Impact of Green Manure on Productivity Patterns of Homegardens and Fields in a Tropical Dry Climate

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ABSTRACT. *Extensive field farming and homegardening (representing an intensive resource management system) on different inclination positions were compared on the basis of soil quality and productivity of maize and Mung bean over two years, in Meegahakiula, Sri Lanka. Soil organic matter (SOM) content of homegardens was greater than in fields irrespective of the inclination and it was more pronounced in the flat category. After two years, SOM declined in both homegardens and fields, the depletion of SOM was greater in homegardens, due to a positive correlation between SOM depletion rate and crop yields. Green manures moderated SOM depletion. Mean maize yields in homegardens with recommended fertilizers (NPK) exceeded 5 Mg.ha^{-1} and was significantly different from Fields in both Flat and Moderate categories. No yield difference was observed in homegardens and Fields in the Steep category. Although mineral fertilizers had an overriding effect over green manures, plots without fertilizers (ZERO and G) had higher yields in homegardens. Mungbean yield was similar in homegardens and Fields with recommended fertilizers (NPK) in Flat category, in both years. However, the difference became significant with increasing inclination. The influence of green manure was overridden by the influence of mineral fertilizers while no difference was observed between homegardens and Fields without mineral fertilizers (ZERO). The study illustrated that homegardens as an intensive resource management system is more fertile and productive than the extensive field farming and more effective in terms of long term sustainability.*

Key words: *Green manure, Homegardens, Intensive resource management system, Sustainability.*

INTRODUCTION

Tropical homegardens are considered to be sustainable systems because of the successful management of resources, while maintaining or enhancing the quality of the environment and conserving natural resources (Pandey *et al.*, 2007). The degree of intensification and the species composition of Homegarden units basically depend on soil and climatic suitability. In addition, socio-economic contexts of farming livelihoods coupled with resource availability have an influence on Homegardens (Meertens *et al.*, 1996). Thus, Homegardens are still a critical complement in local subsistence economies and for food security in the developing nations (Pandey and Singh, 2009). Homegardens in the Meegahakiula region of Sri Lanka, located in the Uva province are considered to be intensive resource management systems,

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characterized by incorporation of substantial quantities of green manures and other organic constituents in the context of low external inputs. Therefore, these could serve as a benchmark for continuous high green manure input. The main objective of this study was to ascertain the impact of green manure application on the yield potential of two model field crops, maize and mungbean, using Homegardens as a positive control representing a receiver of high quantities of organic fertilizers as compared to fields, thus reflecting the maximum long term impact on soil fertility by such measures. A further objective was to compare the soil fertility at these two organic input levels along an inclination gradient.

MATERIALS AND METHODS

This study was conducted from 2007 to 2009 in the Meegahakiula region located in the Walapane valley of the Badulla District, Uva Province, Sri Lanka. Study sites were established in six villages located in close proximity, at 7°07.485'N, 81°02.740'E and at elevations between 270 - 400 MSL covering a total area of 25 km^2. Although the sites were confined to a relatively small land area, physical land characteristics were very heterogeneous. The lands of the region were steep with gradients ranging from 30-70%, and were unproductive due to erosion, with diminishing soil depths and vegetation patterns along the inclination. This region experiences a bi-modal rainfall pattern characterized by two rainfall peaks per year with few months of dry weather separating the two rainy seasons. Agricultural activities within this region are primarily determined by these precipitation patterns.

The study was carried out on 30 selected Homegardens and Fields (10 Homegardens and 10 Fields in each of the 3 inclination categories). The inclination ranges used in this classification were; Flat 0 - 10%, Moderate 10 - 30% and Steep more than 30%. The selected units generally consisted of a Homegarden and a Field on the same farm.

