INVESTIGATING VIABILITY OF PREMIUM INFLUENCED LAND AGRO-USAGE STRUCTURE FOR INCREASED PHYTO-DIVERSITY AND PRODUCTION OF AFRICAN LEAFY VEGETABLES

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other University.

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DEDICATION

This work is dedicated to my mother Gladys Waima Munialo and all my brothers and sisters for moral and financial support.

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List of acronyms

Acronym	Stand for
FAO	Food and Agriculture Organization
NH	Near House
MF	Mid Farm
FF	Farm Farm
ENB	Economic Net Benefits
MoA	Ministry of Agriculture
DAO	District Agriculture Office
SHF	Smallholder Farms
IVs	Indigenous Vegetables
EVs	Exotic Vegetables
LVs	Leafy Vegetables
ALVs	African Leafy Vegetables
WHO	World Health Organization
XRF	X-ray Fluorescence
DAP	Diammonium Phosphate
NBL	Net Benefits to Land
CNB	Crop Net Benefits
CY	Crop Yield
AIVs	African Indigenous Vegetables
EDXRF	Energy Dispersive X-ray Flourescence
MiMi	Mineral Micro-nutrients

Operational definition of terms

Term	Meaning
Premium Influenced Land Agro-usage Structure	A specially constructed structure for growing vegetable crops. It is an introduction in Jinja and Vihiga
Premium	Is an all-embracing term that is a summation of premium status on the smallholder farming system that ultimately culminates in establishment of a product with a market value that contributes to income security and livelihood of the farmers.
Flat beds	Farmers normal beds for growing vegetable crops.
Residence Directional Dependence Patterns	A term used to describe the sections of land found on a farm unit i.e. the Near House, Mid house, Far Farm
An onion layer with Z topography layout	A diagram adopted as a basis on which an inventory of phyto-diversity was done
Farm unit	A piece of land owned by a farmer
Farm format 1	A special diagram showing a farm unit with different types of terrain for example the flat, gentle sloping and valley terrains
Farm format 2	A special diagram showing the location of a farm unit on a certain kind of topography. For example a farm unit can be found on a flat terrain, on a gentle sloping terrain or on a valley bottom
Near House	A section of land located at a close proximity to the main household for growing crops
Mid Farm	A section of land located in the mid part of a farm unit but adjacent to the Near House
Far Farm	A section of land found on the furthest part of the farm unit but adjacent to the Mid Farm
Nutraceutical value	The nutritional and health giving value of food items. The word "nutraceutical" is coined from "nutrition" and "pharmaceutical"
Nutra metric grade	Mineral micro-nutrient graded

General Abstract

Decreasing land holdings among smallholder farmers in Vihiga and Jinja have resulted in intensive land utilization. This has in turn led to low soil fertility level which has resulted in decline in the abundance and distribution of phyto-diversity found on farms of smallholder farmers. The declining amount and distribution of phyto-diversity has negatively affected the nutrition and the economic well being of the smallholder farmers. Therefore, as land holdings and soil fertility continue to decrease, there needs to be some impetus in place that can retain phyto-diversity (indigenous and exotic diversity) in the intensively cultivated systems, hence the introduction of cropping bed, the Premium Influenced Land Agro-usage Structure as a novel land use practice in these sites.

This study, therefore, endeavoured to investigate the viability of Premium Influenced Land Agro-usage practices in line with a premium implied cropping bed for increased African Leafy Vegetable production on smallholder farming systems in Vihiga and Jinja sites of Kenya and Uganda respectively. The specific objectives were: (1) To identify the status and value of land and phyto-diversity on smallholder cultivation system (2) To investigate and justify the performance of selected vegetable variants 'penned' into a Premium Influenced Land Agro-usage Structure introduction based on a Mineral Micro-nutrient (MiMi) content criterion. (3) To evaluate the benefits of a Premium Influenced Land Agro-usage Structure as a novel land use introduction.

The smallholder farm was delineated on a three Residence Directional (RD) Phyto-diversity Dependence Patterns with respect to distance from the main household. These patterns were; the Near House (NH), Mid Farm (MF) and Far Farm (FF). An onion layer with Z topography layout (onion-Z layout) was adopted to represent these patterns. In each pattern, an inventory

of phyto-diversity contained therein was tracked across on 76 selected households (38 in Vihiga and 38 in Jinja) using a pre-coded questionnaire on a farm format 1 and 2 basis. An approximate area occupied by crops was also collected. Further analysis included determination of the Economic Net Benefits on each RD Phyto-diversity Dependence Pattern.

Vegetable leaf samples and their corresponding soil samples for both indigenous and exotic vegetable crops from Vihiga and Jinja were sampled. They were sun-dried, ground to a powder of 0.2mm sieve size, pelletized and ran in X-ray Fluorescent (XRF) spectrometer and multi-channel analyser. Further data analysis included a nutrametric grading of the vegetables.

Raised bed cum Premium Influenced Land Agro-usage were constructed on 20 randomly selected smallholder farm (10 from Vihiga and 10 from Jinja). Premium branded vegetable crops (indigenous and exotic types) were grown on these beds. The following agronomic appeal attributes were monitored to determine the performance of the vegetable crops namely; yield, leaf density, leafiness, disease incidence and branching. The same procedure was done on the flat beds. Further analysis included the determination of the benefits of Premium Influenced Land Agro-usage Structure using the Net Present Value and the assessment of the Satisfaction Index of the bed to the farmers.

In Vihiga and Jinja, RD Phyto-diversity Dependence Patterns Near House, Mid Farm and Far Farm were consistently similar for both farm format 1 and 2 scenarios. A T test analysis showed a high significant difference $p \leq 0.001$ in mean ENB between the Near House (Ksh 9,926.3) and Far Farm (Ksh 5,933.6) and Mid Farm (Ksh 8,860) and Far Farm (Ksh 5,933.6).

Patterns at a closer proximity to the main household had a high total mean Economic Net Benefits compared to ones that were located further from the main household.

Results showed that there were high significant differences ($p \leq 0.001$) in the MiMi densities between Indigenous Vegetables (IVs) and Exotic Vegetables (EVs) in the following minerals; K, Ca, Fe and Mn. High significant differences at ($p \leq 0.001$) in MiMi densities on selected vegetable crops were also noticeable between Jinja and Vihiga sites in the following minerals; K, Ca, Fe, Cu and Zn. Comparisons of MiMi on selected vegetable crops between long rains (LR) and short rains (SR) for both sites were significantly different at ($p \leq 0.001$) for the following mineral; K, Ca, Fe, and Zn. Further analysis showed a high correlation at ($R=0.9969$) in Mineral Micro-nutrient between vegetable samples and the corresponding soil samples. *Amaranthus hybridus* and *Solanum nigrum* from Vihiga and Jinja respectively were found to be nutraceutically superior to *Cleome gynandra, Brassica acarinata, Daucas carota, Oleum cepa and Spinacia oleracia.* Generally, Indigenous Vegetables had higher nutra-ceutical grade rankings compared to Exotic Vegetables.

In both Vihiga and Jinja, there were high significant differences at $p \leq 0.001$ in performance of vegetables crops grown on Premium Influenced Land Agro-usage Structure compared to flat beds, in yield and height (Premium Influenced Land Agro-usage Structure yield (kg/ha) was 42254 versus 27772 for flat beds, Premium Influenced Land Agro-usage Structure 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 ($p=0.001$) as shown by the means of the following agronomic appeal attributes; mean yield (kg/ha) for the Long Rain (LR) was 36064 against 33962 for the Short Rain (SR). Also significant differences in vegetable performance were detected between Vihiga and Jinja in the following agronomic appeal attributes 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 Premium Influenced Land Agro-usage Structure had high Net Present Value (KSHS191390) compared to the flats beds (KSH122087). Further analysis showed the Premium Influenced Land Agro-usage Structure having a Satisfaction Index of 61.8%. The farmers were somehow satisfied with the Premium Influenced Land Agro-usage Structure introduction.

The higher incidence of phyto-diversity at the Near house illustrates the nutrition and bio-economic benefits likely to be derived from growing vegetables at the Near House and Mid farm patterns. The indigenous leafy vegetables being superior to exotic ones in MiMi content suggests a justification for niching them in a specially constructed Premium Influenced Land Agro-usage Structure structure also as a way of increasing their production for a marketable value. Even though performance of vegetable crops on Premium Influenced Land Agro-usage Structure was better than on flats, the costs of construction of the former were high. The next phase of study is necessary to target measures for increasing the longevity of the Premium Influenced Land Agro-usage Structure and reducing associated costs of construction for increased viability.

CHAPTER ONE

GENERAL INTRODUCTION

1.1 Background information

Land subdivision occasioned by population increase has resulted in reduced land sizes among smallholder farmers in Jinja and Vihiga. For instance, the current land holdings in the two study areas are at 0.4 ha per household, which are below the recommended FAO standards of 1.4 ha per household for subsistence use (FAO, 2008). Consequently, land is intensively utilized which has in turn led to low soil fertility level. The low soil fertility level has resulted in decline in the abundance and distribution of phyto-diversity found on farms of smallholder farmers. The situation of decline in phyto-diversity and its use has also been manifested in Vihiga and Jinja and is increasingly worsening (Vorster et al., 2008; Abukutsa-Onyango, 2008; Mitra and Pathak, 2008).

Furthermore, because of the reduced land sizes, these smallholder farmers have made decisions that have led to reduction in the amount of phyto-diversity. For instance there is increased production of some staple crops like maize at the expense of vegetable crops, indigenous crops being highly affected. Recent studies have shown that indigenous vegetables such as pumpkin leaf, amaranth, spider plant and *solanum* are mineral micro-nutrient (MiMi) rich than cereal crops such as maize and sorghum and, therefore, have a potential role to play in the mitigation of hidden hunger (Akundabweni et al., 2010). However, if nothing is done to increase the availability of these indigenous vegetable crops, their use and conservation might slowly extinct.

The declining amount and distribution of phyto-diversity has negatively affected the nutrition and the economic well being of the smallholder farmers. Therefore, as land holdings and soil fertility continue to decrease, there needs to be some impetus in place that can retain phyto-diversity both indigenous and exotic diversity in the intensively cultivated systems, hence the introduction of cropping bed, the Premium Influenced Land Agro-usage Structure as a novel land use practice in these sites.

Premium Influenced Land Agro-usage Structure as an innovation or technology is suitable for home vegetable growing preferably under high family land population pressure and/or less tillable land. Because of its micro-climate, a Premium Influenced Land Agro-usage Structure planting is known for uniform special plant arrangement and therefore good seedling growth and plant produce of an attractive marketable appearance i.e. (premium sale value). However, Premium Influenced Land Agro-usage Structure planting is not a common practice in both Vihiga and Jinja and can be described as a novelty in both areas. Its relevance is thus as follows: a) convenient to fit the Premium Influenced Land Agro-usage Structure into a main household compound setting; b) none-competitive in space to an already overcrowded arable piece of land in either Near Farm, Mid Farm and Far Farm portions; c) within reach for constant care and protection of a high premium value crop. Crops produced under raised beds (Premium Influenced Land Agro-usage Structure) yield more compared to ones grown under flat beds (Fahong' et al., 2011).

The study was therefore conducted in Vihiga and Jinja sites in Kenya and Uganda respectively. This was a cross border study which involved a collaboration of activities between two students; a Kenyan and a Ugandan student, hence the choice of the two study sites. The study attempted to come up with measures to increase phyto-diversity in smallholder farms and its utilization.

Vihiga and Jinja sites are found in the Lake Victoria Basin. Climate in these areas can support a variety of crop farming such as coffee, tea, sugarcane, maize, horticultural crops and rearing of livestock. For example, the annual precipitation is about 1900mm for Vihiga (Vihiga District Environment Action Plan, 2009-2013). Jinja receives an annual rainfall of 1000mm (State of the Environment Report for Jinja district 2005). Both sites experience bimodal rainfall pattern; the long rain and short rain seasons. Long rains are experienced in the months of March, April and May which are also deemed to be the wettest while short rains are experienced in the months of September, October and November. The driest and hottest months are December, January and February. Major farming activities like cereal, vegetable and cash crop farming are done in the long rain season. Harvesting of crops is done at the end of the short rain season because of the favourable dry conditions experienced. Temperatures range between 14^0C - 32^0C, with a mean of 23^0C for Vihiga site (Vihiga District Environment Action Plan, 2009-2013) and 27^0C-30.9^0C with a mean of 28^0C for Jinja site (State of the Environment Report for Jinja district 2005). In contrast to Vihiga, Jinja has a relatively low humidity, which occurs throughout the year. These sites therefore have favourable climatic conditions for agricultural production.

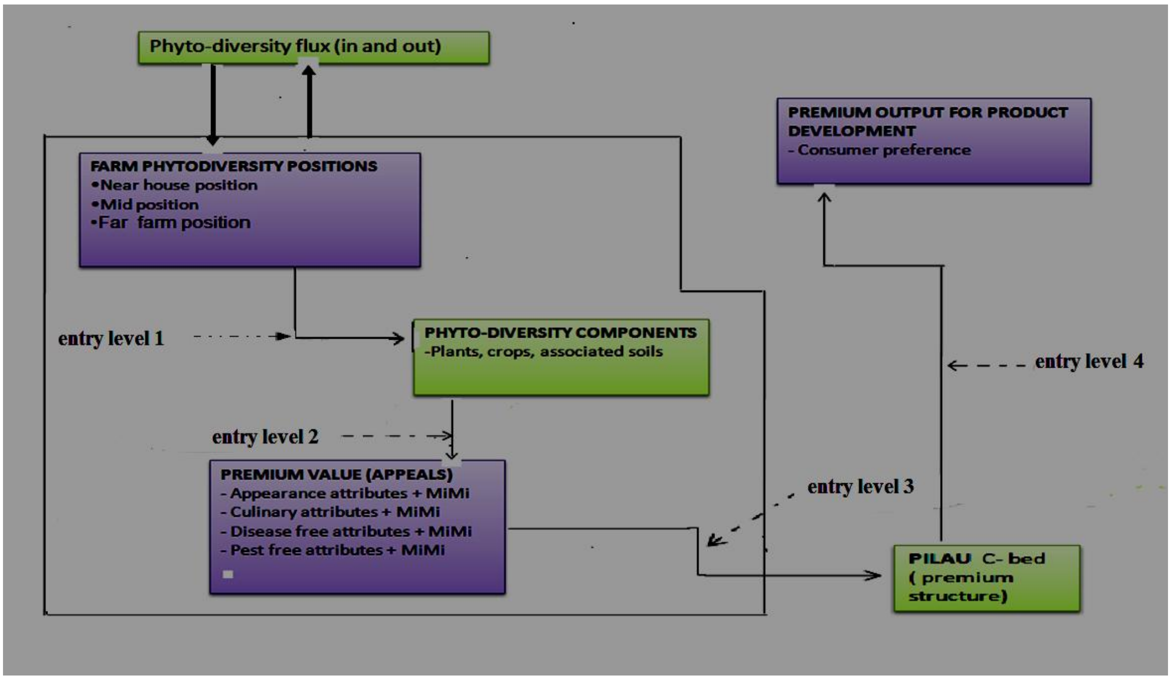
Vihiga is located on the South West of Muhoroni escarpment of the Nandi Hills ridge. It has undulating hills and valleys with streams flowing from Northeast to Southwest and draining into Lake Victoria. There are two main rivers, Yala and Esalwa, which drain into Lake Victoria. These rivers and streams can be utilized for increased agricultural production even during the drier months. On the other hand, Jinja is characterized by extensive undulating lowlands, isolated hills and pediments of approximately 115 m with linear and convex slopes between 2 and 8%. The district is sculptured into rolling landscape with gentle slopes and shallow valleys occupied by papyrus swamps (Vihiga District Environment Action Plan, 2009-2013). The almost gentle sloping to flat land in Jinja is quite ideal for crop production.

Patterns of land use in Vihiga and Jinja are highly determined by rainfall amounts and soil characteristics (Maitima et al., 2010). Land use in the two study sites consist of both crop and livestock production systems. Crop production includes growing of maize, beans, tea, bananas, sugarcane, finger millet, vegetables (indigenous and exotic) coffee, cassava, sweet potatoes, and arrowroots. Agricultural production is mainly centred towards subsistence use, the surplus being sold locally (Maitima et al., 2010). Agricultural productivity in the area is mainly hampered by low landing holdings which has resulted in low income and high poverty levels (Nyangweso et al., 2007).

The declining quantity, distribution and consumption of edible phyto-diversity has led to reduction in the diversity of traditional crops grown at the household level in Jinja and Vihiga thus restricting the otherwise traditional dietary diversity that was once beneficial to the locals. Indigenous vegetables are important as a source of food base of the people, particularly those in marginal and tribal areas, as they are most vulnerable to food shortages and famines. Many indigenous vegetables are nutritious, having medicinal properties or even serving as sources of novel industrial products but they are underutilized and underexploited. In vihiga and Jinja indigenous crops found are *Solanum scabrum, Cleome gynandra and Amaranthus* spp. Production of these crops has been going on for the past few years. However, production is not adequate in terms of meeting food requirements and income. This has been attributed to low land size holdings. Faced with the problem of reduced land for crop productivity especially vegetables, the smallholder operators in these areas have relinquished production of the otherwise high value indigenous vegetables and introduced exotic varieties.

Trends in land use show an increase in industrial and construction activities. Compared to agricultural activities, the rate at which industrial and manufacturing activities is growing is high. For instance, in the upper parts of the LVB; Vihiga and Jinja included, Agro industries based on sugar, cotton and tea predominate (Maitima et al., 2010). Agricultural land is therefore, decreasing. Production of some crops is being preferred at the expense of others. For example, in Vihiga cereals crops like maize are preferred at the expense of vegetable crops; indigenous vegetable being affected (DAO report 2010). Sustainable utilization of the limited land parcels is therefore, important in these sites where agricultural production is for sustenance (Mutiga et al., 2011). Since no approaches are possible in expanding the land resource, improved crop production techniques and management promise better yields. Premium Influenced Land Agro-usage Structure is one of such techniques.

Therefore, an intervention study based on 'Entry-level-1-to-level-4' conceptual framework (Figure 1) was thus undertaken at Vihiga and Jinja to identify phyto-diversity as a determinant of land use and basis of subsequent premium value addition tagging, culminating to a premium produce with marketable value.



Legend
MiMi- Mineral Micro-nutrient, entry level- window for intervention for generating possible innovations, Premium Influenced Land Agro-usage Structure
Source: Akundabweni , 2010

Figure 1 : Conceptual framework of the study

The framework's rationale is that a resource flow is in a state of the in-and-out flux for both indigenous and exotic germplasm occurring in intensively cultivated small holder farms. This flux provides entry levels up to the Premium Influenced Land Agro-usage Structure intervention, by which time; a premium value has been added via processes to the selected choice of a valued crop along the chain.

