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Investigating viability of the premium influenced land agro-usage structure for production of African leafy vegetables in Vihiga and Jinja

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Land subdivision has reduced land for agricultural production resulting in its intensive cultivation. This has lowered soil fertility which has contributed to reduction in the diversity of African Leafy Vegetables thus restricting the otherwise traditional dietary diversity that was once beneficial to smallholder farmers. As land continues to decline, there needs to be some impetus in place that can retain the diversity of African Leafy Vegetables. This study therefore recognized the need to niche the African Leafy Vegetables to a none-competing, specially constructed raised cropping bed referred to us the Premium Influenced Land Agro-usage structure (PILA). A study to investigate the viability of the PILA structure for production of vegetable crops was undertaken in Vihiga and Jinja. The objective of the study was to evaluate the benefits of the PILA structures. PILA structures were constructed on 20 smallholder farms in Vihiga and Jinja. Vegetable crops *Solanum scabrum, Cleome gynandra, Amaranthus hybridus*) and exotic vegetables (*Daucas carota*) were grown on these structures. The same procedure was done on farmers' conventional plots (Flat beds). Analysis to compare the performance of vegetable crops between the PILA and Flat beds was done using Genstat. The net present value was used to assess the viability of the structure for long term use. Results indicated high significant differences (p≤0.001) in yield and height of vegetables crops grown on PILA and flat beds, (PILA yield (kg/ha) was 42254 versus 27772 for flat beds, PILA height in (cm) was 14.8 versus 10.8 for flat beds). Comparisons in vegetable performance between seasons showed better performance of vegetable crops in the Long Rains than the Short Rains seasons for both sites with significant difference (p=0.001) in yield (kg/ha) for the Long Rain (LR) was 36064 against 33962 for the Short Rain (SR), mean height (cm) for LR was 13 against 12.5 for SR, mean branching (score out of 3) for LR was 2.5 against 2.4 for SR. Also significant differences in vegetable performance were detected between Vihiga and Jinja in height and yield; mean yield (kg/ha) for Vihiga was 34962 and 36064 for Jinja, mean height (cm) for Vihiga was 12.8 and 16.6 for Jinja. The PILAs had a high net present value (KSH191390) compared to flats beds (KSH122087). Vegetable crops on PILA structure performed better than on Flat beds, the PILA structure can be promoted for production of vegetables in areas with small land sizes like the urban and peri-urban. However, there is need to increase the acceptability and adoption of the structure through awareness.

Key words: Raised bed planting, land size, premium land agro-usage structure, african leafy vegetables, dietary diversity.

INTRODUCTION

Land subdivision as a result of population pressure has resulted in reduced land for agricultural production which has had an effect on soil fertility. Traditionally, farmers would restore soil fertility by leaving part of their land uncultivated for many years while new and more fertile land was cultivated for food production. The small land sizes have otherwise destabilized this traditional system of maintaining soil fertility (Amadalo et al., 2003). For instance, the current land holdings on smallholder farms are approximately 0.4 ha which is usually considered to be below the FAO recommendation for subsistence food purposes of 1.4 ha / household (FAO, 2008). Consequently, long-duration natural fallows are no longer possible. The apparent implication of the low soil fertility status and reduced land holding is the decline in the abundance and distribution of phyto-diversity found on smallholder farms (Tittonell et al., 2005).

The declining quantity, distribution and consumption of edible phyto-diversity has led to reduction in the diversity of African leafy vegetables (ALV) grown on the smallholder farms thus restricting the otherwise traditional dietary diversity that was once beneficial to the locals (Vorster et al., 2008; Abukutsa-Onyango, 2008; Mitra and Pathak, 2008). Recent studies have shown that ALV's such as *Curcubita maxima, Amaranth* spp., *Cleome gynandra* and *Solanum nigram* are mineral micro-nutrient (MiMi) richer than cereal crops such as maize and sorghum (Akundabweni et al., 2010). In fact, almost all the leafy vegetables are good sources of micronutrients including iron and calcium as well as vitamins A, B complex, C and E. For example, *Amaranth* contains a multiple of these nutrients compared to *Brassicca oleracea* (IPGRI, 2003; Abukutsa-Onyango, 2007). Some of the African leafy vegetables even contain micro-nutrients content higher than those found in their exotic counterparts (Steyn et al., 2001; Odhav et al., 2007; Nangula et al., 2010). These indicates that the consumption of these leafy vegetables has both nutritional, health and a potential role to play in the mitigation of 'hidden hunger' [Hidden hunger is a condition manifested in increased malnourished children and adults because of lack dietary diversity (Hughes, 2008)].

Unfortunately, because of intense cultivation of the small land holdings, these ALVs can easily be marginalized in favour of the major agronomic crops. For instance there is increased production of some staple crops like maize at the expense of vegetable crops resulting in low dietary diversity. Diets poor in leafy vegetables may lead to xerophthalmia (a form of blindness) associated with vitamin A deficiency. It is also recognised that a diet rich in energy but lacking other essential components can lead to a heart disease, diabetes, cancer, and obesity (Frison et al., 2004). These conditions are no longer associated with affluence; they are on the increase among poor people from urban and rural areas in developing countries. A diverse diet offers nutritional buffers and there should be a key policy reform to combat this unhealthy trend (Johns and Sthapit, 2004). Since no approaches are possible in expanding the land resource, sustainable utilization of the limited land parcels for increased yield and dietary diversity is paramount (Mutiga et al., 2011).

Raised beds have been widely used in the production of commercial crops like rice, wheat and maize than vegetable crops. (Aquino, 1998; Hobbs and Gupta., 2003; Limon-Ortega et al.,2003,2006). Raised beds concentrate a large percentage of crops on a small piece of land thus increasing yield. Raised bed planting has also been shown to offer better weed control, water and fertilizer management, thus leading to the lower inputs of water and fertilizers and higher stress-resistance (Tripathi et al., 2005; Kong et al., 2010). Additionally, raised beds create a micro-climate (Microclimate- In this context, micro-climate refers to creation of an internal warm climate by plants that makes plant mature fast) in the field of the growing crop that reduces crop lodging and disease incidences (Fahong et al., 2004).

