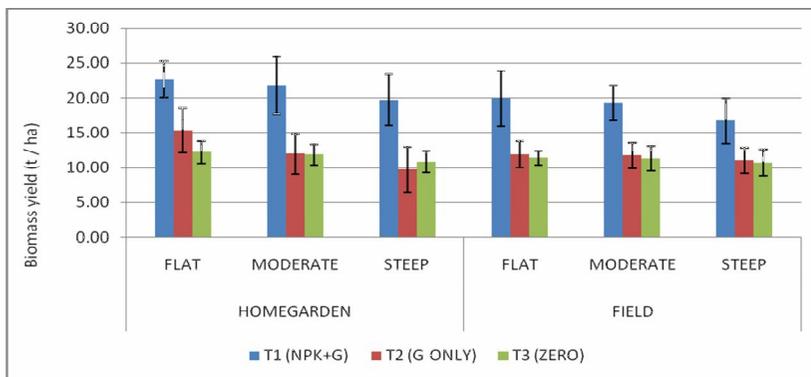
Fig. 1.   **Mean total biomass (t/ha) of maize in homegardens and fields in the three elevation categories (flat, moderate and steep)**

Homegardens at each elevation class produced significantly ($p<0.05$) greater amount of seed yield of maize than the cropping fields in all treatments (Fig. 2). However, in the steep gradient category, fields produced significantly greater amounts of grain yield especially with T1 (11%, $p = 0.042$) and T3 (28%, $p = 0.04$) than homegardens in the same gradient category. Sangakkara *et al.*, (2005) reported that short or long term fallows have the ability to maintain productivity and sustainability of tropical smallholder upland cropping units. Fallowing in-between cropping seasons in this elevation class may have contributed to the increase in biomass and grain yield production of maize in fields. Both the biomass and grain yield production of maize (t/ha) decreased significantly ($p<0.05$) along the gradient in the study region irrespective of being homegardens or cropping fields (Figs. 1 and 2).

Since a large portion of *Gliricidia* leaf biomass was added to the homegardens, the fertility status of soils in homegardens is higher compared with the fields. The results further proved that the productivity of the flat gradient category was high when compared to the other two gradients. Fields of the steep category are vulnerable to soil erosion, especially during the heavy rainy season. Thus the productivity of these lands would be lower than the lands that exist in the flat gradient category.
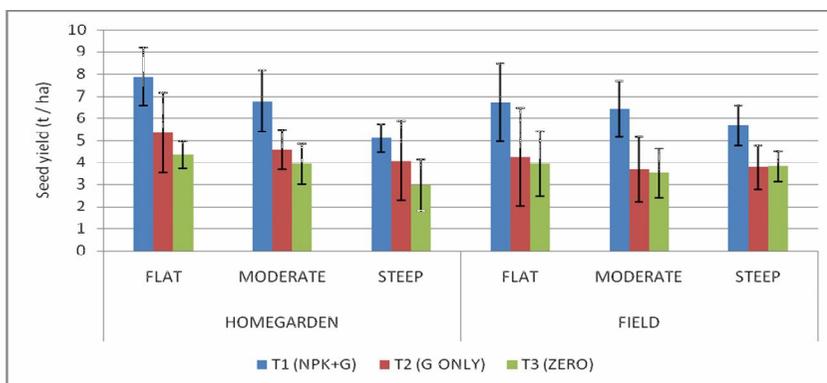

Fig. 2.   **Mean seed yield (t / ha) of maize in homegardens and fields in the three elevation categories (flat, moderate and steep).**

Productivity of mung bean in homegardens and cropping fields

In the minor season, the adopted treatments had no significant impact ($p > 0.05$) on biomass production and seed yield of mung bean grown in homegardens and the fields in the flat gradient category. However, the difference between these two systems was evident in the moderate and steep slope categories. Homegardens produced significantly higher biomass (12%, 15%, 17% with T1, T2 and T3 respectively) than fields for all treatments in the moderate category. Similarly, homegardens in this category produced significantly greater seed yield (21%, 19% respectively for T2 ($p = 0.0361$) and T3 ($p = 0.0258$)) than the fields in the same category (Fig. 3). In the steep slope category, homegardens produced significantly higher amounts of biomass than the fields with T2 ($p < 0.01$) and T3 (27% and 13% for T2 and T3 respectively) in the same elevation class.
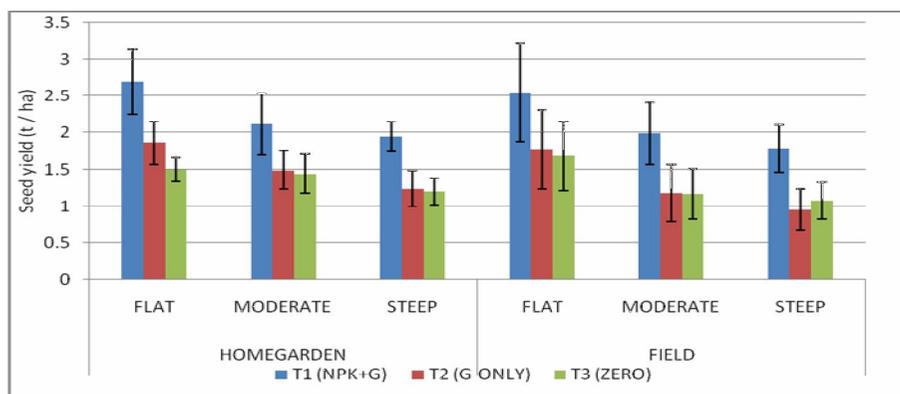

Fig. 3.   Mean seed yield (t / ha) of mung bean in homegardens and fields in the three elevation categories (flat, moderate and steep).

The biomass production of mung bean (t/ha) decreased with increasing inclination significantly ($p < 0.05$) in both systems of farming (homegardens and fields). Mung bean yields during the minor season also proved the high productivity of the flat lands. This finding agreed with those of Ojiem *et al.,* (2007), who reported that the N fixing ability of legumes decreased with the decline in soil fertility. Addition of green manure in the previous season would contribute to increase in soil fertility up to some extent. Seed yields of maize and mung bean were also positively correlated, especially with N and soil organic matter. However, fallowing the fields in the steep gradient category helps the development of soil nutrient status.

CONCLUSIONS

Sustainable agricultural practices such as inclusion of green manure (*G. sepium*), organic manure and agroforestry systems have the ability to develop degraded smallholder lands. As hypothesized, productivity of homegardens were better than that of fields in flat and moderate slope categories. This was due to the addition of greater quantities of green manures and other organic sources to the homegardens. The yields of steep fields were better than that in homegardens since the fields were subjected to fallowing in-between major cropping seasons. This helped to reduce erosion and nutrient build up whereas in

homegardens, soils were subjected to continuous production and erosion, which could deplete soil nutrients. Therefore, it is not advisable to develop homegardens without proper soil conservation methods on steep lands. Furthermore, soil fertility parameters of homegardens show a positive correlation with the maize and mung bean yields indicating the importance of these parameters in increasing the yields of these crops. Homegarden soils can sustain the supply of soil nutrients. However, to produce economically viable yields, partial supply of external nitrogen is essential. Therefore, there is a greater possibility to develop these farming systems with the adoption of integrated nutrient management strategies.

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