The above conceptual framework is also useful for the following questions; 1. Which are the types of phyto-diversity found on the smallholder farms? Which are the economic benefits of land in terms of crop gross margins? Which are the benefits of indigenous vegetables in terms of micronutrients? What are the benefits of growing crops on a raised beds compared to flat beds? 2. For crystallising the problem statement, 3. For devising the methodology

1.2 The problem statement

The favorable climatic conditions coupled with a high population provide ideal conditions for agricultural production in Vihiga and Jinja sites. Jinja site is located close to Lake Victoria while Vihiga is well endowed with a number of rivers ensuring availability of water for agricultural production even in dry periods. Furthermore, the proximity of these sites to towns can provide a market for its produce. For instance, both Vihiga and Jinja are located close to Kisumu City with well developed infrastructural conditions for preservation and transportation of the produce to far markets. These sites would, therefore, do much better with larger sized land for production of a variety of both food security and cash valued crops.

However, land holding in these sites is small and is continually decreasing among smallholder farmers as a result of land subdivision due to population growth. This has resulted in intensive use of land leading to low soil fertility levels. As an adaptation mechanism, these smallholder farmers in these sites have made decisions that have affected the quantity and quality of the foods produced by the households. For example, the smallholder farmers have relinquished production of the otherwise high quality indigenous vegetables. This has resulted in the reduction in the amount and distribution of on-farm phyto-diversity which has in turn affected the nutrition of food consumed as well as economic well being of the smallholder farmers. If the situation is not contained, there will be emergence of nutritional related illnesses which will affect agricultural productivity.

Sustainable utilization of the limited land parcels is therefore important in these sites where agricultural production is for sustenance. Since no approaches are possible in expanding the land resource, Land use management techniques that increase the premium of the limited parcels of land therefore promise better yields. A determination of the status of phyto-diversity and the economic value of different fields found on the smallholder farm was necessary to help understand factors leading to decline in phyto-diversity. An understanding of micro-nutrient content of different vegetable crops was also necessary as a basis of justifying the introduction of premium land use structures (Premium Influenced Land Agro-usage Structure). A determination of the benefits of Premium Influenced Land Agro-usage Structure introduction was also done. This was necessary to provide an information basis for recommending appropriate intervention decision that could be taken in improving the quantity and quality of food consumed at the household as well as the economic well being.

1.3 Justification

The primary reason for decline in phyto-diversity on smallholder farms in Jinja and Vihiga could be as a result of small land holdings due to land subdivision occasioned by increase in population growth. As an adaptation mechanism, these smallholder farmers have made decisions that have affected the quantity and quality of the foods produced by the households. For instance, the smallholder farmers have relinquished production of the otherwise high quality indigenous vegetables. The situation is worsened by the fact that information on indigenous vegetables both as nutrient and income providers is inadequately available. All these factors have contributed to lower phyto-diversity and overall crop yield on smallholder farms thus affecting the nutrition of food consumed at the household. It was, therefore, necessary to determine the phyto-diversity on the smallholder farms and value of land in order to come up with reasons as to why phyto-diversity was under decline and why value some farm (closer or further from the main household) had low value. This was necessary as a way of providing measures aimed at improving phyto-diversity as well as quantity and quality of food consumed at the household level. Additionally, analysing micro-nutrient content in vegetable crops was necessary as way of justifying the introduction of the Premium Influenced Land Agro-usage Structure and to provide an information basis for recommending appropriate intervention decision that could be taken in improving the quantity and quality of food consumed at the household.

1.4 Objectives and hypothesis

1.4.1 Overall objective

To investigate the viability of Premium Influenced Land Agro-usage practices for increased African phyto-diversity and production of Leafy Vegetables.

1.4.2 Specific objectives

1) To identify the status and value of land and phyto-diversity on smallholder cultivation system
2) To determine the micro-nutrient content of African leafy vegetables as premium value branding for their worth of cropping them on a Premium Influenced Land Agro-usage Structure To evaluate the benefits of a Premium Influenced Land Agro-usage Structure as a novel land use introduction

1.5 Hypothesis

The underlying hypotheses in this study were;

1) On farm phyto-diversity is not affected by distance from the main household
2) Micro-nutrient status is not related to the success of the Premium Influenced Land Agro-usage Structure

CHAPTER TWO

2.0 GENERAL METHODOLOGY

Figure 2: A map showing the study sites; Jinja (Lat. 1^0 1.5' S; 29^0 30.9' E) and Vihiga (Lat. 0^0 15'N; Long. 34^0 30'E)

2.1 Description of the study sites

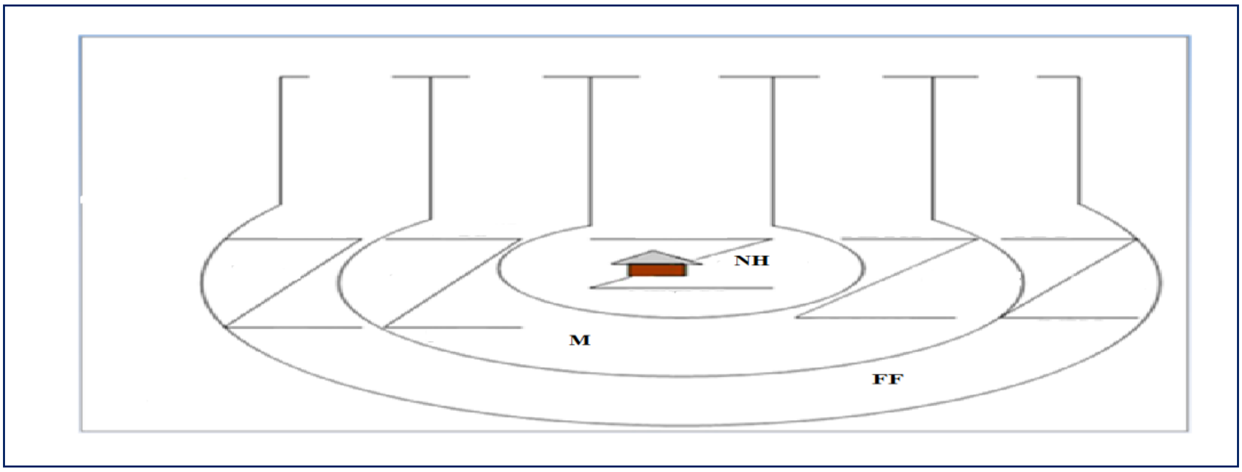
The study sites were Vihiga and Jinja as shown in figure 2. The Vihiga site is in Vihiga County which borders Kakamega County to the North and West, Nandi County to the East, Kisumu County to the South and Siaya County to the Southwest. The county lies between longitudes 34^o30' and 35^o0'and latitudes 0^o and 0^o15' East and North respectively with a total area of 531km^2 (Vihiga District Environment Action Plan, 2009-2013). The Jinja site is in Jinja District which is located in the eastern part of Uganda at Latitude 1^0.5' S and Longitude 29.3^o and 30.9 E. It covers a total surface area of 734Km^2, of which 90% (677 Km^2) is arable land (State of the Environment Report for Jinja District, 2005).

Vihiga county is categorized into two main agro-ecological zones; the upper and lower midlands. These zones dictate the land-use patterns and population settlement in the county. The upper midland zone with well-drained and fertile soils has a high potential for crop production like tea, coffee, maize, beans, bananas and covers parts of Sabatia, Hamisi and Vihiga constituencies. The lower midland zone has mainly the red loamy sand soils derived from sediments and basement rocks and include Emuhaya constituency (Vihiga District Environment Action Plan, 2009-2013).

The largest part of the Jinja District is underlain by un-differential gneisses formerly seen as part of basement complex. Rhodi ferrelistic Nitisol are the most predominant soil type comprising 42% of the total land area, mainly in the sub counties of Budondo, Mafubira, Kakira and Jinja Municipal Council. This soil type has relatively high to moderate fertility level, it is highly permeable, with a stable structure, hence less prone to erosion. Rhodi lixi ferralisols are the second predominate soil type, covering approximately 41.9% of the total land area, mainly found in the sub counties of Butagaya, Buwenge, Busede and Buyengo. Generally, all the soil types in Jinja are of moderate stable structure, low erodibility and high fertility, with ability to support a wide range of activities such as settlement, farming and forest establishment (State of the Environment Report for Jinja district 2005)

2.2 The onion layer and Z-design

The study was based on an Onion Layer Schema and Z design of land use resource allocation and phyto-diversity distribution on the smallholder farmer holding. The onion layer and Z-design (Figure 3), the model developed by Akundabweni (Unpublished), looks at the Smallholder Farm (SHF) as a unit consisting of three RD Phyto-diversity Dependence Patterns; Near house (NH), Mid (M) and Far Farm (FF) patterns. The NH pattern is a piece of land located close to the main household, M pattern is a piece of land located next to the NH but at a far distance from the main household and FF pattern is a piece of land located next to the M but at further distance from the main household as shown in Figure 3.



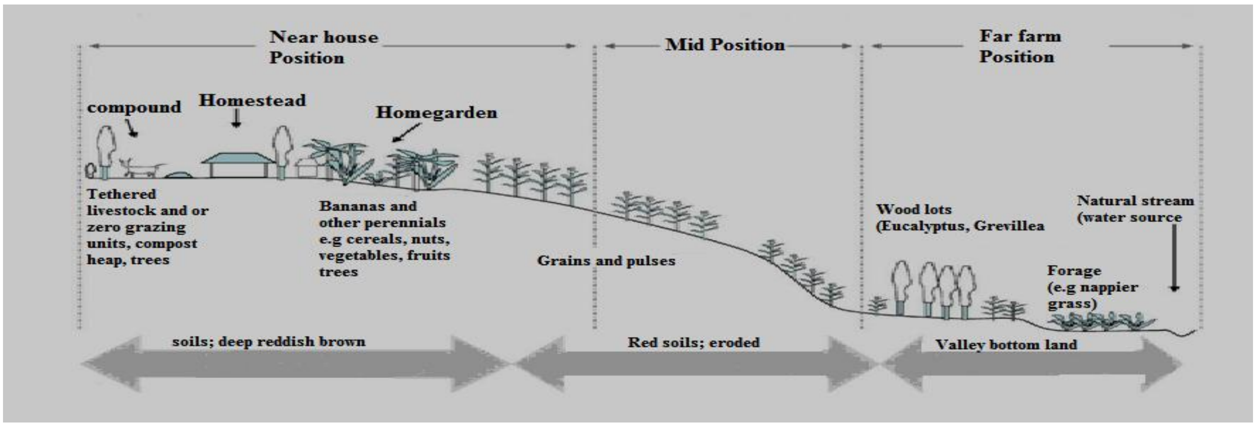
Legend

The Z within each onion layer layout represents (a) the upland land use on the flat arm of the Z figure, (b) the slant arm represents the sloping or steep land and (c) the bottom or valley or plain is represented by the ground floor arm. NH –Near House pattern, M- Mid Farm pattern, FF- Far Farm pattern

Source: Akundabweni 2010

Figure 3: An Onion Layer Schema with a Z topography layout principle

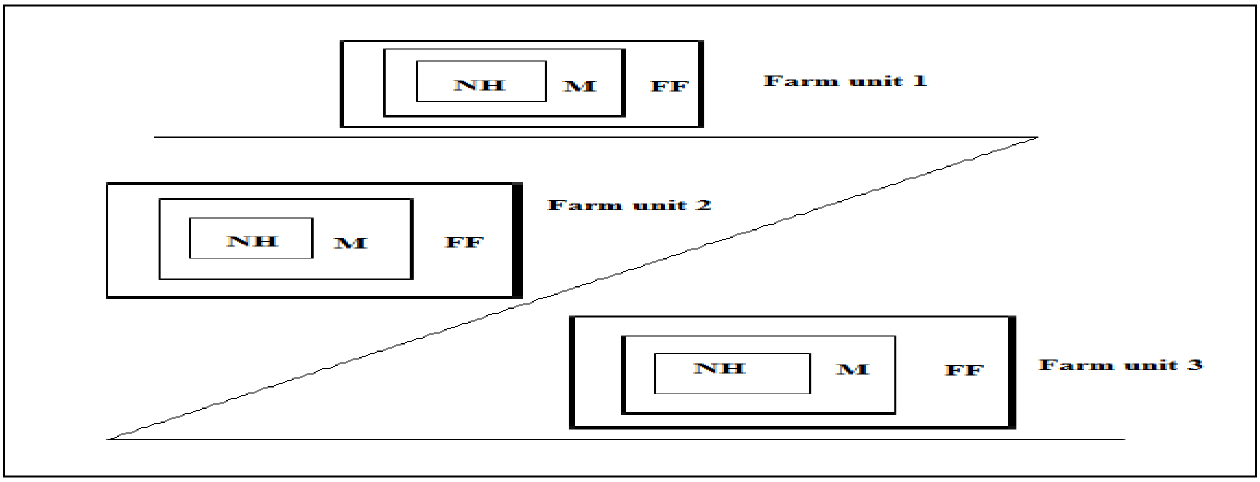
A total of 76 households were sampled from Vihiga and Jinja sites of Kenya and Uganda respectively. Phyto-diversity in each of the patterns (NH, M, and FF) was collected on a Phyto-diversity Farm Format 1 or 2 as shown in Figure 4 and 5. An economic analysis to determine the Economic Net Benefits of the each of the patterns was done using crop gross margins as suggested by Rossiter (1995). Each smallholder farm unit was approximately 0.4 ha.



Legend: Phyto-diversity is distance-positional with respect to distance from the house. Phyto-diversity can be found at the Near house Position or Mid Position or Far farm position. An entire farm unit across three topographic segments. In the above farm format, the whole topographic stretch (the upland, steepland and bottom land) belongs by the traditional allocation to an allocatee.

Source: Akundabweni (Unpublished)

Figure 4: Phyto-diversity Farm format 1



Legend: NH –Near house position, M- Mid position, FF- Far Farm position. The Z design indicates that farm units can either be located (a) the upland land use on the upper flat arm, (b) the slant arm represents the sloping or steep land and (c) the bottom or valley or plain represented by the lower flat arm. The NH, MF and FF in this format are limited to a given specific topography. It occurs where respective topographic segments are too expensive in type to allow allocation all across.

Source: Akundabweni (Unpublished)

Figure 5: Phyto-diversity Farm format 2

2.3 Sampling design

Multi-stage sample design was employed in the selection of the 76 households. Vihiga site was first clustered into 6 locations. In each location a further grouping of 6 sublocation was done. Six respondents were then randomly selected from each sublocation bringing the number to 36. An additional number of 2 respondents from two sublocations were added, making the total number of respondents to be 38. Further clustering of Jinja site into three counties was done (3*1). Each county, three administrative units were identified (3*3). Four respondents were randomly picked from each administrative unit (9*4). An additional number of 2 respondents from two sublocations were added, making the total number of respondents to be 38.

2.4 Sampling and analysis of vegetable crops and corresponding soil samples

Vegetable crops (indigenous and exotic) and their corresponding soil samples were sampled in each of the farmers' conventional plots. They were then sun-dried, ground to a powder of 0.2mm sieve size, pelletized and ran in XRF spectrometer and multi-channel analyser. Further analysis included determining the nutraceutical value of the vegetables.

2.4 Establishment of Premium Influenced Land Agro-usage Structure

Premium Influenced Land Agro-usage Structures cum raised beds (of stair-case like design) were established on farms of 20 (10 from Jinja and 10 from Vihiga) smallholder farms as shown in Figure 6 (1). High grade Indigenous vegetables (*Solanum scabrum*, *Cleome gynandra*, *Amaranthus* spp) and exotic vegetables (*Daucas carota*) were planted on these beds in a two season period (long rain and short rain season). The following growth indicators were monitored on a weekly basis and data taken to show the progress of vegetables; leaf density, height, disease prevalence and yield. The same procedure was done on conventional plots Figure 6 (2). Further analysis included determining the Net Present Value and Satisfaction Index of the Premium Influenced Land Agro-usage Structures.

Figure 6: Premium Influenced Land Agro-usage Structures (1) compared to flat bed (2)

1.6.1 Procedure for construction of Premium Influenced Land Agro-usage Structure

Construction of Premium Influenced Land Agro-usage Structure is shown in Figure 7. Diagram 1, 2, 3, 4, 5, 6, 7, 8; Land clearing, land marking, construction of stairs, putting of poles around the stairs, putting sacks, putting of filler materials, completed Premium Influenced Land Agro-usage Structure, planting.

Figure 7: Procedure for construction of Premium Influenced Land Agro-usage Structure

1.7 Data analysis

Statistical analyses were conducted on treatment means using the t-test and F-test procedure of SPSS software V.12.0, Genstat software V.14.0 and the Microsoft Excel data analysis functions. Analysis of variance tables were prepared for each response variable investigated.

CHAPTER THREE

3.1 GENERAL LITERATURE REVIEW

3.1.1 Phyto-diversity on smallholder farming systems

A general classification of a smallholder farm reveal three farm positions; home garden which is a small field located at a close proximity to the main household, the mid distance, which is a piece of land located next to the home garden and away from the main household and the Farm Farm which is a piece of land located next to the Mid Farm but at a far distance from the main household (Tittonell et al., 2005 and Akundabweni et al., 2010). These own farm positions are associated with land use in terms of cropping choices and determine the extent of phyto-diversity and management on the farm. Many African smallholder farmers manage crop production systems using organic and mineral nutrient resources and the net flow of resources is not equal for the various fields belonging to a single farm household (Smaling et al., 1996). For example, farmers invest more resources on the already fertile soils (soils closer to the main household) than on infertile soils (soils located at a further distance from the main household) (Tittonell 2008). Continuous concentration of nutrients in the smaller areas around the main household, at the expense of nutrient depletion in further and larger fields, coupled with continued export of produce and a lack of external inputs into the farm, leads to an overall negative nutrient balance at farm level (Giller et al., 1997). Studies by Tittonell et al. (2005), show strong gradients of decreasing soil fertility with increasing distance from the main household on smallholder farming systems, which has been attributed to differences in soil properties (Van Asten, 2003), agronomic practices (Mutsaers et al., 1995), farmers' resource allocation decisions (Nkonya et al., 2005), or combinations of these factors (Samake et al., 2006). The difference in soil fertility levels across the smallholder farms has contributed to decline in phyto-diversity (Sanchez et al., 1997; Woomer et al., 1997; Okalebo et al., 2003) Loss of farm phyto-diversity on small holder farming systems in

Kenya and Uganda has been documented by Vorster et al., (2008) and Abukutsa-Onyango (2008). Decline in phyto-diversity has had an effect on the quantity and quality of food produced and consumed at the household level.

The quantity and quality of food consumed at the household level is very important. This is because it determines the energy requirements and flow on the farm (Mutiga et al., (2011). Thus any interference with the quantity of food consumed affects energy flow on the farm. Of much importance is the quality of food consumed. The quality of food is measured in its ability to have a high nutritional level (L.S.M. Akundabweni, personal communication, 2012). The nutritional value of harvested food is becoming a major issue because of differences in soil fertility on the farms. High nutrition foods require a growing medium that contains all the elements that enable a food crop to grow to its maximum genetic potential. A biologically alive soil that is balanced in its mineral values and carbon content is necessary (Marler and Jeanne, 2006).

An understanding of the phyto-diversity amount available in different fields is therefore needed. This will help in determining why certain fields on the farm have low phyto-diversity levels and which measures to take to improve overall farm phyto-diversity and soil conditions in an attempt to increase the quantity and quality of food consumed at the household level.