Other studies have shown that raised-bed planting reduces seed mortality rates, increases water- and nitrogen (N)-use efficiency, and improves soil quality. In addition, less labour is required for irrigation and fertilizer is better managed relative to conventional flat planting (Limon-Ortega et al., 2000). This therefore represent the social-economic benefits likely to be derived from using raised beds for production of crops. Can raised beds be improvised to enable production of vegetable crops in areas with land as a scarce resource?

This study sought to investigate the viability of the premium influenced land agro-usage structure (PILA), a land use innovation for production of ALV. The PILA is an improvised raised bed to enable production of vegetable crop.

MATERIALS AND METHODS

The study sites

The study sites were Jinja-Uganda and Vihiga-Kenya, as shown in Figure 1.

The study period

The study was done in the long and short rain of year 2011. The long rain season covered the months of April, May , June and July

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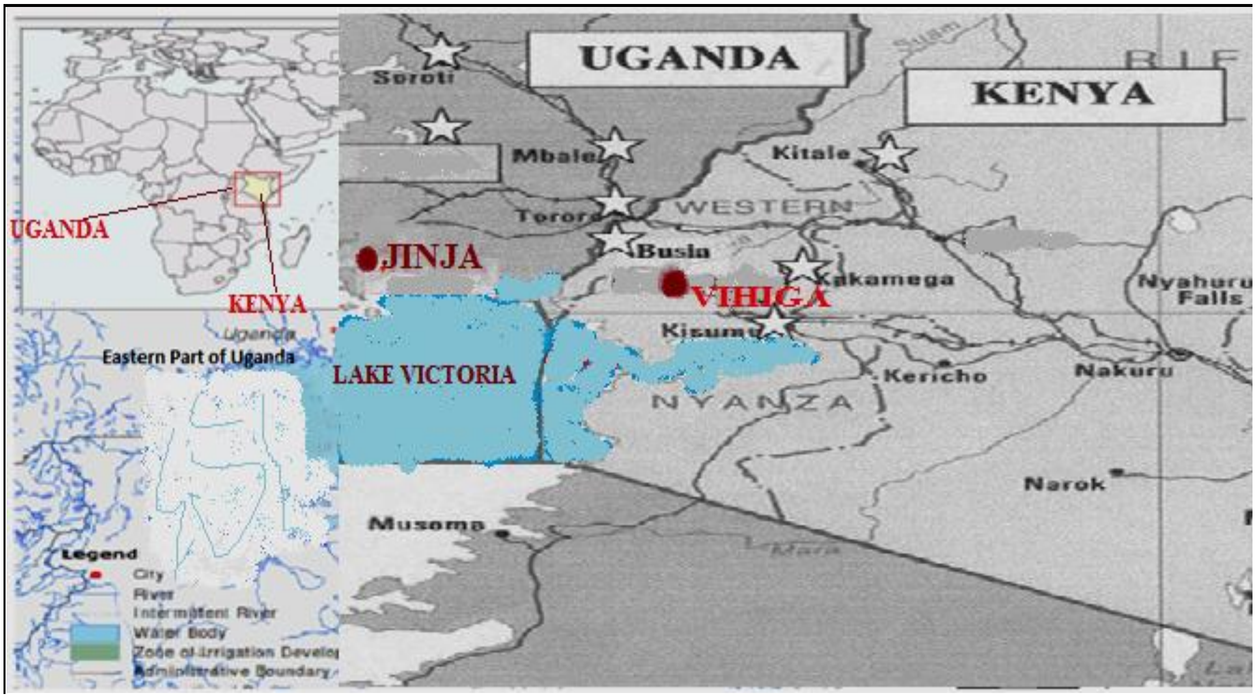

Figure 1. A map showing the study sites; Jinja (Lat. 1° 1.5' S; 29° 30.9' E) and Vihiga (Lat. 0° 15'N; Long. 34° 30'E).

Figure 2. Premium influenced land agro-usage structures (1) compared to flat bed (2).

while season 2 was the short rain season covered the months of September, October November and December.

The experimental design

The treatment was the PILA structure. PILA[1] Structures were established on 10 smallholder farms in Vihiga and the same number in Jinja (Figure 2 diagram 1). Each PILA was designed in three layer stair-case raised bed with each succeeding layer smaller than the preceding one. African Leafy Vegetables (*Solanum scabrum, Cleome gynandra, Amaranthus hybridus*) and exotic vegetables (*Daucas carota*) were planted on these beds. Weekly monitoring of the plots was done to determine their performance. The following agronomic appeal attributes were taken; vigour and robustness, plant height, branching and leaf density. Yield was also determined. A similar procedure was done on the flat beds as shown in Figure 2 diagram 2. The Flat beds[2] were the farmers' conventional way of planting vegetables. The measurements of PILA and flat beds were kept the same (21.3 m^2). The plant spacing was also similar. However, the size of the Flat bed could not contain the seed density as had been applied on the PILA structures. The seed density used on PILA structure was 300 gm compared to 250 gm that was appliedo n the flat bed.

[1]PILA structure was the treatment factor. This is an improvised raised beds constructed in a special way. See explanation of how the structures were constructed in description 1.2.4.

[2]The Flat beds were the control plots. These were the farmers conventional planting beds where farmers ploughed long rows and planted crops.