Simultaneous trials were conducted in the selected fields and Homegardens. There were 4 treatments in the Field experiment - 1) Total recommended fertilizer (NPK) 2) No fertilizer (ZERO) which was combined with gliricidia green manure. Four treatments were used in the Homegarden experiment - 1) Total recommended fertilizer with gliricidia green manure (NPKG) 2) Total recommended fertilizer (NPK) 3) gliricidia green manure only (G) and 4) No fertilizer or gliricidia (ZERO). Maize and mungbean were cultivated both in Fields and Homegardens, in the major and minor seasons respectively. The field plots were 30 x 10 m divided into 3 subplots and in Homegardens 10 x 10 m plots were divided into 4 subplots. Gliricidia was applied at a rate of 3 $Mg.ha^{-1}$ (dry weight basis with 80% moisture) (which provided 24 kg N, 3 kg P, 18 kg K per hectare per season) in both minor and major rainy seasons, adding up to 6 $Mg.ha^{-1}$ per year. Application of green manure in the field trials depended upon the history of using gliricidia as green manure, derived during a survey of farming practices. At each inclination category, five fields and Homegardens received gliricidia (G YES), chosen due to a recorded practice of previous application; in these cases the Homegarden plots received the same amount of G YES as well. All other plots, Fields as well as Homegardens, did not receive green manure during the experimental phase (G NO). Application of green manure was done in two splits for maize: at land preparation before planting and with the 1st top dressing of fertilizers between 4 and 5 weeks after planting. In mungbean, green manure was applied once at the beginning of land preparation, and was gradually incorporated into the soil at land preparation. Incorporation of other organic or inorganic constituents was prohibited during the period of the experiment. Plots in both Field and Homegardens were kept fallow between crops. Fertilisers applied for maize and mungbean were based on regional recommendations by the Department of Agriculture, Sri Lanka (1995).

Experimental plots were marked in each unit for on-farm trials and sample collection. Soil samples were taken at the beginning of the programme between January and February 2007 and after 4 seasons of cropping (2 years) in March and April 2009. The second sampling considered both gliricidia and non gliricidia plots. For the soil analysis, 4-6 soil samples were randomly collected from each plot at depths of 0-10 cm, 10-20 cm, 20-30 cm and 30-60 cm respectively. The basis used for selecting these depths was the rooting pattern of maize, the primary crop of the region. An undisturbed soil sample was taken from top soil (up to 20 cm) for determination of bulk density. The second soil sampling was carried out in March 2009, after two years, from both types of plots i.e. with and without gliricidia. Soil organic matter contents were determined by the Walkey and Black method (van Ranst *et al*., 1999), using a conversion factor of 1.724 (Broadbent, 1953).

In maize, total biomass yield and grain yield were determined. In mungbean, at full maturity (65 days after sowing) total biomass yield and seed yield were determined. Analysis of variance (ANOVA) was performed as needed, using the statistical software SAS 9.2 (SAS Institute Inc, Cary, NC, USA). In case of significant effects and interactions between main factors, Tukey's test was used to separate the means.

RESULTS AND DISCUSSION

Soil quality

Homegardens had the highest total SOM concentrations showing the benefits of intensive incorporation of green manures. Flat category Homegardens had a higher SOM content than those in Moderate and Steep categories (Table 1). This showed that the intensive incorporation of green manure and some organic constituents are good options for long-term amelioration when compared to seasonal green manure incorporation in Fields.

Homegardens were inherently richer both in SOM and in TN (Tables 1 and 2). The correlation between SOM and TN was significant ($p<0.001$) in both seasons. Homegardens were significantly ($p< 0.001$) richer in SOM and TN contents than the Fields in the 0 - 30cm layer in all inclination categories; these differences were more pronounced in the Flat and Moderate categories. A greater nutrient content in the surface soil (0 to 30cm) when compared to that of the deeper layers indicated that green manure/ decomposed organic manures and mineral fertilizers were incorporated superficially in both Homegardens and Fields (Tables 1 and 2). However, this was more pronounced in the Fields where the frequency of incorporation of green manures was restricted to once or twice per season at land preparation. In contrast, in Homegardens there was a frequent incorporation of green manures and decomposed manures coupled with frequent tilling, which allows incorporation into deeper layers. However, the tilling depth never exceeds 30cm, because no deep ploughing is practiced in tropical Homegardens as stated by Pandey and Singh (2009). Generally, in tropical fields, SOM contents tend to be low (less than 2%) (Van Holm, 1991). A soil organic matter content of 1-2% was common in fields of the Meegahakiula region. Although SOM content was greater in the Homegardens which were managed by the same farmer, it was still considered to be low which reflects a certain degree of degradation.
In Homegardens, a robust decreasing trend of SOM was identified with increasing inclination ($p<0.001$) in Year 1, with a rate of decline of 0.25 $g.kg^{-1}$ of SOM per unit

inclination increase. In Year 1, no significant trends of SOM dynamics were observed in Fields of both G NO and G YES treatments. After a sequence of cropping for two years, in Year 2, SOM content of Homegardens in all inclinations were stable, when compared to the Fields, irrespective of the use of gliricidia.