3.1.2 Economic valuation land to determine its premium value

The problem of persistently low quantity and quality of food in many households can be attributed to differential resource allocation on smallholder farms. In most cases, fields located near the main household tend to be more fertile than those located further from the main household. Thus making farmers apportion more nutrients and other inputs to these already fertile fields. Over time, these resource allocation patterns feed back to positively reinforce the spatial variation in soil fertility and hence yields (Tittonell. (2008). This has negatively affects the amount and nutritional status of food consumed in various households.

Studies to determine the economic benefits of land and profitable enterprises on the smallholder farms have been done by Kibet et al. (2011), Kipsat et al. (2001), and Onyango et al., 2009. These studies however, assume soil fertility levels across the farm are the same. Differentiation of the farm into positions with respect to distance from the main household is not considered. An apportionment of land into positions with regard to distance from the main household is needed in carrying out an economic land evaluation in order to have a clear picture of exactly which fields have higher and low benefits in terms of returns to land, and the type of measures to be taken to improve overall crop yield and consequently the quantity and quality of food consumed at the household level.

3.1.3 Phyto-diversity components

Components of phyto-diversity are classified into three broad categories; the soil diversity, the plant diversity and the animal diversity (BIODATA East Africa final report, 2004). These components interact in a kind of symbiotic relationship. For example plant diversity increases soil stability by increasing the root types, while soil provides nutritional elements necessary for plant growth (Mandy, (2008). However, soil properties greatly influence the amount and quality of phyto-diversity on the farm. For instance poor physical soil properties directly constrain root growth resulting in low phyto-diversity and crop yield. Land misuse and soil mismanagement, resulting from a desperate attempt by farmers to increase production of food, fiber, fuel wood and feeds for the growing population, exacerbate soil degradation. Some of the smallholder practices in Vihiga and Jinja like deforestation combined with unstable agricultural practices e.g over-cultivation of land have contributed to poor soils and consequently low phyto-diversity (Maitima et al., 2010).

The Country Report on the state of plant genetic resources for food and agriculture for 2009 provides a documentation of plant diversity found in Kenya. This includes; maize, rice wheat, cowpeas, green grams, mangoes, nuts, pineapples, oranges, avocado, bananas, sugarcane and vegetables. Among these, maize, beans, nuts (groundnuts), cowpeas, green grams and vegetables are found in Jinja and Vihiga study sites.

However, the diversity of plant, like diversities of other life forms has since the recent past been on the decline due to genetic erosion brought about mainly by desertification, population pressure on land, changes in land use, over-exploitation, drought, floods and negative agricultural development policies.

3.1.4 Land size and its effect on phyto-diversity and nutrition

Land size greatly influences the amount of phyto-diversity on smallholder farming systems which in turn affects the quantity and quality of food consumed at the household level. The bigger the farms size the more the phyto-diversity and consequently the better the nutrition. Land holdings among smallholder farming systems are decreasing due to increase in land subdivision as a result of human population growth. For instance the current holdings in Jinja and Vihiga 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). This has resulted in overuse of land leading to low soil fertility levels. 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 rapid increase in human population has, however, reduced the amount of land available to the farmer and destabilized this traditional system of maintaining soil fertility. Consequently, long-duration natural fallows are no longer possible. They are replaced by short-duration ones, lasting one or two seasons only (Amadalo et al., 2003). Apparent implications of this particular land-intensive strategy are emerging nutrient deficiencies and resource base degradation (Smale et al., 1994). This has resulted in reduction of crop yield which has affected the quantity and quality of food consumed at the household level thus affecting the livelihood of farmers.

The livelihood (including access to nutrition) of any family is dependent on the size of land holding. Decrease in land size has influenced phyto-diversity production. Some crops are preferred for production at the expense of others; for example farmers concentrate efforts in the production of staple crops than vegetables, indigenous vegetables being highly affected. This has resulted in low dietary diversity and nutritional status among smallholder households. Since no approaches are possible in expanding the land resource, improved crop production techniques and management promise better yields (Mutiga et al., 2011). Introduction of the raised cropping bed technology for vegetable production is thus proposed. An evaluation of the viability of raised cropping bed (Premium Influenced Land Agro-usage Structure) in the production of vegetable crops as one of these techniques to help improve land use efficiency is therefore needed.

3.1.5 Raised beds as Premium Influenced Land Agro-usage (Premium Influenced Land Agro-usage Structure) cropping beds

Studies show that raised beds have been widely used in the production of rice, wheat and maize though on a large on large scale (Aquino et al., 1998, Hobbs et al., 2003, Fahong et al., 2004, Limon-Ortega et al., 2000, 2003, 2006). This is because crops produced under raised bed yield more as a higher percent of crops are concentrated per unit area of land, compared to ones grown under flat beds (Fahong et al., 2011). Raised beds therefore increases yield of crops. More crop yield increases the quantity as well as the quality of food consumed by households. An increase in the quantity of crops produced ensures that there is a surplus food supply with a marketable value. This in turn contributes to income security and livelihood of farmers. An accumulating body of evidence has also verified that raised bed planting offers better weed control, water and fertilizer management, thus leading to the lower inputs of water and fertilizers and higher stress-resistance (Wang et al., 2004; Tripathi et al., 2005; Singh et al., 2009; Kong et al., 2010). The fact that water and fertilizer use is efficient under raised cropping beds makes them ideal for use in areas where there is scarcity of water and fertilizer like the semi-arid areas. Additionally, raised beds create a micro-climate in the field of the growing crop that reduces crop lodging and disease incidences (Wang et al., 2004).

The African Press International (2011) has reported use of raised beds in Zambia. In Kenya, double dug raised beds have been used in the production crops in Kitale. In Vihiga and Jinja raised beds are used for production of root and tuber crops like sweet potatoes and cassava. Vegetable production using raised cropping beds is scanty. Information on the use of raised cropping beds for vegetable production in Vihiga and Jinja is still scanty. A modification of raised cropping bed for production of crops especially vegetable crops on a small-scale will help improve the food situation of smallholder farmers in the two study sites. Earlier discussions depict premium value as the summation of premium status on the smallholder farming system that ultimately culminates in establishment of a product with a market value that contributes to income security and livelihood of the farmers. Together, the above mentioned advantages therefore make raised beds be classified as Premium Influenced Land Agro-usage cropping beds (PILAU). Furthermore, raised cropping beds concentrate a large percentage of crops on a small piece of land thus increasing yield. They can therefore be constructed as vegetable gardens in places where land sizes are small like urban areas.

3.1.6 Phyto-diversity of Indigenous vegetables

Most people in the sub-Saharan Africa include indigenous and traditional vegetables in their diet. The consumption patterns differ from region to region among households. For instance, in South Africa, the consumption pattern is highly variable and depends on factors such as poverty status, degree of urbanization, distance to fresh produce markets and season of the year. Poor households use these leafy vegetables (LVs) more than their wealthier counterparts (Rensberg et al., 2007). Ethnicity strongly influences households' choice and consumption of LVs (Kimiywe et al., 2007). In Bulamogi County of Uganda, the consumption of wild food plants is limited to casual encounters, periods of food shortages and as supplements to major food crops (Tabuti et al., 2004). These patterns of consumption have contributed to lower the nutrition of food consumed by households in terms of dietary diversity.

African leafy vegetables (ALVs), also known generically as African spinach, contribute significantly to household food security and add variety to cereal-based staple diets (Van-den-Heever, 1997). However, studies by Eyzaguirre et al. (2006) show that the availability of these vegetables is declining due to a number of factors. These are; lack of sufficient empirical data to link dietary diversity and biodiversity, poor image of traditional foods, poor production, lack of partnerships and networking, low capacity within institutions, poor policies and lack of policy implementation structures, undeveloped value chains and markets and low research priority. There is need to address these issues so as to increase utilization of ALVs at various households levels. This will also go in handy to address the problem of nutritional insecurity.

Mineral elements are essential components of plant metabolism and often accumulate in seeds. Minerals can be classified as nutritionally essential macronutrients that are required in large amounts such as calcium (Ca), chlorine (Cl), potassium (K), magnesium (Mg), sodium (Na), phosphorus (P) and sulphur (S); and nutritionally essential micronutrients, which are needed in relatively small amount e.g. boron (B), iron (Fe), iodine (I), and silicon (Si); and those termed toxic or with the essential/toxic duality including cadmium (Cd), copper (Cu), manganese (Mn), molybdenum (Mo), nickel (Ni), selenium (Se) and zinc (Ihnat, 2003 and Nguni et al., 2011). Indigenous leafy vegetable are rich in micro and macro nutrient elements. A study by Nnamani et al. (2009) in Nigeria on three African vegetables namely Zanthoxylum zanthoyloides Herms, Vitex doniana Sweet and Adenia cissamploides Zepernick using proximate analysis technique shows a high presence of Ca, Mg and Cu in these vegetables. The study also demonstrates the availability of crude proteins and carbohydrates at significantly higher levels. Furthermore, several studies have indicated that the ALVs contain micronutrient levels as high as or even higher than those found in most exotic LVs (Kruger et al., 1998; Odhav et al., 2007; Steyn et al., 2001) Additionally, Cowpea leaves, like many green leafy vegetables, are an excellent source of minerals in the human diet. They provide an inexpensive and abundant supply of minerals such as calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), phosphorus (P), iron (Fe), zinc (Zn), manganese (Mn), copper (Cu) and selenium (Se). Minerals play an important role in the different body functions (FAO/WHO, 2004).

In many instances ALVs have levels of these components that are higher than those of exotic vegetables such as spinach and cabbage (Uusiku et al., 2010). For example while the iron contents of spinach (*Spinacia oleracea)* found in most parts of Africa is known to be 1.7 mg per 100 g edible portion (FAO, 2004), the values observed for amaranth and nightshade are as high as 37 mg. Other good sources of iron include spider flower (Cleome gynandra) plant and hairy lettuce (up to about 50 mg per 100 g of edible portion). Indigenous vegetables may help meet daily requirements of other essential nutrients not found in other food substances, especially in individuals with marginal nutritional status.

Some ALVs are excellent sources of iron (Odhav et al., 2007), but the levels are influenced by factors such as soil type and pH, water availability to the plant, climatic conditions, plant variety (Khader and Rama, 2003), plant age (Gupta et al., 2005) and the use of fertilizers (Guerrero et al., 1998). Extreme or low conditions of these factors results in low availability of micro-nutrients in ALVs, interfering with the nutrition status of these vegetables. These factors should be carefully analysed when producing ALVs so as to maintain a high level of macro and micro-nutrient contents in ALVS which positively feeds back in ensuring higher nutritional status in households.

ALVs are easier to grow and produce. Some of the agronomic advantages of African Leafy Vegetables include: short growth period, where some of these vegetables are ready for harvest within 3-4 weeks; the ability to produce seed under tropical conditions; respond well to organic fertilizers and can tolerate both biotic and abiotic stress (Maundu, 1997 and Onyango, 2002). ALVs are therefore suitable for production in any environment. They can be used in marginalised communities to reduce high malnutrition levels.

Indigenous vegetables may serve as income sources and may be marketed or traded locally, regionally, even internationally, and the primary importance of edible wild species during periods of drought and or social unrest or war is well documented (Humphry et al., 1993, Smith et al., 1995, Smith et al., 1996). Indigenous vegetables fetch a higher price than exotic vegetables on the urban and rural markets. This implies that they can offer potential to entrepreneurs in the informal sector (Onyango, 2003).

In vihiga district studies by Onyango, (2008) shows collection and classification of ALVs that are found and used in the area. Furthermore, documentations by Akundabweni et al. (2008) in Vihiga reveal classification of the ALVs to grade levels from high to low grade levels according to the macro and micro-nutrient content found in them. Abukutsa-Onyango (2008) has noted that the role of African indigenous vegetables (AIVs) in poverty alleviation and food and nutrition security in Kenya has not been fully exploited. Kimiywe, (2009) details some indigenous vegetable recipes and their energy and micronutrient contents but their level of availability to households for consumption needs to be established. This study will therefore contribute to increase the knowledge on the importance of IVs as nutrient providers and income generators in order to increase their use among households.

3.1.7 X-ray Fluorescence Spectroscopy

X-ray fluorescence spectroscopy (XRF) is a method of elemental analysis that assesses the presence and concentration of various elements by measurement of secondary X-radiation from the sample that has been excited by an X-ray source. The method is rapid, does not destroy the sample and with automatic instruments is suitable for routine operation. Elements from the heaviest down to atomic number 9, F, can be determined at levels of a few mg kg^{-1} or less (Jones, 1991). When a primary x-ray excitation source from an x-ray tube or a radioactive source strikes a sample, the x-ray can either be absorbed by the atom or scattered through the material. During this process, if the primary x-ray had sufficient energy, electrons are ejected from the inner shells, creating vacancies. As the atom returns to its stable condition, electrons from the outer shells are transferred to the inner shells and in the process give off a characteristic x-ray whose energy is the difference between the two binding energies of the corresponding shells. Because each element has a unique set of energy levels, each element produces x-rays at a unique set of energies, allowing one to non-destructively measure the elemental composition of a sample (Wanjiru, 2004)

CHAPTER FOUR

THE STATUS OF PHYTO-DIVERSITY AND VALUE OF LAND AS FOUND ON SMALL HOLDER'S FARM UNITS IN VIHIGA-KENYA AND JINJA-UGANDA

4.1 Abstract

The status of phyto-diversity distribution and abundance on smallholder farms in Vihiga and Jinja is continually declining. Declining phyto-diversity abundance and distribution has consequently resulted in low quantity and quality of food consumed at the household. This has affected the nutrition as well as the economic status of the households. This study therefore sought to determine the status of phyto-diversity and value of land on the different fields found on smallholder farms. A division of the smallholder farms into three Residence Directional (RD) Phyto-diversity Dependence patterns of Near House (NH), Mid Farm (MF) and Far Farm (FF) was done. An (onion-Z layout) was adopted to represent these patterns. An inventory of phyto-diversity in each of the RD Phyto-diversity Dependence patterns was done on 76 households from Jinja and Vihiga. Further analysis included determination of the Economic Net Benefits of the various fields found on smallholder farms. Results indicated high phyto-diversity of 50.7% in the Near House pattern, compared to the MF pattern which ranked second in phyto-diversity with 29.8% while the FF pattern had the lowest phyto-diversity of 19.5%. As distance increased from the main household, phyto-diversity decreased. Phyto-diversity is therefore a function Distance from the main household. A T test analysis showed a high significant difference $p \leq 0.001$ in mean ENB between the (Near House= KSH 9926.3 and Far Farm=KSH 5933.6) and (Mid Farm=KSHS 8860 and Far Farm=KSH 5933.6) Patterns. The existence of high phyto-diversity and Economic Net benefits in the Near House and Mid Farm patterns therefore illustrates the economic and nutritional benefits likely to be derived from growing crops these patterns.

Key words

Phyto-diversity, Distribution, Abundance, Near House, Mid Farm, Far Farm

4.2 Background

The status of phyto-diversity distribution and abundance on smallholder farms in Vihiga and Jinja is continually declining. Declining phyto-diversity abundance and distribution has consequently resulted in low quantity and quality of food consumed at the household. This has affected the nutrition as well as the economic status of the households.

Phyto-diversity can be described as the amount and distribution of plant matter growing on a farm unit. Phyto-diversity can either be Natural or Artificial. Natural phyto-diversity is the one that grows on its own while artificial is usually cultivated. Both Natural and Artificial phyto-diversity has an effect on dietary diversity and subsequently on food security. For instance, Natural phyto-diversity comprises of indigenous plants like amaranth, spider plant and pumpkin leaves which are high nutritious and could be beneficial as mitigation against hidden hunger (Akundabweni et al., 2010).

A general classification of a smallholder farm reveal three farm positions; home garden which is a small field located at a close proximity to the homestead, the mid distance, which is a piece of land located next to the home garden and away from the homestead and the far farm position which is a piece of land located next to the mid position but at a far distance from the homestead. (Tittonell et al., 2005 and Akundabweni et al., 2010). The location of these fields away or near the homestead could have consequences on the amount and distribution of phyto-diversity which might affect the nutrition as well as the economic well being of the smallholder farmers.

Several studies have been conducted on phyto-diversity in Lake Victoria Basin (Jinja and Vihiga included. (Abukutsa-Onyango, 2008 and Orwa, 2011) Most of these studies have quantified the amount and types of phyto-diversity found in Vihiga and Jinja. Few of these studies have attempted to document some of the factors affecting diversity. For example Orwa, 2011) found out that declining phyto-diversity in Vihiga on smallholder farms had been affected by reduced land holdings. However, questions on how the location of the different types of fields (Near House, Mid Farm and Far Farm) with regard to distance from the main household affect phyto-diversity remain an answered.

Furthermore, variability in soil fertility as a result of topography has had an effect on the quantity and distribution of phyto-diversity found on smallholder farms (Tittonell et al., 2005). There exist different types of topography ranging from steep, gently sloping to valley bottoms on smallholder farms. Mostly, there will be plenty of phyto-diversity in areas with high soil fertility. Mostly, valley bottoms will tend to accumulate more phyto-diversity because of the high soil fertility (Akundabweni, personal communication). These valley bottoms should, therefore, be targeted for increased phyto-diversity.

Population growth has resulted in land subdivision and subsequently small land holdings among smallholder farmers (Vihiga District Environment Action Plan 2009-2013). As a result, farmers have made decisions that have negatively affected the quantity and distribution of phyto-diversity on the farm. For example, there is preference in the production of some crops which farmers consider as important mostly the staple crops at the expense of other crops that are of high quality (Tittonell et al., 2008). This has adversely affected the quantity and quality of food consumed. The low quantity and quality of food consumed at the household level has been linked to nutritional insecurity. Consequently poor nutrition has been linked to emergence of chronic ailments such as cancer, diabetes. This is increasingly becoming a major concern in Jinja and Vihiga.

Economic land valuation is important as it helps farmers determine the profitable enterprises to be undertaken on the farm (Rossiter, 1995). Studies on economic benefits to land have focussed on the most profitable crop enterprises in Kenya. For instance, Kibet et al., 2011 analysed profitable enterprises and determined benefits to land using gross margin analysis. Studies by Onyango et al. (2009), Kibet et al. (2011), Otieno and Kipsat et al. (2001) have been done on the economic analysis of land for different agricultural enterprises using gross margins. However, in determining the profitable enterprise, the basic assumption has been that soil fertility levels across the farm are the same. However soil fertility levels on the farm vary according to distance from the main household and topography. Differentiation of the farm into positions with respect to distance from the main household is not usually considered. A division of land into positions with regard to distance from the main household is needed in carrying out an economic land evaluation in order to have a clear understanding of which fields have higher and low benefits in terms of returns to land, and the type of measures to be taken to improve crop yield and subsequently, the Economic Net Benefits.

4.3 Materials and methods

4.3.1 Phyto-diversity determination

Observations to identify phyto-diversity were done on the farms of 76 smallholder households. Each farm was delimited on a 3- RD Phyto-diversity Dependence patterns of NH, MF and FF according to Akundabweni *et al.*, (2010) for phyto-diversity determination. An (onion-Z layout) was used to refer to these RD Phyto-diversity Dependence patterns as described in Chapter 2 section with the General Methodology. The study was carried out in the year 2011.