Construction of premium influenced land agro-usage structures

The beds were prepared using old sacks, posts and manure. Each bed measured 21.3 m^2. Land preparation by clearing to remove unwanted trash was done on the specific site where the beds were to be situated. The initial procedure involved taking measurements of the bed using a tape measure and a rope. This was done by making a central spot for the bed. A diameter measuring 240 cm from the central spot was then marked. The bed was then divided into three micro-beds measuring 60 cm in diameter. Vertical posts of 40 cm long were put all round the first stair from the ground. Filling materials (a mixture of stones and plant material) were then put up to the 20 cm mark from the ground. The purpose of putting stones was to help in strengthening and prevent sinking of the soil in case of rain. The remaining 20 cm up was filled with a mixture of soil and manure. The second stair case was constructed by erecting posts up to the 60cm length from the ground. Filling materials were put to 40 cm mark, a mixture of soil and manure was then put in the remaining 20cm length. The same procedure was repeated for the third and fourth stair cases. Posts were used to provide support. Sheeting of harvesting sacks was then put round to help in retaining the soil and control soil erosion in the case of rainfall.

Determination of costs and benefits of the PILA structures and flat bed

The costs for production and the corresponding revenue of vegetable crops contained in the PILA structures and flat beds were determined. The annual crop net benefits were computed by taking the total revenue less total variable costs as in the formula:

GMy=TRy-TCy

Where GM was the gross margin, TRy was the total revenue, TC total costs and y a selected vegetable crop.

The net present values of vegetable crops were then calculated for a period of 30 years at the rate of 12%. The 12% was the average rate of inflation for the past 10 year according to the World Bank Data (Appendix 3). Assumption made included; the rate of inflation of 12% would remain constant for the next 30 years, the 30 years period was the time that a person could be actively involved in farming, the cost of constructing the premium influenced land agro-usage structures would be incurred in the first year and after every five years, the costs of the flat beds would be the same throughout the farming period.

To compute the NPVs of the PILA structures, the NPVs of vegetable crops growing on the premium influenced land agro-usage structures were summed as in the following formula;

NVPpl=NPVi+NPVj+…….NPVz

Where NPVpl was the net present value of the PILA Structures, while NPVi, NPVj and NPVz were the net present values of various vegetable crops grown on the PPILA structures. The same procedure was repeated with the Flat cropping beds. A comparison of the NPVs of the PILA structures and flat cropping beds was done to determine the most viable cropping bed.

The NPV or discounted cash flow method was used as it is a preferred method for evaluating the economic worth of an investment, because it considers the time value of the entire stream of net cash flows over the life of the investment (Casler et al., 1993).

Data analysis

Data analysis was done using Genstat version 14 and excel. Results were presented in table and graphs.

RESULTS

Seasonal variations in the means of the agronomic appeal attributes of selected vegetable crops produced on the PILA Structures

There was a high significant difference (P≤0.001) in vegetable performance between the long rain and short rain seasons in the means of the following agronomic appeal attributes; Yield and height, as shown in Tables 1 and 2. A significant difference of (P=0.001) was observed in the following agronomic indicators; branching and disease incidences in both Vihiga and Jinja. In Jinja, vegetable crops had higher yields, longer height, better leaf density, low disease prevalence than in Vihiga. Generally vegetable crops performed better in the long rain season as compared to the short rain season in both Vihiga and Jinja (Appendix 2).

Differences in the means of the agronomic indicators of selected vegetables grown on PILA structures and flat beds

There was a high significant difference (P≤0.001) in vegetable crops grown on PILA structures and flat beds in the following agronomic appeal attributes; yield and height. A low significant differene was oberved for leaf density, branching and disease prevalence as shown in Tables 3 and 4.

Generally vegetable crops grown on PILA structures performed better than the ones that were grown on flat beds (Figure 3). Notice the effective use of space in the PILA structure compared to flat beds.

Variations in agronomic appeal attributes of selected vegetable crops grown on PILA Structures in Jinja and Vihiga

There was a high significant difference in yield and height (P≤0.001) of vegetables crops grown in Jinja compared to the ones that were grown in Vihiga as shown in Table 2. The difference in the following crop indicators was however significantly lower; leaf density (P=0.004), branching (P=0.004) and disease prevalence (P=0.070) as shown in Table 5. Generally, vegetable crops grown in Jinja showed a better performance compared to ones that were grown in Vihiga. More analysis is as shown in Appendix 2.

The germination percent of vegetable crops on PILA and flat beds

The germination percent of vegetable crops growing on PILA was higher than on Flats beds except for *S. Scabru* (Figure 4).

Table 1. Seasonal variations in the means of the agronomic indicators of vegetable crops grown on PILA Structures in Vihiga.

Season	Yield in (kg/ha)	Height in (cm)	Leaf density (score out of 3)	Branching (score out of 3)	Disease prevalence (score out of 3)
Long rain	36064	13	2.4	2.5	2.5
Short rain	33962	12.5	2.4	2.4	2.4
cv%	24.7	68.8	17.1	18.6	16.3
P-value	≤0.001	≤0.001	0.075	0.001	0.001
Least significance difference	273.4	0.543	0.02	0.03	0.01524
Standard error	197.1	0.201	0.00976	0.01498	0.00927

CV, Coefficient of variation.

Table 2. Seasonal variations in the means of the agronomic indicators of vegetable crops grown on PILA Structures in Jinja.

Season	Yield in (kg/ha)	Height in (cm)	Leaf density (score out of 3)	Branching (score out of 3)	Disease prevalence (score out of 3)
Long rain	40064	18	2.8	2.5	2.5
Short rain	36962	15.5	2.3	2.3	2.2
cv%	24.7	68.8	17.1	18.6	16.3
P-value	≤0.001	≤0.001	0.001	0.001	0.001
Least significance difference	400.4	0.743	0.012	0.05	0.01624
Standard error	234.1	0.3601	0.00876	0.01898	0.01127

CV, Coefficient of variation.

Table 3. Differences in the means of the agronomic appeal attributes of selected vegetables on PILA Structures and Flat cropping beds in Vihiga.