Table 1. Initial soil quality of the experimental sites, based on the use of green manure (G YES) and (G NO)

Inclination category	Farming system	Use of gliricidia	Soil property			
			SOM ($Mg.ha^{-1}$)	TN ($kg.ha^{-1}$)	P ($kg.ha^{-1}$)	K ($kg.ha^{-1}$)
Flat	HG	G YES	67.40 (10.7)	40.94 (11.2)	45.0 (2.8)	26.4 (3.9)
	Field	G YES	46.65 (3.8)	35.28 (5.1)	40.7 (8.7)	27.4 (3.5)
	% difference †		30**	12*	9*	-3
		G NO	43.40 (3.5)	35.94 (8.2)	39.5 (5.2)	27.5 (5.2)
	% difference		36**	12*	12*	-3
Moderate	HG	G YES	57.85 (10.2)	35.65 (4.7)	41.5 (5.9)	21.6 (5.2)
	Field	G YES	43.51 (11.5)	29.64 (6.3)	40.2 (7.2)	26.6 (4.8)
	% difference		25**	12*	3	-23*
		G NO	44.13 (8.9)	31.97 (4.2)	38.9 (8.7)	25.6 (8.9)
	% difference		23**	10*	6	-18*
Steep	HG	G YES	44.14 (10.7)	28.90 (5.1)	31.7 (6.8)	22.7 (3.7)
	Field	G YES	38.56 (6.8)	30.50 (3.2)	31.5 (5.3)	21.9 (4.0)
	% difference		19*	- 5	0	3
		G NO	42.51 (11.2)	25.50 (8.7)	30.5 (11.2)	21.7 (5.3)
	% difference		4	11*	3	3

Numbers in parentheses are standard deviations of the mean
† Percentage change, in comparison with Homegarden and Field to corresponding treatment combination
* Means significantly different at $p<0.05$; ** Means significantly different at $p<0.001$, significance from the Homegarden mean

Two years of cropping caused a depletion of SOM in Fields; this was clearly evident in the Steep category. This depletion of SOM was present even in the G YES plots. Decline rates of 0.25 $g.kg^{-1}$ ($p=0.001$) in G NO and 0.23 $g.kg^{-1}$ ($p=0.06$) in G YES plots per unit increase of inclination of Fields was observed while there were no such trends in Homegardens. Inclination was the main influencing factor reducing the difference between Homegardens and Fields. This difference may be due to the negative impact of erosion, especially in Fields of the Steep category that was under extensive management. The degree of intensification of Homegarden cultivation was reduced with increasing inclination as well, when compared to the Homegardens in the flat category. On the other hand, the mean range of SOM

(30-40 g.kg^{-1}) in Homegardens was considered to be high in relation to a study in Vietnam (Vezina *et al.*, 2006), which reported a reduction of 30-45 g.kg^{-1} of SOM in a landscape with a maximum inclination of 30%.

Soil organic matter content decreased significantly ($p<0.001$) during the two years in Homegardens and Fields, which was linked to the significant three-way interaction of Inclination, Year and Farming system ($p=0.009$). The depletion of SOM in Homegardens was greater than in the corresponding Fields (Table 2), which was clearly illustrated by the significant interaction between Season and the Farming system ($p=0.009$). There was a marginal increase or zero depletion of SOM in G YES Fields in Flat and Moderate categories while there was a net decrease in the Steep category in both G NO and G YES conditions. A significant three-way interaction of Inclination, Year and Farming system ($p=0.001$) was also found in both farming systems, indicating the impact of all parameters on SOM.