In each pattern, an inventory of phyto-diversity found was done, followed by a classification into their culti-groups. Also, crops grown and their corresponding yields from the previous cropping season were collected. Additionally, approximate area occupied by various crops like maize, beans, vegetables and etc was also collected.

Approximate annual gross margins per acre of the crops identified were then calculated as in the formula;

$$GMy = \mathbf{TRy} - \mathbf{TCy}$$

Where GM was the Gross Margin of crop y for example *Solanum scabrum* or kales, while TR was Total returns of crop y and TC was the Total Cost involved in the production of crop y. The gross margins of the various crop enterprises are shown in appendix 1 and 2.

To determine the net benefits of crop, the annual gross margins per acre of crops were first multiplied by the specific area occupied by a certain type of crop as in the following formula;

$$\mathbf{CNBy = GMy * Ay}$$

Where CNB was the annual Crop Net Benefit of crop y, GMy was the gross margin of crop y while Ay was the area in acres occupied by crop y in a certain land position.

The Economic Net Benefit of a given phyto-diversity pattern was computed by summing all the Crop Net Benefits on each smallholder farm as shown in equation;

$$\mathbf{ENBp1} = \sum_{k=0}^{n} \left(\mathbf{CNB}_{k}^{n}\right)$$

Where ENBp1 was the Net Benefit of a certain farm pattern for example the Near House, CNB was the Net Benefit of various crops that were summed in a given phyto-diversity pattern, while n and k were the various types of crops like maize, beans growing on the smallholder farm. The total net benefits were then analysed using SPSS version 14 to determine the difference in the benefits across the three RD Phyto-diversity Dependence patterns.

4.4 Results

4.4.1: The percentage of farmers with a farm unit having the various Residence Directional Phyto-diversity Dependence Patterns

About 60.5% of farmers in Vihiga had their farms having the three RD phyto-diversity dependence patterns of NH, MF and FF, 21.1% of farmers had two RD phyto-diversity dependence patterns i.e NH and FF, and 18.4% of farmers had only one i.e. the NH. This illustrated in Table 1. In Jinja, about 55.6% of farmers in Vihiga had their farms having the three RD phyto-diversity dependence patterns of NH, MF and FF, 27.2% of farmers had two RD phyto-diversity dependence patterns i.e NH and FF, and 17.2% of farmers had only one i.e. the NH. This is also shown in table 2.

Table 1: The percentage of farmers with a farm having the various Residence Directional Phyto-diversity Dependence Patterns in Vihiga

RD Phyto-diversity dependence patterns	Percentage
NH, MF, FF	60.5
NH, FF	21.1
NH	18.4

Legend NH- Near House, MF- Mid Farm, FF- Far Farm, N= 38 farmers
Year 2011

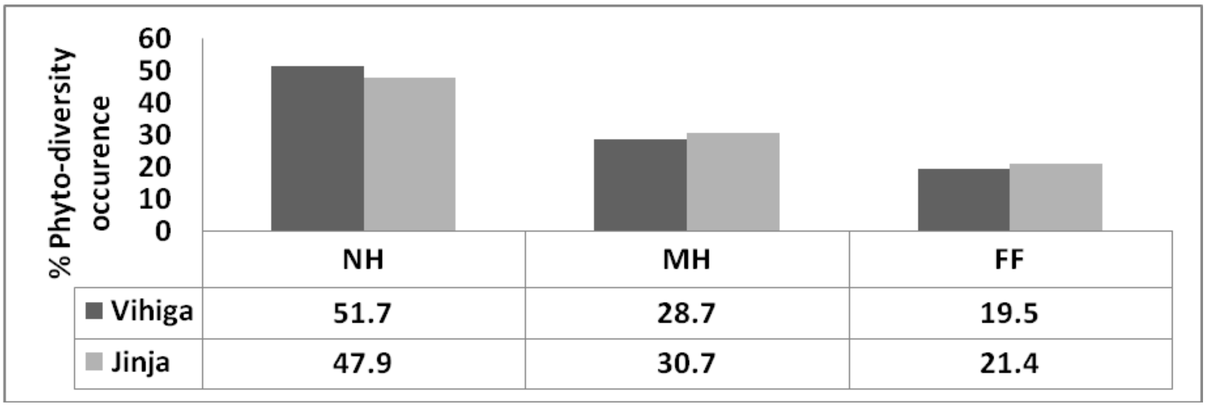
Table 1: The percentage of farmers with a farm having the various Residence Directional Phyto-diversity Dependence Patterns in Jinja

RD Phyto-diversity dependence patterns	Percentage
NH, MF, FF	55.6
NH, MF	27.2
NH	17.2

Legend NH- Near House, MF- Mid Farm, FF- Far Farm, N= 38 farmers
Year 2011

4.4.2 Occurrence of phyto-diversity in Near House, Mid Farm Far Farm Phyto-diversity Dependence Patterns according to farm format 1 and 2

Patterns of phyto-diversity were the same across the two study sites (Vihiga and Jinja) as shown in Figure 8. The frequency of phyto-diversity occurence was high in the NH pattern followed by the MF and the FF for both Jinja and Vihiga. In both Vihiga and Jinja, the NH was the highest in phyto-diversity occurence (Figure 8)



Legend; NH-Near House, MH-Mid House, FF-Far Farm, Year 2011

Figure 8: Phyto-diversity occurrence as a percentage according to farm format 1 and 2 for Vihiga and Jinja respectively

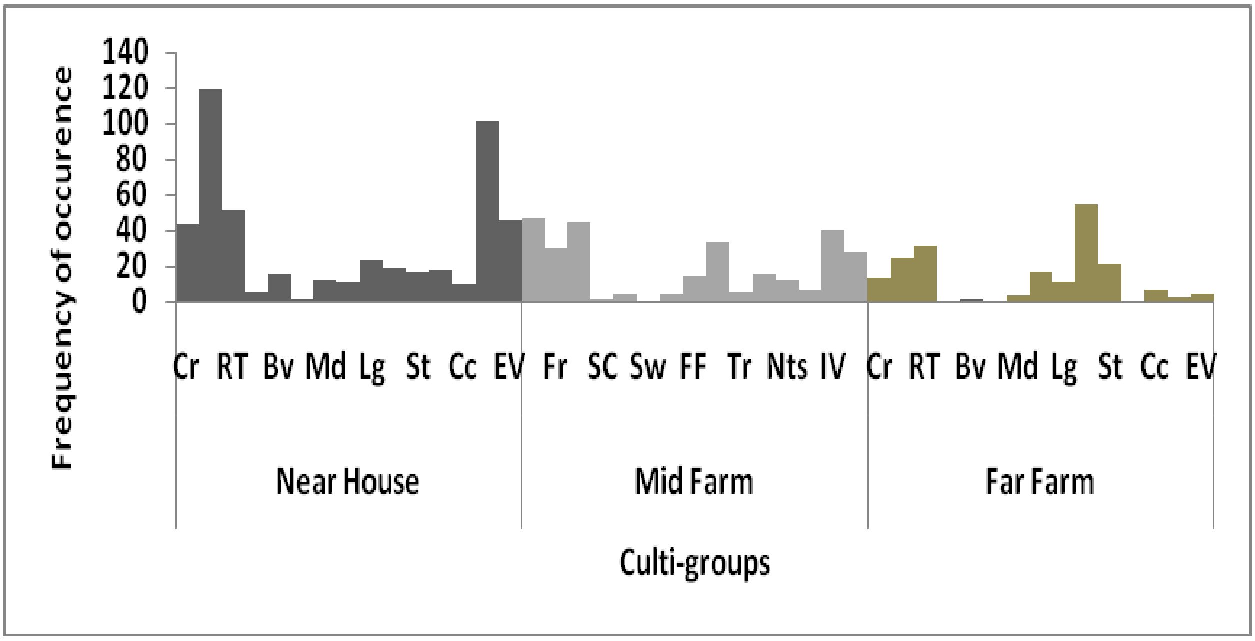
4.4.3 Frequency of occurrence of various culti-groups in the three Residence Directional Phyto-diversity Dependence Patterns

A wide variety of crop species were found growing in the NH compared to the MF and FF RD Phyto-diversity Dependence Patterns as shown in Figures 9 and 10. This included cereals, fruits, roots & tubers, spices & condiments, beverages, sweeteners, medicinal, legumes, stimulants, nuts, cash crops and indigenous & exotic vegetables.. A large percentage of farmers grew fruits in all the three positions of the farm with a high percentage being found in the near house portion. Most fruits grew in Jinja than in Vihiga. Fruits identified included bananas, mangoes, pineapples, oranges and jack fruits. In each of the study areas bananas were found growing in all the farms visited with a high concentration in Jinja. Jack fruits were found in Jinja but none was present in Vihiga. Most of the mangoes were found in Jinja as opposed to Vihiga.

Cereals were found growing in the three RD Phyto-diversity Dependence Patterns of the farm house, with maize being the major cereal that was accessorised. The concentration of cereals was in the MF. A large percentage of were found growing in Vihiga site, the frequency of cereal occurrence being 66 and 37 for Vihiga and Jinja sites respectively. Like cereals, root & tuber were found in all the three positions (NH, MF and FF) of the farm house. More root and tuber occurred in the Jinja site than in Vihiga (81 against 46). Cassava, sweet potato, arrow roots and iris potatoes were the major root and tuber accessorised. The former three mostly occurred in the Jinja site while the latter in the Vihiga site.

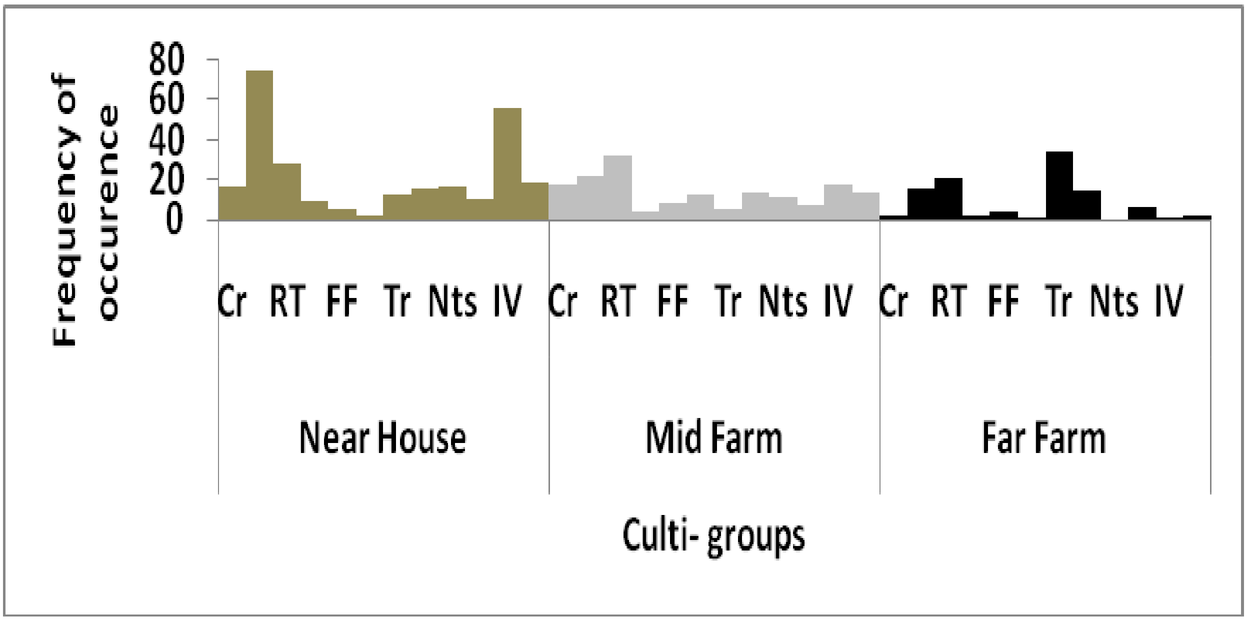
Vegetables identified were classified either as indigenous or exotic varieties. The indigenous varieties comprised of amaranth, Solanum nigrum, Cleome gynandra, Clotalaria spp (mito) and Jute spp (mrenda). While exotic varieties consisted of kales, spinach, egg plant, tomatoes, onions, carrots and cabbage. A high percentage of indigenous plants were found growing in the NH with few exceptions in the MH and FF. The same scenario was with the exotic vegetables. Indigenous plants ranked higher in terms of occurrence compared to exotic species with more of the IVs being found in the Jinja site. The case was different with EVs that were ranked highest in occurrence in the Vihiga site. In some cases farmers grew vegetable crops in the FF to make use of water from a stream of water passing by.

Most farmers preferred growing trees in the FF for the purpose of providing protection to other crops against predators. Fodder and forage was grown in the MF and FF mostly as strips in between other crops, as a conservation measure against nutrient and soil loss, and in places that were unfertile to allow soil and nutrient regeneration. Nuts were found growing the NH. Most nuts were found in Jinja than Vihiga site. Tea and sugarcane were cited as the major cash crops found in Vihiga and Jinja sites respectively. Other crops cited of low occurrence were beverages, sweeteners, medicinal, fodder, legumes, stimulants and spices and condiments.



Legend: Cr-Cereals, RT- Root and Tiber, FF- Fodder and Forage, Tr- Trees, Nts- Nuts, IV- Indigenous Vegetables, EV-Exotic Vegetables

Figure 9: The frequency of occurrence of the various culti- group in the RD Phyto-diversity Dependence Patterns according to Phyto-diversity Farm Format 1 in Vihiga



Legend: Cr-Cereals, RT- Root and Tiber, FF- Fodder and Forage, Tr- Trees, Nts- Nuts, IV- Indigenous Vegetables, EV-Exotic Vegetables

Figure 10: The frequency of occurrence of the various culti-group in the RD Phyto-diversity Dependence Patterns according to Phyto-diversity Farm Format 1 in Jinja

4.4.1 Variation in the mean Economic Net Benefits of the Residence Directional Phyto-diversity Dependence patterns for both Vihiga

There were variations in the mean Economic Net Benefits across the RD Phyto-diversity Dependence patterns as shown in Table 3. A high significant difference (P≤0.001) in the mean ENB between the NH (Ksh 9,926.3) and FF (Ksh 5,933.1) were detected as shown in Table 4. The same difference was also observed in the mean Economic Net Benefits between MH (Ksh 8,860) and FF (Ksh 5,933.61) patterns as shown in Table 5. General patterns closer the main household had high ENB compared to the ones that were located far from the main household.

Table 2: Differences in the mean Economic Net Benefits between the Near House and Far Farm patterns in Vihiga according to farm format 1 and 2

	Mean ENB in Ksh	Standard deviation	Standard error
NH	9926.3	2115.55	242.67
FF	5933.61	5771.41	662.02

ENB-Economic Net Benefit

N=76, Test statistic t=5.501 on 75 degrees of freedom, P≤0.001

Table 3: Differences in Economic Net Benefits between the Mid Farm and Far Farm patterns in Vihiga

RD Pattern	Mean ENB in Ksh	Standard deviation	Standard error
MF	8860	2936.9	336.89
FF	5933.61	5771.41	662.02

ENB-Economic Net Benefit

N=76, Test statistic t=2.369 on 75 degrees of freedom, P≤0.001

However, significant difference (P=0.001) in the mean ENB between the Near House Ksh 9926.3) and Mid Farm (Ksh 8860) patterns were also found. This is shown in Table 5.

Table 4: Differences in Economic Net Benefits between the Near House and Mid Farm patterns Vihiga according to farm format 1 and 2

RD Pattern	Mean ENB in Ksh	Standard deviation	Standard error
Near House	9926.3	2115.55	242.67
Mid Farm	8860	2936.9	336.89

ENB-Economic Net Benefit

N=76, Test statistic t=3.756 on 75 degrees of freedom, P=0.001

4.4.4 Crop rankings according to Economic Net Benefits of the Residence Directional Phyto-diversity Dependence patterns for both Jinja and Vihiga on farm format 1 and 2 basis

Different crops had different ENB. But some crops had higher ENB than the others. For instance in Jinja, bananas had the highest ENB and ranked first and second in NH and MF respectively as shown in Table 6. Sugarcane had the highest ENB in the FF and MF. Cassava ranked best in Jinja site. Beans, coffee and groundnuts had lowest ENB in all the three farm phyto-diversity patterns in Jinja. Other crops that had a higher score in ENB were *Amaranth*, beans, onions, coffee.

Table 5: Crop rankings according to mean Economic Net Benefit of the Residence Directional Phyto-diversity Dependence patterns on a farm format 1 and 2 basis for Jinja

NH			MF			FF		
Crop	ENB in KSH	Crop Rank	Crop	ENB in KSH	Crop Rank	Crop	ENB in KSH	Crop Rank
banana	3757.6	1	cassava	3730.3	1	sugarcane	5626.7	1
amaranth	2663.7	2	bananas	3722.9	2	beans	1538.7	2
cassava	2254.1	3	sugarcane	2314.3	3	coffee	1316.5	3
onions	2138.2	4	amaranth	920.5	4	bananas	969.2	4
sugarcane	485.3	5	beans	613.2	5	amaranth	704.8	5
maize	322	6	onions	493.7	6	onions	481.1	6
nappier grass	264.7	7	groundnut	491.9	7	maize	295.5	7
groundnut	244.7	8	nappier grass	278.4	8	cassava	126.1	8
coffee	165.2	9	maize	194.4	9	bananas	29.6	9
beans	88.8	10	coffee	154.3	10	groundnut	0	10

Legend; NH-Near House, MF- Mid Farm, FF- Far Farm

Compared to Jinja, vegetable especially the indigenous types had a high ENB in Vihiga site. For instance managu (*Solanum scabrum*) ranked best in ENB in the Near House and Mid Farm RD Phyto-diversity Dependence patterns as shown in Table 7. *Amaranth* and kale ranked second in ENB in the Near House and Mid Farm RD Phyto-diversity Dependence patterns. Tea, sweet potato and maize in FF showed a good performance in ENB. Groundnuts scored lowest in ENB

Table 6: Crop rankings according to the mean Economic Net Benefits of the RD Phyto-diversity Dependence patterns in Vihiga

NH			MF			FF		
Crop	**ENB**	**Crop rank**	**Crop**	**ENB**	**Crop rank**	**Crop**	**ENB**	**Crop rank**
managu	3514.5	1	managu	2748.9	1	tea	608	1
amaranth	1687	2	kales	1466.1	2	sweet potatoes	499.9	2
kales	1562.9	3	amaranth	1385.2	3	maize	436.4	3
tomatoes	1460.8	4	tomatoes	935.7	4	managu	435.6	4
saga	976.8	5	maize	729	5	eucalyptus	434.3	5
sweet potatoes	646.7	6	sweet potatoes	514.6	6	amaranth	313.6	6
maize	463.9	7	saga	458.7	7	tomatoes	296.2	7
beans	196.9	8	beans	277.2	8	kales	232.3	8
eucalyptus	68.3	9	tea	76.7	9	beans	208.3	9
nappier grass	33.5	10	nappier grass	55	10	nappier grass	161.5	10
mangoes	23.2	11	mangoes	52.4	11	saga	145.2	11
tea	0	12	eucalyptus	27.6	12	mangoes	41.3	12
ground nuts	0	13	ground nuts	0	13	ground nuts	0	13

Legend; NH-Near House, MF-Mid Farm, FF-Far Farm

4.5 Discussion

Residence Directional Phyto-diversity Dependence Patterns (NH, MF, and FF) are associated with land use in terms of cropping choices. These patterns determine the cropping choices. They also determine the extent of the phyto-diversity in terms of garden or horticultural utility.