Vegetable	Treatment	Yield in (kg/ha)	Height (cm)	Leaf density	Branching	Disease prevalence
Amaranthus hybridus	PILA	47440	15.8	2.6	2.7	2.8
	Flat bed	21360	11.9	2.2	2.3	2.1
Solanum scabrum	PILA	44600	16.2	2.5	2.6	2.8
	Flat bed	27160	10.5	2.1	2.2	2.3
Cleome gynandra	PILA	47440	14.2	2.7	2.7	2.8
	Flat bed	21360	12.5	2.2	2.3	2.4
Daucus carota	PILA	24672	11.7	2.4	2.4	2.7
	Flat bed	20081	9.3	2.3	2.1	2.0
P-value		≤0.001	≤0.001	0.191	0.01	0.061
Least significance difference		273.4	0.543	0.0234	0.0246	0.543
Standard error		139.4	0.277	0.0119	0.0125	0.0078
cv%		12.3	67.1	15.3	15.5	9.6

CV, Coefficient of variation.

Analysis of the viability of PILA Structures versus flat beds using NPV method

There was a high significant difference (P≤0.001) in the mean Net NPV of the PILA structures and flat beds as shown in Table 6. More analysis is given on Appendix 3 and 4.

DISCUSSION

Seasonal effect on vegetable crop performance grown on PILA structures

There was a difference in crop performance between the short and long rain seasons across all the two sites of

Table 4. Differences in the means of the agronomic indicators of selected vegetables on PILA structures and flat cropping beds for Jinja.

Vegetable	Treatment	Yield in (kg/ha)	Height (cm)	Leaf density	Branching	Disease prevalence
Amaranthus hybridus	PILA	49302	18.8	2.6	2.7	2.8
	Flat bed	35981	13.9	2.2	2.3	2.1
Solanum scabrum	PILA	43720	14.2	2.5	2.6	2.8
	Flat bed	20465	9.5	2.1	2.2	2.3
Cleome gynandra	PILA	55813	15.2	2.7	2.7	2.8
	Flat bed	36279	11.5	2.2	2.3	2.4
Daucus carota	PILA	30046	11.3	2.4	2.4	2.7
	Flat bed	18604	8.3	2.3	2.1	2.0
P-value		≤0.001	≤0.001	0.187	0.02	0.071
Least significance difference		273.4	0.543	0.0234	0.0246	0.543
Standard error		139.4	0.277	0.0119	0.0125	0.0078
cv%		12.3	67.1	15.3	15.5	9.6

Figure 3. A caption of vegetable crops growing on 1 PILA and 2 Flat beds.

studies (Vihiga and Jinja). The long rain season indicated better crop performance compared to the short rain season mostly in the yield. The difference in yield were likely caused by a variation in the amount of rainfall. The long rain season normally receive high amounts of rainfall compared to the short rain season (Okoola et al., 2008). High amount of rainfall positively interacts with soil nutrients to give a high crop yield. Differences in seasonal vegetable production have also been reported in cowpea (*V. unguiculata*) as in a study by Chesney et al. (2010) and Kimithi et al. (2009) also found that the yield of chick pea was high in the long rain period as compared to the short rain period.

Difference in the performance of selected vegetables crops grown on premium influenced land agro-usage structures between Jinja and Vihiga

There was a high significant difference in the performance of vegetables grown on PILA structures in both Vihiga and Jinja in yield and height (Table 5). There were however small significant differences in the leaf density, branching and disease prevalence in the two study sites. This would have been as a result of differences in soil properties and climatic conditions across the two study sites. Even though the two study sites are found in the Lake Victoria Basin, differences in

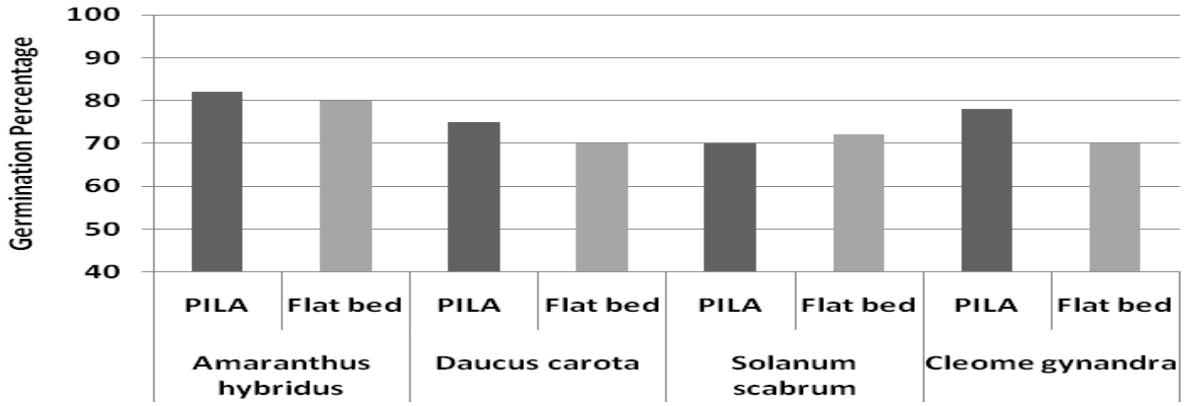

Figure 4. Germination percentage of vegetable crops growing on the PILA and Flat beds.

Table 5. Differences in the agronomic appeal attributes of selected vegetable crops grown on PILA Structures in Jinja and Vihiga.