Table 2. Mean soil quality of top soil (0-30cm) after two years (four seasons of cropping) in Homegardens (HG) and Fields in three inclination categories, with (G YES) and without (G NO) using gliricidia green manure, and respective changes

Inclination category	Farming system	Use of gliricidia	SOM	% Change within two years
Flat	HG	G YES	48.5(7.1)	-28*
	Field	G YES	38.1(2.9)	-18*
% change			22*	
Flat	HG	G NO	45.8(6.5)	-32*
	Field	G NO	37.9(4.5)	-13*
% change			17*	
Moderate	HG	G YES	49.8(11.0)	-14
	Field	G YES	44.4(7.8)	0
% change			11*	
Moderate	HG	G NO	45.4(6.2)	-21*
	Field	G NO	39.84(5.5)	-10
% change			12*	
Steep	HG	G YES	40.1(6.9)	-10
	Field	G YES	28.2(3.9)	-27*
% change			36*	
Steep	HG	G NO	37.0(11.3)	-16*
	Field	G NO	25.4(8.3)	-40*
% change			32*	

Numbers in parentheses are standard deviations of the mean
† Percentage change, in comparison with Homegarden and Field to corresponding treatment combination
* Means significantly different at $p<0.05$; ** Means significantly different at $p<0.001$, significance from the Homegarden mean

The soil quality differed clearly between Homegardens and Fields due to organic matter incorporation. Prior to the establishment of the study, greater quantities of organic matter had been incorporated into Homegardens at different times, while it was limited to land preparation in Fields. The addition of organic matter increases soil aggregation and aggregate stability which in turn reduces the vulnerability to erosion (Titan *et al.*, 2005). However, cultivation of annual field crops generally exhausts SOM stocks. Higher yields without adequate inputs may have created this depletion of SOM which strengthens the significant correlations between grain yield and SOM content in Homegardens. This is a general phenomenon in tropical farming systems (Vanlauwe *et al.,* 2005). The less productive lands in the Steep category did not show the same rate of SOM stock depletion in both Homegardens and Fields. Although many studies suggest a persistent influence of green manures (Vanlauwe *et al.,* 2005) in alley cropping or hedgerows systems, which was more similar to the Homegarden conditions in the Meegahakiula region, this effect seems to be quite variable and subject to cultivation measures adopted by the farmer.

Model crop production

The hypothesis of this study was that the Homegardens are more fertile and productive than Fields even when managed by the same farmer. Maize and mungbean grain yields were indeed greater in Homegardens, proving this hypothesis.

Grain yield was significantly ($p<0.001$) influenced by year (season); therefore the two years (2007/08 and 2008/09) were considered separately to isolate the influence of using gliricidia as green manure, which was significant during Year 2 (2008/09). The differences of the two years were mainly due to the variation in rainfall, illustrated by the reduction in mean grain yield in Year 2 (Tables 3 and 4), and also due to the significant three-way interactions of inclination, use of Gliricidia and Year ($p=0.011$), use of Gliricidia, system and year ($p<0.001$) and the marginal ($p=0.06$) two-way interaction of use of Gliricidia between the two systems.

Grain yields of both Homegardens and Fields were significantly influenced ($p<0.001$) by the inclinations irrespective of the year. The relative influence of inclination was most pronounced in gliricidia alone (G) and ZERO treatments. In plots without NPK amendments, which was a simulation of low external input agriculture, the yield was about 50 to 60% lower, while the difference between Steep and Flat categories was even more, especially in the second year. In ZERO there was a positive but erratic advantage of Homegardens for yield. In Year 1, this effect was most pronounced in Flat and Steep categories; in Year 2 in the Moderate category. Gliricidia alone increased the yields by 20% to 100% in Homegardens, but most remarkable was the significant and positive impact of gliricidia in Homegardens which increased maize yields by about 2 $Mg.ha^{-1}$. The relative benefit of gliricidia in Fields was about 50%. The much higher yields with NPK alone seemed to mask any differences between the systems. In Year 1, the yields were significantly higher in Homegardens in Flat and Moderate Categories, where the relative differences were 15% and 10%, respectively. The highest absolute difference in maize yields (0.8 $Mg.ha^{-1}$) was between field and homegardens in the Steep category. Application of NPK along with gliricidia marginally increased the yield in some cases (Table 3) when compared to yields with NPK alone. The difference between yields of Fields and Homegardens without Gliricidia, but with NPK alone was greater when compared the plots to which the green manure was added along with NPK. In the Steep category, a more pronounced advantage of Homegardens became visible in Year 2. In general, yields of the Steep category were significantly lower than those of the Moderate and Flat categories, where the addition of NPK increased yields. In Year 1, the greatest impact was in the Steep category; this trend was reversed in Year 2, where the impact was greater in the Flat category probably due to the differences in moisture availability along the inclination. The productivity of Homegardens was higher, due to inherent fertility caused by better soil management and a longer history of using organic amendments. Application of NPK removed this effect to some extent, and the addition of gliricidia had only a marginal beneficial impact.