Patterns of phyto-diversity (Near house, Mid and Far farm) between Vihiga and Jinja were identical, suggestive of eco-regional similarity both culturally and phyto-sociologically. For instance, most vegetable crops and bananas were found growing in the Near House pattern in Vihiga, the same scenario was manifested in Jinja. Most food crops were found in the Mid Farm pattern, for example, sweet potatoes, cassava and bananas which are the main food crops in Jinja were found in Mid Farm pattern, likewise for maize in Vihiga. Most cash crops were located in the Far Farm pattern, for example, sugarcane and tea were found in the Far Farm pattern of Jinja and Vihiga respectively. This means that the communities residing in Jinja and Vihiga are identical in their cropping patterns and land use practices. Though, production of vegetable crops was limited to a small piece of land (Near House) which is found at the main household. These could result in low quantity and diversity of vegetables which might have consequences on dietary diversity of the smallholder farmers.

The NH indicated the highest phyto-diversity than the other patterns, suggesting a dynamic entry of incoming resource flow that in turn kicks off land use choices, genetic resource conservation and utilization along the entry level of the value chain. The Near House had a high phyto-diversity ranging from annual to perennial. This illustrates the nutritional benefits likely to be derived from growing food crops especially vegetables in this pattern of land. Nonetheless, the occurrence of high phyto-diversity at the Near House pattern could also imply high competition for soil nutrients which could lead to low micro-nutrients content of phyto-diversity in this pattern. The same findings on occurrence of high phyto-diversity in the Near House pattern have been documented by Watson and Eyzaguirre (2002) and Gautman, et. al (2004).

There was a decrease in phyto-diversity from the NH towards the FF. Tittonell et al., 2005, Giller et al., (2005) and Vanlauwe et al., (2000) have provided preliminary evidence of decreasing phyto-diversity with increasing distance from the main household within smallholder farms as a result of differences in soil fertility levels. Variation in phyto-diversity across the smallholder farm could be due to different management of the fields on the smallholder farms. Most farmers invest more resources on the already fertile soils than on the infertile soils. There is therefore continuous accumulation of nutrients in areas around the main household at the expense of nutrient depletion in further and larger fields (Giller et al., 1997). The same findings on variations in phyto-diversity on smallholder farms have been documented by Watson and Eyzaguirre, (2002).

Furthermore, a significant difference in Economic Net Benefits was seen among various crop enterprises. For example, managu (Solanum scabrum) ranked best in ENB in Vihiga in the NHP and MP. The difference in ENB could be because of location of these crops on farm. Most vegetables were found growing at the Near House and Mid Farm RD Phyto-diversity Dependence patterns. There is better management (weeding, fertilizer application, pest control, irrigation and harvesting) of crops located near the main household compared to the crops located further from the main household (Tittonell, 2008). The better management of the vegetable crops could have translated into high yield and subsequently high ENB.

Mostly, vegetable crops (managu, amaranth, kales, onions, and tomatoes) had a higher ENB compared to cereals (maize) and cash crops (sugarcane, coffee). Differences in ENB among the various culti-groups (cereals, cash crops and vegetables) could be attributed to differences in inputs, management and the time the crop takes to mature. The longer the time the crop takes to mature the lesser times it is planted in a given year, resulting in low gross margins hence low CNB. Vegetable crops on the other hand utilize fewer inputs in production and take a lesser period of time to mature and could be produced number of times ensuring continuous flow of income. Same findings showing vegetables (Amaranth) having more returns than cash crops (maize) have been documented by Onyango et al. (2009) and Kibet et al. (2011).

4.6 Conclusion

Phyto-diversity and Economic Net Benefit at the NH was higher compared to the MF and FF. Phyto-diversity therefore is a function Distance from the main household. Location of different fields on the smallholder farms with regards to distance from the main household has an effect on the quantity and distribution of phyto-diversity and subsequently the economic as well as the nutritional well being of the farmers.

4.7 Recommendation

- Highly diversity of food substances are supplied by a portion of land located near the main household i.e. the Near House RD Phyto-diversity Dependence pattern. This also illustrates the nutritional benefits likely to be derived from growing vegetables at the Near House positions.

- Fields located far from the main household (MH and FF) which have low phyto-diversity levels represent the majority of the farming area in Vihiga and Jinja and need to be targeted with major rehabilitation strategies like fertilizer and manure application to improve phyto-diversity and consequently crop productivity. Such rehabilitation strategies will not, however, translate into improved crop productivity unless accompanied by improvements in agronomic practices, such as planting density and timeliness of planting and weeding.

- Resource allocation should therefore be on an equitable basis on all RD Phyto-diversity Dependence patterns, consideration being given to patterns with poorer soil quality (FF).

- Importantly, vegetable production should be encouraged in areas where land sizes are small, as they would act as alternative sources of income by ensuring continuous cash flow. Vegetables especially the indigenous varieties have shown to have a high ENB and short maturity period compared to cereals, cash-crops and root and tubers.

CHAPTER FIVE

INVESTIGATING THE AFRICAN LEAFY VEGETABLES MINERAL MICRO-NUTRIENTS AND INTER-SPECIFIC ATTRIBUTES SO AS TO JUSTIFY THEIR ESTABLISHMENT ON A RAISED CROPPING BED (PREMIUM INFLUENCED LAND AGRO-USAGE STRUCTURE C-BED)

5.1 Abstract

The declining quantity, distribution and consumption of edible phyto-diversity has led to reduction in the diversity of traditional crops grown at the household level in Jinja and Vihiga. This has been linked to reduced land sizes. As land continues to decline, there needs to be some impetus in place that can retain the indigenous diversity in the intensively cultivated systems. This study therefore recognized the need to niche the indigenous leafy vegetables to a none-competing, specially constructed raised cropping bed so as to match its physical value with the MiMi premium value; hence the coinage of the structure as a Premium Influenced Land Agro-usage Cropping bed (Premium Influenced Land Agro-usage Structure). The objective of this study was, therefore, to investigate and justify the performance of selected vegetable variants 'penned' into a Premium Influenced Land Agro-usage Structure introduction based on a MiMi content criterion. The latter criterion has the equivalent rationale that can be likened to a premium value (grade) animal justifying its confinement in a specially constructed zero grazing (shed) structure. Vegetable and soil samples were collected from Vihiga and Jinja respectively. They were sun-dried, ground to a powder of 0.2mm sieve size, pelletized and ran in XRF spectrometer and multi-channel analyser. Further data analysis included a nutrametric grading. Results showed that there were high significant differences ($p \leq 0.001$) in the MiMi densities between Indigenous Vegetables (IVs) and Exotic Vegetables (EVs) in the following minerals; K, Ca, Fe and Mn. High significant differences at ($p \leq 0.001$) in MiMi densities on selected vegetable crops were also noticeable between Jinja and Vihiga sites in the following minerals; K, Ca, Fe,Cu and Zn Comparisons of MiMi on selected vegetable crops between long rains (LR) and short rains

(SR) for both sites were significantly different at ($p \leq 0.001$) for the following mineral; K, Ca, Fe, and Zn. Further analysis showed a high correlation at ($R=0.9969$) in MiMi between vegetable samples and the corresponding soil samples. Amaranthus hybridus and Solanum nigrum from Vihiga and Jinja respectively were found to be nutraceutically superior to Cleome gynandra, Brassica acarinata, Daucas carota, Oleum cepa and Spinacia oleracia. Generally, Indigenous Vegetables had higher nutra-ceutical grade rankings compared to Exotic Vegetables. The indigenous leafy vegetables being superior to exotic ones in MiMi content suggests a justification for niching them in a specially constructed Premium Influenced Land Agro-usage Structure.

Key words

African Leafy Vegetables, Mineral Micro-nutrient, Branding, Indigenous vegetables, Exotic vegetables, Nutraceutical

5.2 Background

The declining quantity, distribution and consumption of edible phyto-diversity has led to reduction in the diversity of traditional vegetables grown at the household level thus restricting the otherwise once beneficial traditional dietary diversity (Maundu et al., 1999 (Abukutsa-onyango, 2008; Mitra and Pathak, 2008; Vorster et al., 2008). Traditional vegetables represent cheap but quality nutrition for large parts of the population in both rural and urban areas (Chweya and Eyzaguirre, 1999). In fact, almost all of these vegetables are good sources of micronutrients including iron and calcium as well as vitamins A, B complex, C and E and, for example, amaranth contains a multiple of these nutrients compared to green cabbage (IPGRI, 2003 and Obukutsa-Onyango, 2007). Unfortunately, because of intense cultivation of small holdings, these African leafy vegetables species can easily be marginalized in favour of the major agronomic crops (Schippers, 2002). In fact, the the Impact Assessment Brief 1, (2010) noted that the consumption of ALVs is under decline. As land continues to decline, there needs to be some impetus in place that can retain the indigenous diversity in the intensively cultivated systems.

5.2.1 ALVS as sources of micro-nutrients

African Leafy Vegetables (ALVs) are important in the diet of many African communities. They are used as accompaniment with other staple foods during consumption. They therefore play a crucial role in ensuring food security and in improving nutrition among families. African Leafy Vegetables are rich in micro and macro nutrient elements. Both Indigenous and Exotic vegetables provide an abundant supply of minerals such as calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), phosphorus (P), iron (Fe), zinc (Zn), manganese (Mn), copper (Cu) and selenium (Se) (Nmani et al., 2009). However, several studies have indicated that the Indigenous Vegetables contain micronutrient levels as high as or even higher than those found in most Exotic Vegetables (Kruger et al., 1998; Nangula et al., 2010; Odhav et al., 2007; Steyn et al., 2001). Indigenous vegetables may therefore help meet daily requirements of other essential nutrients not found in other food substances, especially in individuals with marginal nutritional status.

5.2.2 Factors affecting availability of macro and micro-nutrients in African Leafy Vegetables

Conditions such as soil type and pH, water availability to the plant, climatic conditions, plant variety (Khader and Rama, 2003), plant age (Gupta et al., 1989) and the use of fertilizers (Guerrero et al., 1998) affect availability of nutrients. For example high or low conditions of these factors results in low availability of micro-nutrients in ALVs, which affects the nutrition status of these vegetables. These factors should be carefully analysed when growing ALVs so as to maintain a high level of macro and micro-nutrient contents in ALVS which positively feeds back in ensuring higher nutritional status in households.

5.2.4 The state of ALVs in Vihiga and Jinja

Recent studies have shown that African Leafy Vegetables such as pumpkin leaf, amaranth, spider plant and solanum are Mineral Micro-nutrient (MiMi) rich than cereal crops such as maize and sorghum. In vihiga district studies by Obukutsa-Onyango (2008) shows collection and classification of ALVs that are found and used in the area. However, Abukutsa-Onyango (2008) has noted that the role of African Indigenous vegetables (AIVs) in poverty alleviation and food and nutrition security in Vihiga has not been fully exploited. The author noted that AIVs have been generally neglected and are facing extinction, unless urgent measures are taken. Kimiywe, (2009) details some ALVs recipes and their energy and micronutrient contents but their level of availability to households for consumption needs to be established. Furthermore, documentations by Akundabweni et al. (2008) in Vihiga reveal classification of the ALVs to grade levels from high to low grade levels according to the macro and micro-nutrient content found in them. Therefore they have a potential role to play in the mitigation of hidden hunger (Akundabweni unpublished, 2011). Unfortunately, because of intense cultivation of small holdings in Vihiga and Jinja, these African leafy vegetables species can easily be left to undergo extinction in favour of the major agronomic crops.

5.2.5 Factors influencing consumption of ALVs

The consumption patterns of ALVs differ from place to place. This has been associated to factors such as poverty status, degree of urbanization, distance to fresh produce markets and season of the year (Rensberg et al., 2007). Rich people consume these leafy vegetables in considerably low amounts compared to their poor counterparts (Rensberg et al., 2007). Ethnicity also has a strong strongly influence on the consumption patterns of ALVs (Kimiywe et al., 2007). These patterns of consumption have contributed to lower the nutrition of food consumed by households in terms of dietary diversity resulting in emergence of chronic like diseases related to diet and nutrition as diabetes, hypertension, obesity, cardiovascular disease (CVD), cancer, osteoporosis and dental disease (Thiam et al., 2006)

5.2.3 Soil-plant micro-nutrient relationship

There exist a relationship between mineral concentration in the soil and plants. For instance, most soils have far more nutrients than are needed by a plant in a growing season, yet often very little of these nutrients are in solution for plant uptake and use (Minja et al., 2008). The availability of mineral uptake by plants is affected by several factors.

5.6 Study design

5.6.1 Sampling plant and soil samples

Thirty vegetable crop and the corresponding soil samples for indigenous and exotic vegetables were sampled from each of the farmers' conventional plots in the long rain and short rain season of year 2011 in Jinja and Vihiga. Soil sampling was done to a depth of 10 cm. Both the vegetable crop and corresponding soil samples were sun dried for a period of two to three days. The dry samples were then ground and passed through a 0.2 mm sieve. Half a gram of the powder was placed in a pellet die and introduced into a manual hydraulic press and compressed to a pressure of between 10 and 15 kg. This process produced a round pellet of 2.5cm in diameter and was repeated three times for each sample to obtain three pellets to be taken through X-ray fluorescence spectroscopy (XRF) analysis.

5.6.2 X-ray Fluorescence (XRF) Spectroscopy for mineral micro-nutrient analysis

The Energy Dispersive X-ray Fluorescence (EDXRF) spectroscopy system at the University of Nairobi's Institute of Nuclear Science and Technology laboratory was used to analyze the mineral micronutrient content of plant samples. The system consists of an X-ray spectrometer with Cd-109 radioisotope source, a Canberra Si (Li) detector, an ORTEC spectroscopy shaping amplifier (model 571), an ORTEC high voltage supply bias (model 459), an ORTEC liquid nitrogen monitor, a Canberra multichannel analyzer or a spectral data processing unit: MCA (100) linked to a personal computer (Figure 11). The computer is used for data storage and quantitative analysis.

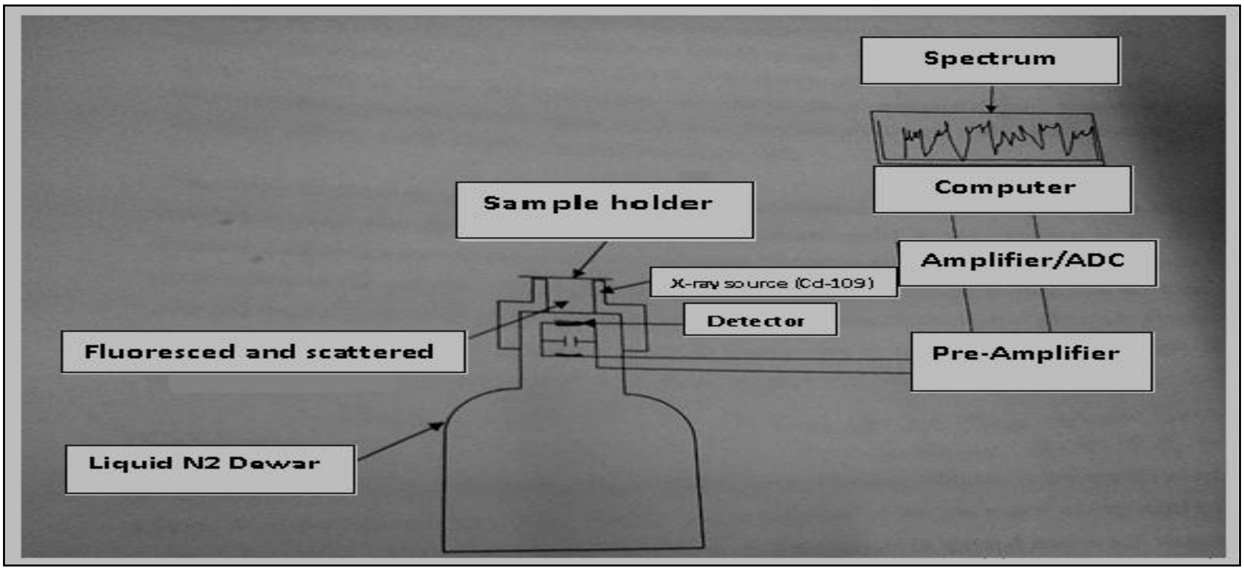


Figure 11: Outline of the University of Nairobi Electronic set-up for energy dispersive X-ray fluorescence spectroscopy (EDXRF) analysis.

5.6.3 XRF based Nutraceutical analysis of Mineral Micro-nutrients in selected vegetable test crops

After XRF analysis, the results of the vegetable crops were subjected to nutra-ceutical analysis to identify the high grade and low grade vegetable crops as in the following procedure developed by Akundabweni et al (2010);

Step 1:

The mineral concentration data in PPM was entered into excel worksheet

Step 2:

The five-category delimitation rule was applied separately for each element. The concentration range for each element was separated into five suitably chosen groups, or intervals chosen such that the interval ranges were equal to each other, and the interval midpoints were simple numbers as shown in table 8.

Table 7: Table pre-determined scale for ranking of elements

K and Ca ppms	Fe and Mn ppms	Cu ppms	Zn ppms	Rank
>24000	>3800	>80	>170	1
18000-23999	2700-3799	60-79	130-169	2
12000-17999	1800-2699	40-59	90-129	3
6000-11999	900-1799	20-39	40-89	4
<6000	<900	<20	<40	5

Legend; Different elements have different ppms. K and Ca are macro-nutrients that occur in large quantities and almost same ppms, these elements were therefore grouped together, Fe and Mn almost have the same ppm, they were also put in the same group. Zn and Cu are trace elements and occur in smaller quantities. Zn and Cu were separately grouped because the ppms of Cu are much higher than those of Zn. K-Potassium, Ca-Calcium, Zn-Zinc

The interval boundaries were then expressed in the formula bar using the IF function to assign NHIV rank values ranging from 1 for the highest density interval to 5 for the lowest density interval [The formula bar for potassium (K) and Calcium (Ca) ranks, for example was entered as:

=IF(B2<6000,5,IF(B2<11999,4,IF(B2<17999,3,IF(B2<23999,2,IF(B2>24000,1)

Step 3:

Rationale: The geometric mean of all the six elements for each sample (accession) was calculated instead of using an arithmetic mean that is only relevant any time several quantities add together to produce a total. However, physiological reactions are not about some true value in terms of the central tendency to which the arithmetic mean ascribes to but a synergistic effect of the total dose elements. In other words, trace elements have such a profound physiological effect compared to large concentrations of macroelements such as K or Ca but together which constitute a total dose response. Infact, trace element concentrations that are above an acceptable threshold can be lethal. An arithmetic mean of 200 ppm of Zn for instance and 8000 ppms of Ca would be 5000 ppms. Physiologically this is meaningless. The arithmetic mean thus answers the question, "if all the quantities had the same value, what would that value have to be in order to achieve the same total?".