Variety		Yield in (kg/ha)	Height in (cm)	Leaf density (score out of 3)	Branching (score out of 3)	Disease prevalence (score out of 3)
Amaranthus hybridus	Vihiga	42174	18.1	2.5	2.7	2.9
	Jinja	47907	19	2.5	2.7	2.8
Solanum scabrum	Vihiga	48230	10.8	2.7	2.7	2.8
	Jinja	40465	17.7	2.5	2.8	2.7
Cleome gynandra	Vihiga	51301	13.2	2.6	2.8	2.9
	Jinja	51163	17.2	2.6	2.7	2.7
Daucus carota	Vihiga	25488	9.4	2.5	2.6	2.7
	Jinja	31302	13.3	2.6	2.7	2.8
cv%		11.2	64.9	15.9	13.4	10.1
P-value		≤0.001	≤0.001	0.004	0.004	0.070
Least significance difference		553.8	1.717	0.075	0.066	0.051
Standard error		199.7	0.619	0.027	0.024	0.019

CV, Coefficient of variation.

climatic and soil properties are noticeable. Similar results on differences in crop performance as a result of variations in soil conditions in the Lake Victoria Basin, have been documented by Fungo et al. (2011).

Performance of vegetable crops grown on PILA structures compared to flat bed

There was a high significant difference in vegetable crop performance between the PILA structures and flat beds. Vegetable crops grown on PILA Structures performed better in the following agronomic appeal attributes; yield, height, leaf density, branching and disease prevalence compared to the ones that were grown on flat beds. The performance of vegetable crops on PILA Structures could have been attributed to better utilization of space, solar energy, water and nutrients.

Vegetable crops grown on PILA Structures had a higher germination percentage, were densely packed compared to the ones on Flat beds. Although the plot sizes and spacing was kept the same for PILA and flat beds, the seed densities varied. The design of the PILA structures permitted a special arrangement of the rows resulting in a higher seed density than on the flat bed. This arrangement could not be replicated on the Flat beds. This would have caused the vegetable crops grown on the PILA structures to have more yield than on the flat beds. Notice the effective utilization of space on the PILA beds as shown in Figure 3. The vegetable crops on PILA grew taller than on the Flat beds. But whether this was as a result of competition or sunlight need be investigated.

Table 6. Mean NPV of PILA Structures versus NPV of Flat beds for Vihiga.

	Mean NPV	Standard deviation	Standard error
PILA	191390	25007	4566
Flat bed	122087	25508	4657

NPV is the net present value; PILA is the premium influenced land agro-usage structure; N=60, test statistic t=10.63 on 58 degrees of freedom, P≤0.001.

Creation of an internal micro-climate also helped in reducing disease incidences and promoting growth as well as ensuring better nutrient use. Similar findings on better performance of crops grown on raised beds have been recorded by Wang et al. (2011) in a study on morphological and yield responses of winter wheat (*Triticum aestivum)* to raised bed planting. Other studies by Singh et al. (2010) and Fahong' et al. (2004) have recorded similar findings.

Comparison of the cost and benefits of the PILA Structures and flat beds

The NPV of the PILA structures were more than for the flats bed. This could be attributed to better crop performance. The total revenue that was obtained from vegetable crops contained on PILA Structures was higher than on flat beds in year 1 as shown in Appendix 1. This is because costs used for production of vegetable crops grown on flat beds were low compared to PILA Structures. Costs of production for vegetable crops contained on PILA structures included costs of construction (purchase of sheeting materials and rope). These costs were not incurred in making flat beds. As the years progressed as shown in Appendix 1, the revenue obtained from vegetable crops grown on PILA structures became higher and continuously increased than the revenue that was obtained from vegetable crops that were grown on flat beds. This made the net present value that was obtained from vegetables crops grown on PILAStructures to be higher compared to flat beds.

Conclusion

Vegetable crops grown on the PILA structures performed better compared to the ones that were grown on the flat beds. This was shown in the high yield, reduced disease incidences and the high net present value of the vegetables crops that were produced on PILA Structures in comparison to the Flat beds. PILA structures as an innovation or technology could be suitable for home vegetable growing preferably under high family land population pressure and/or less tillable land. Because of its micro-climate, a PILA Structure planting is known for uniform special plant arrangement and therefore good seedling growth and plant produce of an attractive marketable appearance, that is, (premium sale value). Its relevance is thus as follows: (a) Convenient to fit the Premium PILA structures into a main household compound setting; (b) None-competitive in space to an already overcrowded arable piece of land; (c) Within reach for constant care and protection of a high premium value crop.

Conflict of Interest

The authors have not declared any conflict of interest.

REFERENCES

Abukutsa-Onyango MO (2008). The Role of Universities in Promoting Underutilized Crops: The Case of Maseno University, Kenya. Acta Hortic. 806:155-162.
Akundabweni LSM, Munene RW, Maina DM, Bartilol SK (2010). Mineral Micronutrient Density in local cereals sampled from Bungoma, Maseno and Kibwezi areas. Afr. J. Food Agric. Nutr. Dev. 10(11):4301-4319.
Amadalo B, Juma B, Niang A, Noordin Q, Nyasimi M, Place F, Franzel S, Beniest J (2003). Improved Fallows for Western Kenya; An Extension Guideline, Nairobi.World Agroforestry Centre (ICRAF), P. 48.
Aquino P (1998). The adoption of bed planting of wheat in the Yaqui Valley, Sonora, Mexico. Wheat Special Report. CIMMYT, Mexico.
Casler GL, Anderson BL, Aplin RD (1993). Capital Investment Analysis: Using Discounted Cash Flows. 5th ed. Ithaca, NY: Cornell University.
Chesney Leslie A, Patrick EK Simpson R, Nigel C, Oudho H, Floyd B, (2010). Cowpea Yield Performance in an Alley Cropping Practice on an Acid Infertile Soil at Ebini, Guyana. Open Agric. J. 4:80-84.
Fahong W, Ling'an Kong KS, Shengdong LI, Jisheng SI, Bo F, Bin Z (2011). Morphological and yield responses of winter wheat (*Triticum aestivum* L.) to raised bed planting in Northern China. Afr. J. Agric. Res. 6(13):2991-2997.
Fahong W, Xuqing W, Sayre K (2004). Comparison of conventional flood irrigated, flat planting with furrow irrigated, raised bed planting for winter wheat in China. Field Crops Res. 87:35–42.
Food and Agriculture Organization of the United Nations (2008). Climate Change and Food Security: A framework document. Available at website: http://www.fao.org/docrep/010/k2595e/k2595e00.htm (Verified September 25, 2012). Foods: Vegetables and Fruit. Medical Research Council, Cape Town, South Africa.
Frison EA, Cherfas J, Eyzaguirre P, Johns T (2004). Biodiversity, nutrition and health: making a difference to hunger and conservation in the developing world. Key note Address of IPGRI DG to the Conference of the Parties to the Convention on Biological Diversity (COP7).
Fungo B, Grunwald S, Tenywa MM, Vanlauwe B, Nkedi-Kizza P (2011). Lunnyu soils in the Lake Victoria basin of Uganda: Link to toposequence and soil type. Afr. J. Environ. Sci. Technol. 5(1):15-24.
Hobbs PR, Gupta RK (2003). Resource conservation technologies for