The higher productivity of Homegardens was clearly visible in the absence of mineral fertilizers, e.g. in the gliricidia or ZERO fertilized plots. Gliricidia as green manure had a significant advantage on yields, irrespective of the inclination positions and fertilizer application, especially in Homegardens. Frequent applications of green or decomposed manures to Homegardens were the key reasons for high productivity, reflected by similar yields in G NO and G YES plots. Incorporation of green manures and sequential fallowing benefited the G YES Fields to produce yields similar to that of Homegardens. Application of green manures enhances the physical, chemical and biological properties of soil (Hartemink, 2006) and fallowing also influences soil chemical and physical properties (Tittonell *et al.*, 2008). Application of green manures with mineral fertilizers had a beneficial influence on maize yield, especially under moisture limiting conditions in Year 2. This phenomenon may be related to a high nitrogen use efficiency (Sangakkara and Stamp, 2009), a responsiveness of fertilizers to green manuring which enhances soil quality and facilitating moisture retention (Zingore *et al.*, 2007) The more pronounced difference in seed yield between Homegardens and Fields with increasing inclination was an opposite trend to that of Mung bean, where there was no difference in grain yields between Homegardens and Fields in the Steep category. Interestingly, the reduction in differences in seed yield with increasing inclination (i.e. difference between Flat and Steep) was higher in Fields when compared to Homegardens, especially with fertilizer (NPK and NPKG) irrespective of the year. An opposite trend was observed with respect to G and ZERO conditions, where the reduction in seed yield with increasing inclination was higher in Homegardens, in both years.