In the same way, the geometric mean is relevant any time several quantities multiply together to produce a product.

It is calculated as thus: :

$$GM_{\bar{y}} = \sqrt[n]{y_1 y_2 y_3 \cdots y_n}$$

The geometric mean values calculated from the product of the coded interval ranges {See step 2} across elements based on the 'If' logic function presented in in the Microsot Excel had values between 1 and 5. The values were again categorised in the frequency intervals as shown in Table 9 in arriving at what was referred Nutra-metric Health Implied Variation (NHIV) grades.

The geometric mean was used to give a rank of the NHIV grades; this was after ranking each and every element using a pre-determined scale.

Table 8: Predetermined NHIV grades scoring scale

Pre-scaled GM range	NHIV grades	NHIV grade description
1.0-1.4	10	Highly Exceptional Grade
1.5-1.8	9	Highly Exceptional
1.9-2.3	8	Highly Exceptional
2.4-2.7	7	Moderately Exceptional Grade
2.8-3.1	6	Moderately Exceptional
3.2-3.5	5	Moderately Exceptional
3.6-3.9	4	Less Exceptional Grade
4.0-4.3	3	Less Exceptional
4.4-4.7	2	Less Exceptional
4.8-5.0	1	Less Exceptional

NHIV: Nutra-metric Health Implied Variation

5.7 Results

5.7.1 Soil-plant mineral relationship

There was a high correlation (R=0.9969) between the Minerals Micro-nutrient densities in the soil and the vegetable crops as shown in Table 10. Most minerals showed a high soil–plant Correlation ($p \leq 0.001$) between themselves and with other elements, for example K-soil and K-plant, Ca-soil and K-soil, Mn-soil and Mn-plant, Mn-soil and Zn-plant, Fe-soil and Zn-plant, Mn-soil and Fe-soil K, Ca-soil and Cu-plant.

Across Analysis using PROC CORR

Table 9: A correlation of vegetable crop sample and corresponding soil sample

	K-plant	K-soil	Ca-plant	Ca-soil	Mn-plant	Mn-soil	Fe-plant	Fe-soil	Cu-plant	Cu-soil	Zn-plant	Zn-soil
K-plant	-	0.830*	0.895**	0.231	-0.009	0.417	0.011	0.986*	0.027	0.392	0.003	0.514**
K-soil		-	0.031	0.825**	0.394	-0.057	0.398	-0.163	0.454	-0.154	0.453	-0.112
Ca-plant			-	0.516*	0.031	0.498	0.044	0.433	0.020	0.525**	0.039	0.525**
Ca-soil				-	0.411	0.026	0.431	-0.111	0.496	-0.806	0.458	-0.029
Mn-plant					-	-0.873*	0.996**	-0.024	0.980**	-0.010	0.092**	-0.055
Mn-soil						-	-0.052	0.996**	-0.032	0.980**	-0.982**	0.626**
Fe-plant							-	0.562*	0.005	0.012	0.972**	-0.031
Fe-soil								-		0.969**	-0.071	0.945**
Cu-plant									-	0.787*	0.056**	-0.022
Cu-soil										-	-0.963*	0.914**
Zn-plant											-	0.694*
Zn-soil												-

**Correlation is highly significant $p \leq 0.001$; the overall R=0.9969

5.7.2 Relationship between Mineral Micro-nutrient concentrations in vegetable crop and the corresponding soils

The relationship between soil and vegetable samples could be described as being direct. That is the amount of Mineral Micro-nutrients present in soil samples determined the amounts that were present in vegetable samples as shown in Table 11. However, some vegetable samples had the concentration of Mineral Micro-nutrients in soil being lower than in the vegetable samples. For instance, the soil Mineral Micro-nutrient concentration for Zn in Amaranthus hybridus was lower than in its plant. The same was true for Mn in Solanum nigrum.

Table 10: Variations in the vegetable crop and soil Mineral Micro-nutrients in Vihiga

		K	Fe	Br	Ca	Cu	Zn	Mn
Cleome gynandra	Soil	14648	3769	18.39	11348	52.92	63	970
	Plant	8130	1896	28.86	5698	25.67	51.18	825
Amaranthus hybridus	Soil	25250	3348	58.02	22830	19.21	68	2183
	Plant	18716	1978	12.45	5271	18.15	197.2	122
Solanum nigraum	Soil	23026	2412	46.63	18641	34.63	86.51	1413
	Plant	10599	1689	32.64	11631	17.57	64.44	190
P-value		$p \leq 0.001$	$p \leq 0.001$	$p \leq 0.001$	$p \leq 0.001$	$p \leq 0.001$	$p \leq 0.001$	$p \leq 0.001$
Standard error		3599	221	10.6	2186	8.91	20.3	198.2
Least Significance Difference		7249	543	21.9	5678	19.3	41.6	416.3

Legend K-Potassium, Fe-Iron, Br-Boron, Ca-Calcium, Cu-Copper, Zn-Zinc, Mn-Manganese

5.7.3 Seasonal variations in Mineral Micro-nutrient concentrations of selected vegetables crops

There was high significant difference ($p \leq 0.001$) in the means of Mineral Micro-nutrient concentrations between the long rain and short rain periods as shown in Table 12. These differences were observed for K, Fe, Cu, Zn elements. Significant differences were also noticed in values for Mn and Ca. More analysis is shown in appendix 4.0.

Table 11: Variations in Mineral Micro-nutrient concentrations between the long rain and short rain seasons in Vihiga

Sample	Season	K	Ca	Fe	Mn	Cu	Zn
Amaranthus	LR	16048	6174	2896	2602	24.33	118.2
	SR	16394	5257	1748	2263	49	166.9
cowpea	LR	13722	12888	2923	3368	58	78.9
	SR	7592	8975	1579	2263	78.01	94.5
solanum	LR	20767	4823	2300	2813	23.35	208.3
	SR	10227	5683	2677	4307	46.34	158.9
carrots	LR	4012	8917	1789	4183	58	12
	SR	4778	5198	1267	4381	78.01	15.4
Ethiopian Kale	LR	21967	5620	1933	6440	33.1	154.5
	SR	8522	7767	1588	2775	43.67	98.5
spider plant	LR	18637	11061	2927	2830	38.86	86.1
	SR	10543	6038	1674	3603	55.71	133.1
P-value		≤0.001	≤0.001	≤0.001	0.013	≤0.001	≤0.001
Standard Error		3318	1880	537	992.7	11.87	24.75
Least Significance Difference		6581	3729	1082	1969	23.55	32.4

Legennd; Means of elements in ppms, LR- Long rain season, SR- short rain season, K-Potassium, Fe-Iron, Br-Boron, Ca-Calcium, Cu-Copper, Zn-Zinc, Mn-Manganese

5.7.4 Variations in Mineral Micro-nutrient concentrations of vegetables crops from Jinja and Vihiga

A highly significant difference at ($p \leq 0.001$) in K, Ca, Fe and Mn Mineral elements was observed in vegetable crops sampled between Vihiga and Jinja sites as shown in Table 13. No significant difference was observed in the other minerals like Cu and Zn mineral elements. Vegetable crops sampled from Vihiga had a higher MiMi densities in the following elements (K in *Amaranthus hybridus* and Ca in *Solanum nigrum*) compared to ones that were sampled from Jinja. Alternately, a higher mineral nutrient concentration was observed in vegetable crops that were sampled from Jinja than Vihiga in the following elements; Fe, Mn, Cu and Zn in *Amaranthus hybridus.* More analysis is shown in appendix 5.0.

Table 12: Concentration of Minerals Micro-nutrients of selected vegetable crops in Jinja and Vihiga

Sample	Site	K	Ca	Fe	Mn	Cu	Zn
Amaranthus hybridus	Vihiga	24467	14414	2578	1747	29.11	120
	Jinja	15680	4488	2156	2998	45.47	345.4
Solanum nigrum	Vihiga	22166	17628	1654	2282	31.59	112.2
	Jinja	13555	10764	2412	911	23.67	65.5
Cleome gynandra	Vihiga	11963	17949	1789	2204	26.62	193.6
	Jinja	14960	5102	1167	2337	44.39	238
P-value		≤0.001	≤0.001	≤0.001	≤0.001	0.97	0.626
Standard error		5337	2924	815	479	9.477	145.6
Least significance difference		10687	5861	1562	959.9	18.99	291.8

Legend; Means of elements in ppms, K-Potassium, Fe-Iron, Br-Boron, Ca-Calcium, Cu-Copper, Zn-Zinc, Mn-Manganese

5.7.5 Differences in Mineral Micro-nutrient concentration between exotic and indigenous plants in Vihiga

The difference in MiMi densities between the indigenous and exotic vegetable crops that were sampled from Vihiga was significantly high at ($p \leq 0.001$) in K, Ca, Fe and Mn as shown in Table 14. Indigenous vegetables sampled had high mineral concentration compared to exotic varieties in the following elements; K, Ca, Fe and Zn. On the other hand, exotic vegetables had high mineral concentration in the following elements; Mn and Cu. More analysis is shown in appendix 6.0.

Table 13: Differences in Mineral Micro-nutrient concentration between exotic and indigenous vegetables in Vihiga

Vegetable type	K	Ca	Fe	Mn	Cu	Zn
Amaranthus hybridus	18984	10692	2791	2216	35.24	113.9
Cleome gynandra	18780	12102	2278	2306	24.23	135.3
Brassica carinata	11428	9384	1638	2293	38.47	121.7
Solanum nigrum	17100	13590	2420	2218	26.93	82.9
Daucua carota	6200	3978	2126	3002	43.33	153
Ollium cepa	5572	4892	1671	3687	33.32	75.8
Spinacia 0leracea	4366	4693	1751	2606	31.77	78.8
P-value	≤0.001***	≤0.001***	≤0.001***	0.005**	0.615*	0.038**
least significance difference	5600	2578	1414	726.3	22.17	55.37
standard error	2780	1578	638	356	11.14	27.97

Means of elements in ppms; * highly significant, ** significant * no significant, l.s.d- least significant difference, IV- Indigenous Vegetables, EV-Exotic Vegetables, K-Potassium, Fe-Iron, Br-Boron, Ca-Calcium, Cu-Copper, Zn-Zinc, Mn-Manganese**

5.7.6 Differences in mineral concentration of exotic and indigenous vegetable crops in Jinja

There was a significance difference in mineral concentration in vegetable crops that were sampled from Jinja as shown in Table 15. A highly significant difference ($p \leq 0.001$) in mineral concentration was noticed in K, Ca and Fe minerals.

Table 14: Differences in mineral concentration in different varieties of vegetable crops in Jinja

Vegetable type	K	Ca	Fe	Mn	Cu	Zn
Amaranthus hybridus	18984	10692	2791	2216	35.24	113.9
Cleome gynandra	18780	12102	2278	2306	24.23	135.3
Brassica carinata	11428	9384	1638	2293	38.47	121.7
Solanum nigrum	17100	13590	2420	2218	26.93	82.9
Daucua carota	6200	3978	2126	3002	43.33	153
Ollium cepa	5572	4892	1671	3687	33.32	75.8
Spinacia 0leracea	4366	4693	1751	2606	31.77	78.8
P-value	≤0.001***	≤0.001***	≤0.001***	0.005**	0.615*	0.038**
least significance difference	5600	2578	1414	726.3	22.17	55.37
standard error	2780	1578	638	356	11.14	27.97

Means of elements in ppms are * highly significant, * *significant, * No significance, K-Potassium, Fe-Iron, Br-Boron, Ca-Calcium, Cu-Copper, Zn-Zinc, Mn-Manganese**

5.7.7 Ranking of vegetable crops with respect to mineral concentrations

Nutraceutical analysis showed that top grade vegetable crop were *Amaranth hybridus* and *Solanum nigrum* from Vihiga and Jinja respectively as shown in Table 16 and 17. Generally, indigenous vegetables (*Solanum nigrum, Amaranthus hybridus, and Cleome gynandra*) had higher rankings of nutra-grades compared to the exotic vegetables (*Daucas carota, Oleum cepa and Spinacia oleracia)* from both Vihiga and Jinja. Further analysis is shown in appendix 7.0.

Table 15: Ranking of vegetable crops according to their Nutra-grades in Vihiga

Vegetable type	Geo mean	NHIV grades	NHIV grade description	NHIV rank
Amaranthus hybridus	2.7822799	7	Moderately Exceptional	1
Cleome gynandra	2.9880235	6	Moderately Exceptional	2
Solanum nigrum	3.0462584	6	Moderately Exceptional	3
Daucas carota	3.4012536	5	Moderately Exceptional	4
Oleum cepa	3.4924975	5	Moderately Exceptional	5
Brassica acarinata	3.5850231	5	Moderately Exceptional	6
Spinacia oleracea	3.9357355	3	Less Exceptional	7

Legend; Geo mean- Geometric mean, NHIV- Nutra-Health Implied Variations

Table 16: Ranking of vegetable crops according to their Nutra-grades in Jinja

Jinja	Geo mean	NHIV grades	NHIV grade description	NHIV rank
Solanum nigrum	2.609657	7	Moderately Exceptional	1
Amaranthus hybridus	2.884499	6	Moderately Exceptional	2
Cleome gynandra	3.137464	5	Moderately Exceptional	3
Brassica acarinata	3.378592	5	Moderately Exceptional	4
Daucas carota	3.646199	4	Less Exceptional	5
Oleum cepa	4.448213	2	Less Exceptional	6
Spinacia oleracea	4.279738	2	Less Exceptional	7

Legend; Geo mean- Geometric mean, NHIV- Nutra-Health Implied Variations

5.8 Discussion

5.8.1 Variations in mineral concentration in soil and vegetable samples

The high correlation in mineral concentrations between vegetable crop and their corresponding soil samples suggest that the bioavailability of MiMi in plants is highly determined by their concentrations in the soil. Some of the factors that could have contributed this variation include; soil water regimes, mineralization regimes and root amount and its characteristics, soil pH, cation exchange capacity, organic matter content, soil texture, and interaction among the target elements (Comeford, 2005). For instance, it has been found that excess Ca may decrease the bioavailability of trace elements (McDowell, 1997; Lukhele and Ryssen, 2003). Bioavailability of mineral micro-nutrients in the soil is important to plants; therefore, soils with high amounts of some nutrients need be targeted with strategies aimed at containing these nutrients at an optimum level. The same findings on variations in mineral content in plants and soils have been reported by Myung, (2008) and Akundabweni et al. (2010).

5.8.2 Seasonal variations in nutrient content of vegetable crops

Seasonal variations in MiMi densities in selected vegetable crops grown were highly significant for K, Fe, Cu, and Zn. The LR season had high MiMi densities compared to the SR season. There was no significant difference in mineral concentrations for Mn. Variations in MiMi could have been as a result of differences in the soil water regimes between the Long and Short Rain. Desorption is key to bioavailability of MiMi in the soil which in turn determines their density in plants. Desorption is highly influenced by water availability (Comeford, 2005). During the long rain season, there is more water resulting in high solubility and uptake of ions. This could have possibly caused high MiMi densities in vegetable samples in the LR than the SR. Results of variations in MiMi densities between the

LR and SR season have been observed by Birnin-Yauri et al. (2011). In promoting soil and water conservation measures, strategies like irrigation aimed at increasing availability of soil water in the short rain season are therefore encouraged. This will increase solubility and absorption of soil nutrients by plants even in water stress periods. Consequently, the harvested material will be highly nutritious.

5.8.3 Variations in Mineral Micro-nutrient concentration of vegetables crops from different places.

There was a difference in MiMi densities in vegetable crops between Vihiga and Jinja. These variations could have resulted from variation in edaphic factors, land use types and agro climatic conditions. For instances, the amount and extend of fertilizer use determines the availability of some MiMi in vegetable crops as in a study by Reedy and Bhatt, (2001). For example, Diammonium phosphate (DAP) contains K which influences availability of other soil nutrients. These findings coincide with those of Msuya and Katinka, (2004) on indigenous vegetables in Tanzania.

5.8.4 Variation in Mineral Micro-nutrient between exotic and indigenous vegetables

There was a difference in MiMi densities between indigenous and exotic vegetables from the two study sites. These results are similar to other studies which have indicated that the indigenous LVs contain micronutrient levels as high as or even higher than those found in most exotic LVs (Kruger et al., 1998; Odhav et al., 2007; Steyn et al., 2001 and Uusiku et al 2010. Differences in MiMi densities in IVs and EVs could be attributed to factors such as the type of vegetable genotype, edaphic factors and the length of period the vegetable takes to mature.

Indigenous vegetables sampled had high mineral concentration compared to exotic varieties in the following elements; K, Ca, Fe and Zn. On the other hand, exotic vegetables had high mineral concentration in the following elements; Mn and Cu. These results indicate that the consumption of these leafy vegetables has both nutritional and health benefits, particularly for the support of growth and development in children and the prevention of non-communicable diseases like hypertension, cancer, decalcification of the bone, etc. For instance, studies have reported that high intake of potassium coupled with phyto-chemicals in plants play major roles in the management of nutritional related diseases, such as hypertension, cancer, diabetes, and other nutritional-related diseases. (Howard and Kritcherkky, 1997; Fasuyi, 2006).

5.8.5 Crop rankings according to Mineral Micro-nutrient concentration

Indigenous vegetables ranked high in nutra-grading compared to the exotic vegetables. *Amaranth hybridus* ranked best in nutra-ceutical grading. These results agree with findings recorded by Orwa Opiyo, (2010) where three different *Amaranth* species were found to be superior to the exotic species like kale. *Amaranth hybridus* ranked highest in the following nutrient concentration; K and Fe. *Amaranth hybridus* however ranked best in Zn content as shown in Table 5.7. Studies by John Msuya and Katinka 2004 Weinberger have also shown high levels of Zn and Fe in *Amaranth* crop.

Generally, Indigenous vegetables ranked high in nutra-grading compared to the exotic vegetables, showing the nutritional benefits likely to be derived from consumption of indigenous vegetables in large quantities. The nutra-grading of indigenous vegetables could be targeted to improve their production and consequently the marketability as well as the consumption levels.

5.9 Conclusion

Mineral Micro-nutrients in the soils were higher in comparison to vegetable crops. There was a correlation between Mineral Micro-nutrient content found in the soil and plants. The correlation was both positive and negative showing that an increase as well as a decrease in the concentration of a particular Mineral Micro-nutrient in the soil, increased and decreased MiMi in plants.

Different seasons had an effect on the Mineral Micro-nutrient concentration in vegetable crops. Long rain vegetable crop samples had more MiMi densities compared to Short rain vegetables crop samples. Furthermore, vegetable crops grown in places with different agro-ecological and soil conditions had variations in MiMi concentrations.

The existence of high nutra-grade vegetables therefore provides a basis to justify the introduction of the Premium Influenced Land Agro-usage Structure as an innovation for production of vegetables crops with a saleable value.