wheat in the rice–wheat system. In: Ladha, J.K., Duxbury, J.E., Gupta, R.K., Buresh, R.J. (Eds.), Improving the Productivity and Sustainability of Rice–Wheat System: Issues and Impacts, ASA Special Publication 65. ASA, CSSA, SSSA, Madison, WI, pp. 149–171.

Hughes J (2008). Just Famine Foods? What Contributions Can Underutilized Plants Make To Food Security, Acta Hort. 806:39-48.

IPGRI (2003). Rediscovering a forgotten treasure. [Internet] IPGRI Public Awareness. Rome, Italy. http://ipgri-pa.grinfo.net/index.php?itemid=101. Accessed 10 April 2013.

Johns T, Sthapit BR (2004). Biocultural diversity in the sustainability of developing country food systems. Food Nutr. Bull. 25(2):143-155.

Kimithi DK, Kibe AM, Akuja TE (2009). Effects of nitrogen fertilizer and plant population on growth, yield and harvest index (HI) of chickpea *(Cicerarietinum* L.) under dryland conditions in Kenya. J. Appl. Biosci. 22:1359 – 1367 ISSN 1997–5902.

Kong LA, Wang FH, Feng B, Li SD, Si JS, Zhang B (2010). A root-zone soil regime of wheat: physiological and growth responses to furrow irrigation in raised bed planting in Northern China. Agron. J. 102:154-162.

Limon-Ortega, A., Govaerts, B., Deckers, J., Sayre, K.D., 2006. Soil aggregate and microbial biomass in a permanent bed wheat-maize planting system after 12 years. Field Crops Res. 97:302–309.

Limon-Ortega A, Sayre KD, Drijber RA, Francis CA (2003). Soil attributes in a,furrow-irrigated bed planting system in northwest Mexico. Soil Till. Res. 63:123–132.

Limon-Ortega A, Sayre KD, Francis CA (2000). Wheat nitrogen use efficiency in a bed planting system in northwest Mexico. Agron. J. 92:303–308.

Mitra SK, Pathak PK (2008). Underutilized Plant Species: Implications in Main household Farming. Acta Hort. 806:107–114.

Mutiga KJ (2011). Economics of Non-Conventional Fertilizers in Vihiga District, Western Kenya. M.Phil. Thesis Department of Agricultural Resource Economics, Moi University. Kenya.

Nangula PU, Oelofse A, Kwaku GD, Megan JB, Mieke F (2010). Nutritional value of leafy vegetables of sub-Saharan Africa and their potential contribution to human health: A review. J. Food Composit. Anal. 23:499-509.

Odhav B, Beekrum S, Akula U, Baijnath H (2007). Preliminary assessment of nutritional value of traditional leafy vegetables in KwaZulu-Natal, South Africa. J Food Comp. Anal 20:430-435.

Okoola RE, Camberlin P, Ininda JM (2008). Wet periods along the East Africa Coast and the extreme wet spell event of October. J. Kenya Meteorol. Soc. 2(1):65-81.

Singh Y, Humphreys E, Kukal SS, Singh B, Kaur A, Thaman S, Prashar A, Yadav S, Timsina J, Dhillon SS, Kaur N, Smith DJ, Gajri PR (2009). Crop performance in permanent raised bed rice–wheat cropping system in Punjab, India. Field Crops Res. 110:1-20.

Steyn NP, Olivier J, Winter P, Burger S, Nesamvuni C (2001). A survey of wild, green, leafy vegetables and their potential in combating micronutrient deficiencies in rural populations. South African Journal of Science 97:276–278.

Tittonell P, Vanlauwe B, Leffelaar PA, Shepherd KD, Giller KE (2005). Exploring diversity in soil fertility management of smallholder farms in western Kenya Within-farm variability in resource allocation, nutrient flows and soil fertility status. Agriculture, Ecosyst. Environ. 110:166–184

Tripathi SC, Sayre KD, Kaul JN (2005). Planting systems on lodging behavior, yield components, and yield of irrigated spring bread wheat. Crop Sci. 45:1448-1455.

Vorster HJ, Van Rensburg WS, Stevens JB, Steyn GJ (2008). The Role of Traditional Leafy Vegetables in the Food Security of Rural Households in South Africa. Acta Hort. 806:223-228.

Wang F, Wang X, Ken S (2004). Comparison of conventional, flood irrigated, flat planting with furrow irrigated, raised bed planting for winter wheat in China. Field Crops Res. 87:35–42.

Appendix 1: PILA versus flat bed analyisis.