Interestingly, the yield of the ZERO Fields in Flat category exceeded that of the Homegardens by 0.20 Mg ha^{-1}, while in the Moderate category, Homegardens had a significant increase of 0.80 Mg ha^{-1}. In Year 2, water logging in Homegardens early in the season could have suppressed the development of a deep root system in maize which was not a common phenomenon in Flat category Fields located on comparatively higher elevations. Drought at the latter stages of the growing season could affect the acquisition of moisture due to the shallow root system when compared to the Fields. However, a beneficial impact of the green manures and decomposed manures added to the Homegardens was illustrated by the yield difference between the G YES and G NO conditions without NPK amendments when compared to Fields. The enhanced soil physical properties and nutrient retention (Fageria, 2007), CEC and the reserved nutrient stocks (Majumder *et al.*, 2008) of the Homegarden with added SOM created a conducive soil environment for the production of higher yields. Moreover, the net depletion of SOM contents in the Homegardens even in G YES with application of gliricidia green manure at a rate of 3 Mg ha^{-1} per season, suggest that the rate of OM incorporation was high even prior to the study. The yields of the Homegardens suggest that the nutrient rich status of the soil had an influence on early stages of plant growth (Table 1). Mung bean seed yield was not influenced by year ($p=0.060$), although, the interaction with other factors was significant. Therefore, mean seed yields of different fertilizer and system combinations of two years were considered separately (Table 4). NPK amendment increased the yields of Mung bean by some 300%, when compared to ZERO fertilization, whereas the effect of gliricidia application above ZERO fertilization was much lower (a 50 to 80% yield increase). There was a significant influence of the farming system ($p=0.002$) on Mung bean seed yield irrespective of the year. However, the differences in the systems were primarily illustrated by the significant interactions of the different components. In both years, there was no difference between the Homegardens and Fields in the Steep category with ZERO fertilizer. In contrast, in the Flat category in Year 1 and in all inclinations in Year 2, yields increased up to 30% when gliricidia alone was added. In the Flat category in Year 1 and in all categories in Year 2, Mung bean yields in Homegardens were 13% to 30% higher than in Fields. NPK was more effective in Homegardens in the Moderate and Steep categories in Year 1, by increasing the yield by about 14%. In the Steep category in Year 2, NPK increased yields only by 8% when compared to the ZERO treatment. Gliricidia combined with NPK (NPKG) generally increased yields by about 10%; this effect was somewhat more pronounced in Homegardens, especially in the Steep category in both years. Mung bean in this region is generally cultivated extensively using the resources left from the major crop i.e. maize. With external inputs, it was shown that, an economically viable yield is possible even in marginal climatic conditions. A strong synergistic influence of gliricidia and mineral fertilizers was observed in the Homegardens and the yield gap between Homegardens and Fields was above 100 $kg.ha^{-1}$ in all inclination categories. A generally lower response to gliricidia by Mung bean may be due to the short crop duration, and a marginal influence by soil physical and chemical properties when sufficient amounts of nutrients were supplied by mineral fertilizers. In addition, the more fertile nature of the Flat category reduces the yield difference between the two systems. However, with increasing inclination, the yield difference between Fields and Homegardens expanded. Although application of gliricidia had a varied influence on both systems, the absence of any input (i.e. fertilizer or gliricidia green manure) did not show any difference in the Mung bean yields of Homegardens and Fields. This was a different attribute to that of maize, as Mung bean showed no difference in G and ZERO treatments in the Homegardens and Fields. Incorporation of gliricidia had an additive influence in Homegardens which was clearly illustrated by seed yields in Year 2, in all inclination positions, while it was confined only to the Flat category in Year 1 (Table 4). More importantly, even in Homegarden conditions, gliricidia applied plots had a distinct yield increase when compared to ZERO plots. The significant influence of gliricidia may not be completely due to the N supply by the green manures (Shukla and Tyagi, 2009) but the actual stimulation of the rhizosphere.

Soil available P was not a limiting factor in this region, which is a critical nutrient for Mung bean (Tickoo *et al.*, 2006) productivity. However, as reported by Kadilata (2008) K plays an important role in determining the yield of grain legumes such as Mung bean, which can partially be supplied by incorporating gliricidia (De Costa *et al.*, 2005) green manures. Moreover, the better soil conditions and high CEC in Homegardens when compared to Fields would retain the nutrient released by decomposing green manures, which comes to a peak 3 - 4 weeks after incorporation (Reddy *et al.*, 2008).

CONCLUSIONS

The intensity in terms of quantity, quality and frequency of organic matter (i.e. green manure, decomposed plant materials and animal manure) incorporation was greater in Homegardens resulting in a high organic matter reserve and enhanced both soil chemical and physical properties of the soil when compared to Fields. In addition, high density of gliricidia trees within the Homegarden (beside fences) enhanced the effectiveness of nutrient recycling, since a regular pruning strategy increases the soil organic matter and other nutrients. Enhanced soil qualities of Homegardens were reflected by crop yields of both maize and Mung bean. Although Homegardens are more productive and sustainable, inclination is the major factor that determines crop productivity. Especially in the Steep inclination (i.e. more than 30% inclination), the productivity of Homegardens is similar or lower than Fields. This is directly related to the cropping patterns of these steep lands, where

Table 3. Mean maize grain yields (Mg.ha^{-1}) of twinned treatments in Homegardens and Fields in three inclination categories in major seasons of Year 1 (2007/08) and Year 2 (2008/09)