5.10 Recommendations

- Diversification of the existing farming system in rural communities to include indigenous vegetable production could help improve food security. Experiences in many African farming systems have shown that many rural communities rely on indigenous vegetables for food and as source of cash income between cropping seasons. Research has shown that indigenous vegetables have potential comparable to their domesticated counterparts in providing nutrition, food security and cash income to households. Indigenous vegetables are adapted to growing in low rainfall, poor soils and have few insect and disease problems than arable crops. The predicted climate change and global warming is likely to affect crop production negatively causing food shortages. Therefore incorporating indigenous vegetables into existing cropping systems may provide an alternative source of food during years with little or no crop harvest.

- More research is also needed to screen and develop indigenous vegetables so that they can be incorporated into present cropping systems.

CHAPTER SIX

INVESTIGATING VIABILITY OF THE PREMIUM INFLUENCED LAND AGRO-USAGE STRUCTURE INTRODUCTION FOR PRODUCTION OF VALUE BRANDED AFRICAN LEAFY VEGETABLES IN VIHIGA AND JINJA

6.1 Abstract

Land subdivision as a result of population pressure has resulted in reduced land for agricultural production in Vihiga and Jinja. This has resulted in low production of vegetable crops which has had a negative effect on the quantity as well as quality of food consumed at the household level. Sustainable utilization of the limited land parcels is, therefore, an important factor for increasing the quantity of vegetable crop produced in these areas. Premium Influenced Land Agro-usage Structure is one of such techniques. A study was therefore undertaken to investigate the advantages and acceptability of Premium Influenced Land Agro-usage Structure introduction for producing mineral micro-nutrient value branded (premium) vegetable produce in Vihiga and Jinja. The objective of the study was to evaluate the benefits of a Premium Influenced Land Agro-usage Structure as a novel land use introduction. The Premium Influenced Land Agro-usage Structures were constructed on 10 smallholder farms in Vihiga and a similar number in Jinja. High grade vegetables (*Solanum nigrum, Amaranthus hybridus, Cleome gynandra and Daucus carota)* were grown on these structures. Further analysis included the determination of the benefits of these structures using the Net Present Value and the assessment of its Satisfaction Index. In both Vihiga and Jinja, there were high significant differences ($p \leq 0.001$) in performance of vegetables crops grown on Premium Influenced Land Agro-usage Structures compared to flat beds in yield and height (Premium Influenced Land Agro-usage Structures) yield (kg/ha) was 42254 versus 27772 for flat beds, (Premium Influenced Land Agro-usage Structures height in (cm) was 14.8 versus 10.8 for flat beds). Comparisons in vegetable performance between seasons showed better performance of vegetable crops that were produced on the Premium Influenced

Land Agro-usage Structures in the Long Rains than the Short Rains seasons for both sites with significant difference (p=0.001) as shown by the means of the following agronomic appeal attributes; mean 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. Also significant differences in vegetable performance were detected between Vihiga and Jinja in the following agronomic appeal attributes 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. Vegetable crop performance was better in Jinja than Vihiga. The Premium Influenced Land Agro-usage Structures had a high Net Present Value (KSH191390) compared to flats beds (KSH122087). Further analysis showed the Premium Influenced Land Agro-usage Structures having a Satisfaction Index of 61.8%. The mineral micro-nutrient density branding thus justifies the introduction of the Premium Influenced Land Agro-usage Structures as an innovation.

Key words

Advantages and acceptability, Mineral micro-nutrient value branding, raised bed cropping

6.2 Background

Land subdivision as a result of population pressure has resulted in reduced land for agricultural production in Vihiga and Jinja. This has had a negative effect on the quantity as well as quality of food consumed at the household level. Sustainable utilization of the limited land parcels is, therefore, an important factor for increasing the quantity and quality of food produced in these areas. Premium Influenced Land Agro-usage Structure) is one of such techniques. Premium Influenced Land Agro-usage Structure is an improvised raised bed to enable production of premium vegetable crop. This is because most raised beds have been widely used in the production of commercial crops like rice, wheat and maize than vegetable crops. (Aquino, 1998, Hobbs et al., 2003, Fahong et al., 2004, Limon-Ortega et al., 2000, 2003, 2006). The advantages of Premium Influenced Land Agro-usage Structures in crop production are therefore comparing to those of raised beds.

Premium Influenced Land Agro-usage Structures as an innovation or technology is suitable for home vegetable growing preferably under high family land population pressure and/or less tillable land. Because of its micro-climate, a Premium Influenced Land Agro-usage Structure planting is known for uniform special plant arrangement and therefore good seedling growth and plant produce of an attractive marketable appearance i.e. (premium sale value). However, the use Premium Influenced Land Agro-usage Structures for crop production is not a common practice in both Vihiga and Jinja and can be described as a novelty in both areas. Its relevance is thus as follows: a) convenient to fit the Premium Influenced Land Agro-usage Structures into a main household compound setting; b) none-competitive in space to an already overcrowded arable piece of land in either Near Farm, Mid Farm and Far Farm portions; c) within reach for constant care and protection of a high premium value crop.

The African Press International, (2011) has reported the use of raised beds in Zambia. In Kenya, double dug raised beds have been used in the production crops in Kitale. In Vihiga and Jinja raised beds are used for production of root and tuber crops like sweet potatoes and cassava. Information on the use of raised cropping beds for vegetable production in Vihiga and Jinja is still scanty.

6.2.1 Advantages of raised beds/ Premium Influenced Land Agro-usage Structures

An accumulating body of evidence has verified that raised bed planting offers better weed control, water and fertilizer management, thus leading to the lower inputs of water and fertilizers and higher stress-resistance (Wang et al., 2004; Tripathi et al., 2005; Singh et al., 2009; Kong et al., 2010). The fact that water and fertilizer use is efficient under raised cropping beds makes them ideal for use in areas where there is scarcity of water and fertilizer. Additionally, raised beds create a micro-climate 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, 2002). More important, raised-bed planting reduces crop lodging (crops falling over from high winds and/or heavy rain), while increasing yield by permitting farmers to grow more and superior crops (Govaerts et al., 2006; Wang et al., 2009). Raised-bed planting also enhances productivity by increasing availability of essential crop nutrients by stimulating microbial activity, and is potentially important in sustainably increasing supply of maize (Zhang, 2012). Furthermore, raised cropping beds concentrate a large percentage of crops on a small piece of land thus increasing yield. They can therefore be constructed as vegetable gardens in places where land sizes are small like urban areas. This attributes therefore represent the social-economic benefits likely to be derived out of the improvisation of raised beds to Premium Influenced Land Agro-usage Structures to suit vegetable crop production.

Diets poor in leafy vegetables, fruits and animal proteins 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). In this context, the value of Premium Influenced Land Agro-usage Structures as home gardens for family health is paramount as they will harbour a wide range of genetic diversity that increases economic options, dietary variety and nutritional levels for low income households in both rural and urban communities (Helen Keller International, 2001).

6.2.2 The situation of land holdings in Vihiga and Jinja

Land size greatly influences the amount of phyto-diversity on smallholder farming systems which in turn affects the quantity and quality of food consumed at the household level. The bigger the farm size the more the phyto-diversity and consequently the better the nutrition. Land holdings among smallholder farming systems are decreasing due to increase in land subdivision as a result of human population growth. For instance the current holdings in Jinja and Vihiga 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). This has resulted in overuse of land leading to low soil fertility levels. 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 rapid increase in human population has, however, reduced the amount of land available to the farmer and destabilized this traditional system of maintaining soil fertility. Consequently, long-duration natural fallows are no longer possible. They are replaced by short-duration ones, lasting one or two seasons only (Amadalo et al., 2003). Apparent implications of this particular land-intensive strategy are emerging nutrient deficiencies and resource base degradation (Smale et al., 1994). This has resulted in reduction in the amount and distribution of phyto-diversity which has affected the quantity and quality of food consumed at the household level thus affecting the livelihood of farmers.

The livelihood (including access to nutrition) of any family is dependent on the size of land holding. Decrease in land size has influenced phyto-diversity production. Some crops are preferred for production at the expense of others; for example farmers concentrate efforts in the production of staple crops than vegetables, indigenous vegetables being highly affected. This has resulted in low dietary diversity and nutritional status among smallholder households. Since no approaches are possible in expanding the land resource, improved crop production techniques and management promise better yields (Mutiga et al., 2011). Introduction of the raised cropping bed technology for vegetable production is thus proposed. An evaluation of the viability of raised cropping bed (Premium Influenced Land Agro-usage Structures) in the production of vegetable crops as one of these techniques to help increase vegetable production is therefore needed.

6.3 Study design

The study sites were Jinja-Uganda and Vihiga-Kenya. This was done in the long and short rain of year 2011. Premium Influenced Land Agro-usage Structures cum raised beds were established on 10 smallholder farms in Vihiga and a similar number in Jinja. Each Premium Influenced Land Agro-usage Structures was designed in three layer stair-case raised bed with each succeeding layer smaller than the preceding one. **(**Chapter 1: Figure 3; diagram 1). High grade Indigenous 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 robust, plant height, branching and leaf density. Yield was also determined. A similar procedure was done on the flat cropping beds **(**Chapter 1: Figure 3; Diagram 2). The flat beds were the farmers' conventional way of planting vegetables. Both Premium Influenced Land Agro-usage Structures and flat beds had the same measurements (21.3$m^{2.}$). Planting was done in two seasons. Season 1 was the long rain season covering the months of April, May, June and July while season 2 was the short rain season covering the months of September, October November and December.

6.3.1 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 240cm from the central spot was then marked. The bed was then divided into three micro-beds measuring 60cm in diameter. Vertical posts of 40cm 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 20cm 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 20cm 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.

The size of the kitchen garden depends on the designer's willingness to construct. The size increases as the number of stairs increases but the more convenient is to have of 4 to 5 staircases distant from each other. In this study, four stair cases were constructed with a distance of 60cm between them. The height was kept at 20cm from the ground and from each stair.

6.3.2 Determination of costs and benefits of the Premium Influenced Land Agro-usage Structures and flat bed

The costs for production and the corresponding revenue of vegetable crops contained in the Premium Influenced Land Agro-usage 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 below formula;

$$\boldsymbol{GMy} = \mathbf{TRy} - \mathbf{TCy}$$

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%. This period was arrived at as the time that a person could possibly do farming. In calculating the NPVs of the selected crops, the following assumptions were done; the cost of constructing the Premium Influenced Land Agro-usage Structures were incurred in the first year and after every five years, the costs of the flat beds were same throughout the farming period; the rate of inflation was kept constant. To compute the NPVs of the Premium Influenced Land Agro-usage Structures, the NPVs of vegetable crops growing on the Premium Influenced Land Agro-usage Structures were summed as in the following formula;

$$\mathbf{NPVpl = NPVi + NPVj + \cdots NPVz}$$

Where NPVpl was the Net Present Value of the Premium Influenced Land Agro-usage Structures, while NPVi, NPVj and NPVz were the Net Present Values of various vegetable crops grown on the Premium Influenced Land Agro-usage Structures. The same procedure was repeated with the flat cropping beds. A comparison of the NPVs of the Premium Influenced Land Agro-usage Structures and flat cropping beds was done to determine the most viable cropping bed.

6.3.3: Assessment of the Satisfaction of Index of Premium Influenced Land Agro-usage Structures introduction

A survey to assess the Satisfaction Index of the Premium Influenced Land Agro-usage Structures was done on 10 farmers on whose farms the bed had been constructed. The farmers were asked assess the performance of Premium Influenced Land Agro-usage Structures had on the following five parameters on a scale of 1-10; Crop performance, Construction costs, Time of construction, Durability and Income generation.

6.3.4 Data analysis

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

6.4 Results

6.4.1 Seasonal variations in the means of the agronomic appeal attributes of selected vegetable crops produced on the Premium Influenced Land Agro-usage 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, height, leaf density branching and disease prevalence as shown in Tables 18 and 19. Generally vegetable crops performed better in the long rain season as compared to the short rain season.

Table 17: Seasonal variations in the means of the agronomic appeal attributes of selected vegetable crops grown on Premium Influenced Land Agro-usage 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

legend, CV- Coefficient of Variation

Table 18: Seasonal variations in the means of the agronomic appeal attributes of selected vegetable crops grown on Premium Influenced Land Agro-usage 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

legend, CV- Coefficient of Variation

6.4.2 Variations in agronomic appeal attributes of selected vegetable crops grown on Premium Influenced Land Agro-usage 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 20. 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 18. Generally, vegetable crops grown in Uganda showed a better performance compared to ones that were produced in Kenya. More analysis is shown in appendix 10.0.

Table 19: Differences in the agronomic appeal attributes of selected vegetable crops grown on Premium Influenced Land Agro-usage 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

6.4.3 Differences in the means of the agronomic appeal attributes of selected vegetables grown on Premium Influenced Land Agro-usage Structures and flat beds

There was a high significant difference (P≤0.001) in vegetable crops grown on Premium Influenced Land Agro-usage Structures and flat beds in the following agronomic appeal attributes; yield, height, leaf density, branching and disease prevalence as shown in Table 21 and 22.

Table 20: Differences in the means of the agronomic appeal attributes of selected vegetables on Premium Influenced Land Agro-usage Structures and flat cropping beds in Vihiga

Vegetable	Treatment	Yield in (kg/ha)	Height (cm)	Leaf density	Branching	Disease prevalence
Amaranthus hybridus	Premium Influenced Land Agro-usage Structures	47440	15.8	2.6	2.7	2.8
	Flat bed	21360	11.9	2.2	2.3	2.1
Solanum scabrum	Premium Influenced Land Agro-usage Structures	44600	16.2	2.5	2.6	2.8
	Flat bed	27160	10.5	2.1	2.2	2.3
Cleome gynandra	Premium Influenced Land Agro-usage Structures	47440	14.2	2.7	2.7	2.8
	Flat bed	21360	12.5	2.2	2.3	2.4
Daucus carota	Premium Influenced Land Agro-usage Structures	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

Table 21: Differences in the means of the agronomic appeal attributes of selected vegetables on Premium Influenced Land Agro-usage Structures and flat cropping beds for Jinja

Vegetable	Treatment	Yield in (kg/ha)	Height (cm)	Leaf density	Branching	Disease prevalence
Amaranthus hybridus	Premium Influenced Land Agro-usage Structures	49302	18.8	2.6	2.7	2.8
	Flat bed	35981	13.9	2.2	2.3	2.1
Solanum scabrum	Premium Influenced Land Agro-usage Structures	43720	14.2	2.5	2.6	2.8
	Flat bed	20465	9.5	2.1	2.2	2.3
Cleome gynandra	Premium Influenced Land Agro-usage Structures	55813	15.2	2.7	2.7	2.8
	Flat bed	36279	11.5	2.2	2.3	2.4
Daucus carota	Premium Influenced Land Agro-usage Structures	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

Generally vegetable crops grown on Premium Influenced Land Agro-usage Structures performed better than the ones that were grown on flat beds as shown in Figure 12.

Figure 12: Pictorial representation of vegetable crops growing on 1 Premium Influenced Land Agro-usage Structures and 2 Flat beds

6.4.4 Analysis of the benefits of Premium Influenced Land Agro-usage Structures versus flat beds using NPV method

Further analysis showed that vegetable crops grown on the Premium Influenced Land Agro-usage Structures had higher Net Present Value (NPV) compared to the ones that were grown on the flat beds as shown in Table 23. Further analysis is shown in appendix 12.0, 13.0 and 14.0.

Table 22: A comparison of the means of the Net Present Values of selected vegetable crops grown on Premium Influenced Land Agro-usage Structures and Flat beds for Vihiga

Cropping bed	Vegetable type	Mean NPV
Premium Influenced Land Agro-usage Structures	*Amaranthus hybridus*	63130
Flat bed	*Amaranthus hybridus*	51714
Premium Influenced Land Agro-usage Structures	*Solanum scabrum*	74367
Flat bed	*Solanum scabrum*	52117
Premium Influenced Land Agro-usage Structures	*Cleome gynandra*	69655
Flat bed	*Cleome gynandra*	50546
Premium Influenced Land Agro-usage Structures	*Daucas carota*	16249
Flat bed	*Daucas carota*	14016

NPV is the Net Present Value;

6.4.5 Variations in the means of the Net Present Value of vegetable crops grown on Premium Influenced Land Agro-usage Structures and flat beds

There was a high significant difference ($P \leq 0.001$) in the means of the Net Present Value of the Premium Influenced Land Agro-usage Structures compared to the flat beds as shown in Table 24. More analysis is shown in appendix 15.0.

Table 23: Test of null hypothesis that the means of NPV of Premium Influenced Land Agro-usage Structures is equal to means of NPV of Flat beds for Vihiga

	Mean NPV	**Standard deviation**	**Standard error**
Premium Influenced Land Agro-usage Structures	191390	25007	4566
Flat bed	122087	25508	4657

Legend; NPV is the Net Present Value; PREMIUM INFLUENCED LAND AGRO-USAGE STRUCTURE C-bed is the Premium Influenced Land Agro-usage Cropping beds

N=60, Test statistic t=10.63 on 58 degrees of freedom, P≤0.001

6.4.5 Assessment of the satisfaction and acceptability of the Premium Influenced Land Agro-usage Structures

The Premium Influenced Land Agro-usage Structures introduction was found to be 61.8% in satisfying the farmers as shown in table 25 according to the following parameters; Crop performance, Construction costs, Construction time and Durability.

Table 24: Farmer Satisfaction Index of the Premium Influenced Land Agro-usage Structure introduction for Vihiga

Parameters of score	**Satisfaction score**	**Weighting factor**	**Weighted score**
Crop performance	7.7	26.28	2.02
Construction cost	4.4	15.02	0.66
Construction time	5.0	17.06	0.85
Durability	4.9	16.72	0.82
Income generation	7.3	24.91	1.82
Total	**29.3**	**100.00**	**6.18**
Satisfaction index			**61.8%**

Legend
Satisfaction score is an average of the responses of each parameter, weighting factor is a percentage of the satisfaction score, weighted score is a multiple of the satisfaction score and the weighting factor, while the satisfaction index is a summation of all the weighted scores multiplied by 10 because the parameters were score on a scale of 1-10, where 1-4 represented the low satisfaction, 5-7 was moderate satisfaction and 8-10 was high satisfaction
Crop performance include; yield, branching, robust and vigour and disease incidences. Construction costs include materials and labour that were needed.

From Table 26, the farmer's satisfaction index of 61.8% was found in the 34-66% level of satisfaction, implying that the farmers were somehow satisfied with the Premium Influenced Land Agro-usage Structure introduction.

Table 25: Predetermined Satisfaction Index scoring scale

% level of satisfaction	Satisfaction Index ranking	Description of the level of satisfaction
1-33	1	Not quite satisfied
34-66	2	Somehow satisfied
67-100	3	Highly satisfied

6.5 Discussion

6.5.1 Seasonal effect on vegetable crop performance grown on Premium Influenced Land Agro-usage Structures

There was a difference in crop performance between the short and long rain seasons across all the two sites of studies (Vihiga and Jinja). The long rain season indicated better crop performance compared to the short rain season mostly in the yield agronomic attribute. The difference in yield could have been 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 (Vigna unguiculata) as in a study by Chesney et al., 2010.Vegetables in the long rain season showed a high growth performance compared to ones that were produced in the short rain period as shown in table 3. 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.