Analysis of variance table					
Variate: Height					
Source of variation	**d.f.**	**s.s.**	**m.s.**	**v.r.**	**F pr.**
Replications stratum	2	44.58	22.29	0.30	
Plot treatment (PILA versus flat)	1	15174.56	15174.56	205.91	<.001
Vegetable type	3	20722.24	6907.41	93.73	<.001
Plot treatment (PILA versus flat) *Vegetable type	3	438.79	146.26	1.98	0.114
Residual	3830	282254.12	73.70		
Total	3839	318634.30			
Variate: Yield in ha					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replications stratum	2	0.000E+00	0.000E+00	0.00	
Plot treatment (PILA versus flat)	1	2.013E+11	2.013E+11	10788.30	<.001
Vegetable type	3	1.724E+11	5.747E+10	3079.39	<.001
Plot treatment (PILA versus flat) *vegetable type	3	1.892E+10	6.308E+09	338.01	<.001
Residual	3830	7.148E+10	1.866E+07		
Total	3839	4.641E+11			
Site variations					
Variate: Yield in ha					
Source of variation	**d.f.**	**s.s.**	**m.s.**	**v.r.**	**F pr.**
Site treatment (Vihiga and Jinja)	1	8.528E+09	8.528E+09	98.99	<.001
Residual	958	8.253E+10	8.615E+07		
Total	959	9.106E+10			
Variate: Height					
Source of variation	**d.f.**	**s.s.**	**m.s.**	**v.r.**	**F pr.**
Site treatment (Vihiga and Jinja)	1	7891.4	7891.4	67.17	<.001
Residual	958	112556.8	117.5		
Total	959	120448.2			

Appendix 2: Analysis of the costs and benefits of constructing PILA:

Costs and revenue analysis of selected vegetable crops grown on PILA.	
Cost	**Figure in Ksh**
Amaranthus hybridus	
Land	***
Labour	1000
Pegs	***
Manure	***
Filler materials	***
Purchase of 50 empty sacks at 50	2500
Purchase of ropes	300
Fertilizer	200
Total costs (TC)	**4000**
Revenue	
total sales for season 1 (82 kg at Ksh 60)	4920
total sales for season 2 (80 kg at Ksh 60)	4800

Appendix 2. Contd.

Total Revenue (TR)	**9720**
total benefit (TV-TC)	**7240**
Solanum scabrum	
Land	***
Labour	1000
Pegs	***
Manure	***
Filler materials	***
Purchase of 50 empty sacks at 50	2500
Purchase of ropes	300
Fertilizer	200
Total costs (TC)	**4000**
Revenue	
total sales for season 1 (90 kg at Ksh 65)	5850
total sales for season 2 (81 kg at Ksh 65)	5265
Total Revenue (TR)	**11,115**
total benefit (TV-TC)	**7115**
Cleome gynandra	
Land	***
Labour	1000
Pegs	***
Manure	***
Filler materials	***
Purchase of 50 empty sacks at 50	2500
Purchase of ropes	300
Fertilizer	200
Total costs (TC)	**4000**
Revenue	
total sales for season 1 (85 kg at Ksh 65)	5525
total sales for season 2 (77 kg at Ksh 65)	5005
Total Revenue (TR)	**10530**
total benefit (TV-TC)	**6530**
Daucas carota	
Land	***
Labour	1000
Pegs	***
Manure	***
Filler materials	***
Purchase of 50 empty sacks at 50	2500
Purchase of ropes	300
Fertilizer	200
Total costs (TC)	**4000**
Revenue	
total sales for season 1 (60kg at Ksh 30)	1800
total sales for season 2 (70 kg at Ksh 30)	2100
Total revenue (TR)	**3900**
total benefit (TV-TC)	**-100**

*** Provided locally. Prices of vegetables provided by Kisumu Uchumi Supermarket; total revenue, 35265; total costs, 16000; total vegetable crop benefits, 19265.

Appendix 2. Contd.

Analysis of the costs and revenues of constructing flat beds	
Cost	**Figure in Ksh**
A. hybridus	
Land	***
Labour	1000
Manure	***
Fertilizer	200
Total costs (TC)	**1200**
Revenue	
Total sales for season 1 (60 kg at Ksh 60)	3600
Total sales for season 2 (67kg at Ksh 60)	4020
Total revenue (TR)	7620
Total benefit (TV-TC)	**6420**
S. scabrum	
Land	***
Labour	1000
Manure	***
Fertilizer	200
Total costs (TC)	**1200**
Revenue	
Total sales for season 1 (63 kg at Ksh 65)	4095
Total sales for season 2 (55 kg at Ksh 65)	3575
Total revenue (TR)	7670
Total benefit (TV-TC)	**6470**
C. gynandra	
Land	***
Labour	1000
Manure	***
Fertilizer	200
Total costs (TC)	**1200**
Revenue	
Total sales for season 1 (53kg at Ksh 65)	5525
Total sales for season 2 (62 kg at Ksh 65)	5005
Total revenue (TR)	7475
Total benefit (TV-TC)	**6275**
D. carota	
Land	***
Labour	1000
Manure	***
Fertilizer	200
Total costs (TC)	**1200**
Revenue	
Total sales for season 1 (45kg at Ksh 30)	1350
Total sales for season 2 (53 kg at Ksh 30)	1590
Total revenue (TR)	2940

Appendix 2. Contd.

Total benefit (TV-TC)	**1740**

*** Provided locally; Prices of vegetables provided by Kisumu Uchumi Supermarket;Total revenue, 25705; total costs, 4800; total crop benefits, 20905.

Appendix 3. Analysis of Inflation rate.

Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Average
Inflation rate (%)	10.95	14.5	9.8	26.8	10.1	10.7	14	9.65	5.72	6.88	12

Appendix 4. Analysis of the net present value of PILA and Flat bed.