Inclination	NPK-F	NPK-HG	%	NPKG-F	NPKG-G	%	G-F	G-HG	%	ZERO-F	ZERO-G	%
Year 1 (2007/08)												
Flat	4.50(1.3)	5.34**(0.5)	15	5.06(0.5)	5.23(0.5)	3	2.13(1.1)	2.66**(0.7)	20	1.52(0.6)	1.92**(0.3)	21
Moderate	4.60(0.8)	5.10*(0.8)	10	4.81(1.4)	5.11(1.3)	6	1.30(0.8)	2.30**(0.4)	44	1.70(0.6)	1.82(0.3)	7
Steep	3.86(1.6)	4.03(0.7)	4	3.84(0.7)	3.83(0.4)	0	1.10(0.2)	2.20**(0.6)	50	0.95(0.4)	1.75**(0.3)	45
Year 2 (2008/09)												
Flat	4.25(0.3)	4.00(0.5)	-6	4.20(0.6)	4.20(0.5)	0	1.12(0.7)	2.76**(0.7)	60	2.26**(0.8)	2.05(0.9)	-10
Moderate	3.95(1.1)	3.83(0.8)	-3	4.05(0.8)	4.31(0.6)	6	1.25(0.4)	2.56**(0.5)	51	1.05(0.6)	1.84**(0.3)	42
Steep	3.18(0.5)	3.10(1.1)	-3	3.10(1.1)	3.52(0.6)	12	0.80(0.2)	1.38**(0.4)	42	1.03(0.5)	1.12(0.2)	8

Table 4. Mean Mung bean seed yield (Mg.ha^{-1}) comparison of twinned treatments in Homegardens and Fields in three inclination categories in minor seasons of Year 1 (2007/08) and 2 (2008/09)

Inclination	NPK-F	NPK-HG	%	NPKG-F	NPKG-HG	%	G-F	G-HG	%	ZERO-F	ZERO-HG	%
Year 1 (2007/08)												
Flat	0.90(0.2)	0.88(0.1)	-2	0.94(0.1)	1.00(0.2)	6	0.45(0.1)	0.64**(0.1)	30**	0.38(0.2)	0.37(0.08)	-
Moderate	0.65(0.2)	0.77*(0.2)	15**	0.85(0.2)	0.95(0.2)	10	0.62(0.2)	0.63(0.2)	-	0.40(0.2)	0.39(0.12)	-
Steep	0.61(0.1)	0.70*(0.1)	13*	0.77(0.2)	0.88(0.2)	12*	0.45(0.1)	0.44(0.1)	-	0.35(0.1)	0.35(0.2)	-
Year 2 (2008/09)												
Flat	1.03(0.2)	1.00(0.1)	-3	1.01(0.1)	1.12*(0.1)	10	0.50(0.3)	0.61*(0.1)	18**	0.35(0.07)	0.37(0.05)	-
Moderate	0.81(0.2)	0.80(0.1)	-	1.07(0.2)	1.10(0.2)	3	0.46(0.1)	0.53*(0.1)	13*	0.31(0.04)	0.33(0.06)	-
Steep	0.60(0.08)	0.65(0.08)	8	0.60(0.08)	0.76**(0.08)	21**	0.40(0.03)	0.48*(0.07)	16**	0.31(0.05)	0.31(0.07)	-

(NPK-F = full fertilizer recommendation in Fields, NPK-HG = full fertilizer recommendation in Homegardens, NPKG-F = full fertilizer recommendation in Fields with added gliricidia green manure, NPKG-HG = full fertilizer recommendation in Homegardens with added gliricidia green manure, G-F = Sole gliricidia in Fields, G-HG = Sole gliricidia in Homegardens, ZERO-F = no fertilizer in Fields, ZERO-HG = no fertilizer in Homegardens)Numbers in the parentheses are the standard deviation of the mean, Significant difference of means by Duncan Multiple Range Test; * $p<0.05$ and ** $p<0.01$

Fields are normally fallowed for few seasons in between cropping, which can revitalize soils. However, continuous cropping in Homegarden is not a sustainable land use strategy for these steep lands, which can aggravate erosion and degradation which may result in loss of productivity. The high responsiveness to mineral fertilizers is an indication that the physical fertility of soils was still sufficient. Yet, a higher responsiveness to full mineral fertilizer addition plus gliricidia amendment, especially under field conditions, can be interpreted as somewhat reduced soil fertility; may be this indicates clear traces of soil degradation during past 6-7 years that may still be mended. In order to develop a sustainable system in this landscape, Homegardens can be used as a bench mark for upgrading the land use systems. However, agronomic characteristics and social and economic characteristics could have an influence over the sustainability of Homegardens, and finally on the livelihood of the farming community of Meegahakiula region.

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