Years	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
PILA (*A. hybridus*)														
Total benefits	9720	9720	9720	9720	9720	9720	9720	9720	9720	9720	9720	9720	9720	9720
Total costs	4000	1200	1200	1200	1200	4000	1200	1200	1200	1200	1200	4000	1200	1200
Net benefits	5720	8520	8520	8520	8520	5720	8520	8520	8520	8520	8520	5720	8520	8520
NPV	**Ksh 63129.9**													
Flat (*A. hybridus*)														
Total benefits	7620	7620	7620	7620	7620	7620	7620	7620	7620	7620	7620	7620	7620	7620
Total costs	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200
Net benefits	6420	6420	6420	6420	6420	6420	6420	6420	6420	6420	6420	6420	6420	6420
NPV	**Ksh 51714.3**													
PILA (*S. scabrum*)														
Total benefits	11115	11115	11115	11115	11115	11115	11115	11115	11115	11115	11115	11115	11115	11115
Total costs	4000	1200	1200	1200	1200	4000	1200	1200	1200	1200	1200	4000	1200	1200
Net benefits	7115	9915	9915	9915	9915	7115	9915	9915	9915	9915	9915	7115	9915	9915
NPV	**Ksh74366.92**													
Flat (*S. scabrum*)														
Total benefits	7670	7670	7670	7670	7670	7670	7670	7670	7670	7670	7670	7670	7670	7670
Total costs	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200
Net benefits	6470	6470	6470	6470	6470	6470	6470	6470	6470	6470	6470	6470	6470	6470
NPV	**Ksh 52117.04**													
PILA (*C. gynandra*)														
Total benefits	10530	10530	10530	10530	10530	10530	10530	10530	10530	10530	10530	10530	10530	10530
Total costs	4000	1200	1200	1200	1200	4000	1200	1200	1200	1200	1200	4000	1200	1200
Net benefits	6530	9330	9330	9330	9330	6530	9330	9330	9330	9330	9330	6530	9330	9330
NPV	**Ksh 69654.5**													
Flat (*C. gynandra*)														
Total benefits	7475	7475	7475	7475	7475	7475	7475	7475	7475	7475	7475	7475	7475	7475
Total costs	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200
Net benefits	6275	6275	6275	6275	6275	6275	6275	6275	6275	6275	6275	6275	6275	6275
NPV	**Ksh 50546.28**													
PILA (*D. carota*)														
Total benefits	3900	3900	3900	3900	3900	3900	3900	3900	3900	3900	3900	3900	3900	3900

Appendix 4. Contd.

Total costs	4000	1200	1200	1200	1200	4000	1200	1200	1200	1200	1200	4000	1200	1200
Net benefits	-100	2700	2700	2700	2700	-100	2700	2700	2700	2700	2700	-100	2700	2700
NPV	**Ksh 16248.77**													
Flat (*D. carota*)														
Total benefits	2940	2940	2940	2940	2940	2940	2940	2940	2940	2940	2940	2940	2940	2940
Total costs	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200
Net benefits	1740	1740	1740	1740	1740	1740	1740	1740	1740	1740	1740	1740	1740	1740

Years	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
PILA (*A. hybridus*)																
Total benefits	9720	9720	9720	9720	9720	9720	9720	9720	9720	9720	9720	9720	9720	9720	9720	9720
Total costs	1200	4000	1200	1200	1200	1200	4000	1200	1200	1200	1200	4000	1200	1200	1200	1200
Net benefits	8520	5720	8520	8520	8520	8520	5720	8520	8520	8520	8520	5720	8520	8520	8520	8520
NPV																
Flat (*A. hybridus*)																
Total benefits	7620	7620	7620	7620	7620	7620	7620	7620	7620	7620	7620	7620	7620	7620	7620	7620
Total costs	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200
Net benefits	6420	6420	6420	6420	6420	6420	6420	6420	6420	6420	6420	6420	6420	6420	6420	6420
NPV																
PILA (*S. scabrum*)																
Total benefits	11115	11115	11115	11115	11115	11115	11115	11115	11115	11115	11115	11115	11115	11115	11115	11115
Total costs	1200	4000	1200	1200	1200	1200	4000	1200	1200	1200	1200	4000	1200	1200	1200	1200
Net benefits	9915	7115	9915	9915	9915	9915	7115	9915	9915	9915	9915	7115	9915	9915	9915	9915
NPV																
Flat (*S. scabrum*)																
Total benefits	7670	7670	7670	7670	7670	7670	7670	7670	7670	7670	7670	7670	7670	7670	7670	7670
Total costs	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200
Net benefits	6470	6470	6470	6470	6470	6470	6470	6470	6470	6470	6470	6470	6470	6470	6470	6470
NPV																
PILA (*C. gynandra*)																
Total benefits	10530	10530	10530	10530	10530	10530	10530	10530	10530	10530	10530	10530	10530	10530	10530	10530
Total costs	1200	4000	1200	1200	1200	1200	4000	1200	1200	1200	1200	4000	1200	1200	1200	1200
Net benefits	9330	6530	9330	9330	9330	9330	6530	9330	9330	9330	9330	6530	9330	9330	9330	9330
NPV																

Appendix 4. Contd.

Flat (*C. gynandra*)																
Total benefits	7475	7475	7475	7475	7475	7475	7475	7475	7475	7475	7475	7475	7475	7475	7475	7475
Total costs	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200
Net benefits	6275	6275	6275	6275	6275	6275	6275	6275	6275	6275	6275	6275	6275	6275	6275	6275
PILA (*D. carota*)																
Total benefits	3900	3900	3900	3900	3900	3900	3900	3900	3900	3900	3900	3900	3900	3900	3900	3900
Total costs	1200	4000	1200	1200	1200	1200	4000	1200	1200	1200	1200	4000	1200	1200	1200	1200
Net benefits	2700	-100	2700	2700	2700	2700	-100	2700	2700	2700	2700	-100	2700	2700	2700	2700
Flat (*D. carota*)																
Total benefits	2940	2940	2940	2940	2940	2940	2940	2940	2940	2940	2940	2940	2940	2940	2940	2940
Total costs	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200
Net benefits	1740	1740	1740	1740	1740	1740	1740	1740	1740	1740	1740	1740	1740	1740	1740	1740