6.5.2 Difference in the performance of selected vegetables crops grown on Premium Influenced Land Agro-usage Structures between Jinja and Vihiga

There was a difference in the performance of vegetables grown on Premium Influenced Land Agro-usage Structures in both Vihiga and Jinja. Vegetables growing on Premium Influenced Land Agro-usage Structures performed better in Jinja than in Vihiga. Vegetables crops had higher yields in Jinja than Vihiga (36064kg versus 33962kg). Variation in crop yield was significantly smaller that is 2102kg. Differences in vegetable crop performance were also seen in height. Vegetable crop grew taller in Jinja (16.6) than in Vihiga (12.8cm). There were no differences in the leaf density, branching and disease prevalence in the two study sites. This could have been due to differences in soil properties and climatic conditions. Even though the two study sites are found in the Lake Victoria Basin, differences in climatic and soil properties are noticeable. The same 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).

6.5.3 Performance of vegetable crops grown on Premium Influenced Land Agro-usage Structures compared to Flat bed

There was a high significant difference in vegetable crop performance between the Premium Influenced Land Agro-usage Structures and flat beds. Vegetable crops grown Premium Influenced Land Agro-usage Structures (raised cropping beds) 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 Premium Influenced Land Agro-usage Structures could have been attributed to better utilization of space, solar energy, water and nutrients. Vegetable crops grown on Premium Influenced Land Agro-usage Structures were densely packed compared to the ones that were grown on flat beds. The raised Premium Influenced Land Agro-usage Structures were constructed vertically in a stair-case like design. The vertical elevation reduced the distance between the leaves of vegetable crops and sun's rays' thus ensuring faster solar energy capture and absorption by the crops, hence the better solar energy utilization leading to better vegetable crop performance. 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. (2009) and Singh et al. (2010) have recorded similar findings. Similar findings have been documented by Wang et al. (2004).

6.5.4 Comparison of the cost and benefits of the Premium Influenced Land Agro-usage Structures and flat beds

The NPV of the Premium Influenced Land Agro-usage Structures were more than for the flats bed. This could have been attributed to better crop performance. The total revenue that was obtained from vegetable crops contained on Premium Influenced Land Agro-usage Structures was higher than on flat beds in year 1 as shown in appendix 6.3 and 6.4. This is because costs used for production of vegetable crops grown on flat beds were low compared to Premium Influenced Land Agro-usage Structures. Costs of production for vegetable crops contained on Premium Influenced Land Agro-usage 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 6.5, the revenue obtained from vegetable crops grown on Premium Influenced Land Agro-usage 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 Premium Influenced Land Agro-usage Structures to be higher compared to flat beds.

6.5.5 Assessment of the Satisfaction Index of the Premium Influenced Land Agro-usage Structures introduction

The Premium Influenced Land Agro-usage Structures introduction was found to be 61.8% in satisfying farmers. Some of the reasons given by farmers were; high crop performance and improved income levels. Crop performance was assessed in terms of yield, reduced level of disease incidence, growth and robust. The high yield translated into high returns thus increasing the income levels of the farmers. The Premium Influenced Land Agro-usage Structures would have been 100% satisfying save for the following reasons as elucidated by farmers; costly construction costs, more time taken to construct, not durable enough to last for a period of even three years.

6.6 Conclusion

Vegetable crops grown on the Premium Influenced Land Agro-usage Structures performed better compared to the ones that were grown on the flat beds. This was shown in the high yield, reduced disease incidences the high Net Present Value and Satisfaction Index of the vegetables crops that were produced on Premium Influenced Land Agro-usage Structures in comparison to the flat bed. This study therefore justifies the introduction of Premium Influenced Land Agro-usage Structures as an innovation for producing Mineral Micro-nutrient branded vegetables crops with a saleable value especially in areas with limited land sizes.

6.7 Recommendation

- More research on the viability of Premium Influenced Land Agro-usage Structures with regard to water and fertilizer utilization efficiency need be done so as to recommend usage of Premium Influenced Land Agro-usage Structures in fertilizer and water-stressed areas.
- Strategies that aim at reducing construction costs and increasing the longevity of Premium Influenced Land Agro-usage Structures are necessary to help increase the viability of the bed.

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1.0 APPENDICES

3.1: Household questionnaire for land use

HOUSEHOLD SURVEY QUESTIONNAIRE/ TOOL FOR JINJA AND VHIGA

Survey objectives:

1. To capture farming, land use practices and indigenous knowledge of African Indigenous Plants in Jinja and Vihiga districts.
2. To establish the status or place of indigenous knowledge as regards African indigenous plants/ vegetables, and how their use has evolved under the influence of searching for improved food and nutrition security avenues/ livelihood and continuously changing climatic conditions.
3. To establish the efforts/ input communities (farmers) place on conserving African indigenous vegetables/ plants

SECTION A

BACKGROUND

1. RECORDER/ INTERVIEWER'S INITIALS: …………………………………………………………….
2. FARMER/ RESPONDENT NO: …………………………………………………………………………..
3. COUNTRY NAME: ……………………………………………………………………………………………
4. DATE: ………..
5. PROVINCE/REGION………………………………………………………………………………………
6. DISTRICT: ………………..……………………………………………………………………………………….
7. DIVISION/ CONSTITUENCY: ……………………………………………………………………………….
8. LOCATION / SUB COUNTY: ………………………………………………………………………………..
9. SUB LOCATION / PARISH: ………..……..…………………………………………………………….
10. VILLAGE: ……………………………..…………………………………………………………………………...
11. NAME OF FARMER:…………………………………Gender...………………………...................................
12. Level of education
13. Group membership: …………………………………………………………………

SECTION B
HOUSE HOLD/ FARMER DEMOGRAPHICS AND FARMING CHARACTERISTICS

State the major source of income, tick in the boxes

Farming (both crop and animal) ☐ crop farming ☐ Animal farming ☐

Retail outlet/shop ☐ other ☐

State the household income earner(s)

Mother/wife ☐ father/husband ☐ sister/brother ☐ other ☐

State household size

5< ☐ 5> ☐

Observe and indicate the roofing structure by ticking the appropriate box

Grass thatched ☐ aluminum panels ☐ tiles ☐ papyrus ☐ other ☐

Assets

Radio ☐ bicycle ☐ TV set ☐ motorbike ☐ other ☐

Section C

	Income purpose	self employment	Food / nutrition security	making me less poor	healing food crop (e.g. HIV/AIDS)	environment (e.g. soil fertility etc.)	Pressure from the government	My human right to produce and use	For self gratification	others
Crop										
Plant										
land										
Water										
Animal										
Product										
by-product										

Score code: all of it=3; partial=2; surplus=1; none =0; product e.g animal products, honey, plant products, flour. By-products e.g animal manure, cut forage
Other: other sources of income including employment, diaspora

Remark specify column 1

SECTION D
LAND USE SITING OF FARMER'S UNIT OF DIVERSITY (NAME OF PLANT: all names – local; scientific)

NEAR HOUSE FARM PORTION CONTENTS	MID FARM PORTION	FAR FARM PORTION

Specify terrain:

Remark part: Reason(s) for placement:

SECTION E

FARMERS' UNIT OF DIVERSITY (FUD) FOR UTILIZATION IN THE CONTEXT OF PREFERENCE (YIELD & QUALITY, APPEARANCE, TEXTURE, TASTE, SMELL, TRADITION/BELIEF)-DETERMINANTS OF LAND USE

Land use culti-group e.g vegetables, fruit	**Food group e.g protein & part used**	**Proportion of land it occupies**	**Home use raw/home use processed**	**Sold raw/Sold processed**

Fertilizer and manure use

State type of fertilizer used for planting

DAP ☐ SSP ☐ others ☐

State methods of fertilizer application

Row application ☐ Broadcasting ☐ Band application ☐ others ☐

What is the rate of fertilizer application?

Which crops are most preferred for fertilizer application?

Maize ☐ Vegetables ☐ Napier ☐ Others ☐

Name the type of manure used

Farmyard ☐ Compost ☐ Green ☐

What is the composition of manure?

Animal wastes ☐ kitchen wastes ☐ green plants ☐

Which crops are most preferred for manure application?

Maize ☐ Vegetables ☐ Napier ☐ Other ☐

Soil and water conservation measures

State some of the soil and water conservation methods in the area

How effective are these methods?

Technologies/innovations for production enterprises

Are there any structures found farm for crop production?

How have they been made i.e what materials have they been made from?

Where are the materials obtained from?

Approximately what size of land do these structures occupy?

Name crops are grown in/on these structures

What quantity of crops is produced compared to the conventional way of farming?

How effective are these structures in water and nutrient conservation?

REASONS FOR LAND USE CHOICES

When choosing to prepare land how much of input costs does the farmer use?

Cost in shs................

Are the inputs affordable? Yes ☐ No ☐

Are there any shortcuts the farmer uses in preparing land? Yes ☐ no ☐

Name them

State the approximate cost of caring for the plants kes................................

Is the cost affordable? Yes ☐ no ☐

Are there shortcuts yes ☐ no ☐

What are the shortcuts?

How much time is devoted in caring and harvesting crops?

Are the products processed? Yes ☐ no ☐

2.0: Jinja site; gross margins for various crops

Crops	Total gross margins Ksh per/yr 0.4 ha
Cereals	12800
Fruits	19526
Root & tuber	54400
Fodder & forage	35772
Legumes	6000
Stimulants	6977
Nuts	11812
Cash crops	32796
Indigenous vegetables	60000
Exotic vegetables	133644

Source; The District Agricultural annual report on vegetable performance in Jinja

3.0: Vihiga site; gross margins for various crops

Crops	Total gross margins Ksh per/yr 0.4 ha
Maize	9140
Sweet potatoes	14400
Nappier grass	2860
Beans	4800
Eucalyptus	40000
Tea	28000
Kales	53333
Managu	100000
Saga	33333
Amaranth	72000
Tomatoes	68000
Ground nuts	0
Mangoes	2380

Source; The District Agricultural annual report 2011 for Vihiga

4.0 Seasonal variations

Potassium nutrient

	d.f.	s.s.	m.s.	v.r.	F pr.
Season (Long rain and short rain)	1	779976569.	779976569.	18.52	<.001
Vegetable type	5	2155338786.	431067757.	10.23	<.001
Season*vegetable type	5	718712170.	143742434.	3.41	0.007
Residual	103	4338600501.	42122335.		
Total	114	7992628027.	70110772.		

Variate Calcium

	d.f	**s.s.**	**m.s.**	**v.r.**	**Fpr**
Season (Long rain and short rain)	1	76045778.	76045778.	5.62	0.020
Vegetable type	5	298710886.	59742177.	4.42	0.001
Season*vegetable type	5	146122961.	29224592.	2.16	0.064
Residual	103	1392982692.	13524104.		
Total	114	1913862317.	16788266.		

Variate Iron

	d.f.	s.s.	m.s.	v.r.	F pr.
Season (Long rain and short rain)	1	1.896E+09	1.896E+09	15.03	<.001
Vegetable type	5	1.789E+10	3.578E+09	28.36	<.001
Season*vegetable type	5	9.648E+08	1.930E+08	1.53	0.187
Residual	103	1.299E+10	1.261E+08		
Total	114	3.374E+10	2.960E+08		

5.0 Site variations

Variate Iron

	d.f.	s.s.	m.s.	v.r.	F pr.
Season (Long rain and short rain)	1	1.896E+09	1.896E+09	15.03	<.001
Vegetable type	5	1.789E+10	3.578E+09	28.36	<.001
Season*vegetable type	5	9.648E+08	1.930E+08	1.53	0.187
Residual	103	1.299E+10	1.261E+08		
Total	114	3.374E+10	2.960E+08		

Variate: FE

	d.f.	s.s.	m.s.	v.r.	Fpr
Site (Vihiga & Jinja)	1	3.558E+08	3.558E+08	1.57	0.215
Vegetable type	4	6.070E+09	1.517E+09	6.70	<.001
Site*vegetable type	2	2.592E+09	1.296E+09	5.72	0.006
Residual	55	1.245E+10	2.264E+08		
Total	62	2.147E+10	3.463E+08		

Variate: potassium					
	d.f.	s.s.	m.s.	v.r.	Fpr
Site (Vihiga & Jinja)	1	2114769500.	2114769500.	51.23	<.001
Vegetable type	4	735749060.	183937265.	4.46	0.003
Site*vegetable type	2	207445048.	103722524.	2.51	0.090
Residual	55	2270334031.	41278801.		
Total	62	5328297639.	85940284.		

6.0: Differences in nutrient content between indigenous and exotic vegetables

Variate: Calcium					
	d.f.	s.s.	m.s.	v.r.	Fpr
Exotic versus indigenous	1	959886541.	959886541.	25.93	<.001
Residual	85	3146078558.	37012689.		
Total	86	4105965099.	47743780.		

Variate: Manganese					
	d.f.	s.s.	m.s.	v.r.	Fpr
Exotic versus indigenous	1	10450068.	10450068.	13.74	<.001
Residual	85	64652515.	760618.		
Total	86	75102583.	873286.		

Variate:Iron					
	d.f.	s.s.	m.s.	v.r.	Fpr
Exotic versus indigenous	1	1.772E+09	1.772E+09	5.05	0.027
Residual	85	2.981E+10	3.507E+08		
Total	86	3.158E+10	3.672E+08		

7.0: Nutrahealth implied Ionomic Variants (NHIVs)

	Vegetable type	K	Ca	Fe	Mn	Cu	Zn	K rank	Ca rank	Fe rank	Mn rank	Cu rank	Zn rank	NHIV grades	Geo-mean	NHIV grade description
1	Amaranthus hybridus 1	18984	10692	2791	2216	35.24	113.9	2	4	2	3	4	3	6	2.884499141	Moderately Exceptional
2	Cleome gynandra 1	18780	12102	2278	2306	24.23	135.3	2	3	3	3	4	2	7	2.749459274	Moderately Exceptional
3	Brassica carinata 1	11428	9384	1638	2293	38.47	121.7	4	4	4	3	4	3	4	3.634241186	Less Exceptional
4	Solanum nigrum 1	17100	13590	2420	2218	26.93	82.9	3	3	3	3	4	4	5	3.301927249	Moderately Exceptional
5	Daucua carota 1	6200	3978	2126	3002	43.33	153	4	5	3	2	3	2	6	2.993795166	Moderately Exceptional
6	Ollium cepa 1	5572	4892	1671	3687	33.32	75.8	5	5	4	1	4	4	5	3.419951893	Moderately Exceptional
7	Spinacia 0leracea 1	4366	4693	1751	2606	31.77	78.8	5	5	4	2	4	4	4	3.838766207	Less Exceptional
8	Amaranthus hybridus 2	24280	21340	3390	1620	17	117	1	2	2	3	5	3	7	2.376176798	Moderately Exceptional
9	Cleome gynandra 2	12000	9640	1500	4040	89	99	4	4	4	1	1	3	7	2.40187391	Moderately Exceptional
10	Brassica carinata 2	14053	10290	1487	2250	12	119	3	4	4	3	5	3	4	3.595359251	Less Exceptional
11	Solanum nigrum 2	23600	17200	1996	1147	19	71	2	2	3	4	5	4	6	3.140835605	Moderately Exceptional
12	Daucua carota 2	6900	5220	1740	1280	63	142	4	5	4	4	2	2	5	3.295097945	Moderately Exceptional
13	Ollium cepa 2	5730	4430	660	2490	70.1	74	5	5	5	3	2	4	4	3.797696105	Less Exceptional
14	Spinacia 0leracea 2	7860	4950	1440	3300	15.8	12.5	4	5	4	2	5	5	3	3.98422019	Less Exceptional
15	Amaranthus hybridus 3	21700	11900	1900	1080	25	106	2	3	3	4	4	3	6	3.086163688	Moderately Exceptional
16	Cleome gynandra 3	11990	8030	1340	1760	36	67	4	4	4	3	4	4	4	3.812737172	Less Exceptional
17	Brassica carinata 3	11150	8265	860	2735	34	113	4	4	5	2	4	3	5	3.525468767	Moderately Exceptional
18	Solanum nigrum 3	22700	22100	2557	1191	24	47	2	1	3	4	4	4	7	2.696012309	Moderately Exceptional
19	Daucua carota 3	5400	6310	980	2190	6	109	5	4	4	3	5	3	4	3.914867641	Less Exceptional
20	Ollium cepa 3	2700	5220	1023	2710	60.6	102	5	5	4	2	2	3	5	3.259844428	Moderately Exceptional
21	Spinacia 0leracea 3	8243	8777	566	2838	13	30	4	4	5	2	5	5	3	3.98422019	Less Exceptional
	Jinja															
22	Amaranthus hybridus 4	12700	9600	1345	2710	61	105	3	4	4	2	2	3	6	2.884499141	Moderately Exceptional
23	Cleome gynandra 4	18000	15660	1760	2350	26	185	3	3	4	3	4	1	7	2.749459274	Moderately Exceptional

24	Brassica carinata 4	13605	7780	1070	3130	23	78	3	4	4	2	4	4	5	3.396762659	Moderately Exceptional
25	Solanum nigrum 4	25550	11750	1158	2386	24	58	1	3	4	3	4	4	6	2.884499141	Moderately Exceptional
26	Daucua carota 4	7190	2900	1240	1170	38	76	4	5	4	4	4	4	3	4.151563262	Less Exceptional
27	Ollium cepa 4	3700	2100	456	1591	7	47.4	5	5	5	3	5	4	2	4.424289571	Less Exceptional
28	Spinacia 0leracea 4	4830	1990	720	3300	15.3	64	5	5	5	2	5	4	3	4.135185542	Less Exceptional
29	Amaranthus hybridus 5	18100	23910	1700	1829	22	79	3	1	4	3	4	4	6	2.884499141	Moderately Exceptional
30	Cleome gynandra 5	23150	12650	1126	1119	13	59	2	3	4	4	5	4	5	3.525468767	Moderately Exceptional
31	Brassica carinata 5	18800	9470	710	1970	23	114	2	4	5	3	4	3	5	3.360421454	Moderately Exceptional
32	Solanum nigrum 5	15226.67	11593.67	4146.667	2666.667	45	121	3	3	1	2	3	3	8	2.334815149	Highly Exceptional
33	Daucua carota 5	9050	4640	1120	1040	89.3	99	4	5	4	4	1	3	6	3.140835605	Moderately Exceptional
34	Ollium cepa 5	1340	8700	696	1481.9	13.6	47.2	5	4	5	4	5	4	2	4.472135955	Less Exceptional
35	Spinacia 0leracea 5	4955	2500	430	1550	12.1	76.8	5	5	5	3	5	4	2	4.424289571	Less Exceptional

8.0: Rainfall amount (mm)* in Vihiga site during the year 2011

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Vihiga	64	95	153	220	157	80	71	75	85	86	140	100	1326

9.0: Rainfall amount (mm)* in Jinja site during the year 2011

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Vihiga	56	85	141	194	145	66	62	86	98	134	163	94	1324

10.0: Cropping bed variations (Premium Influenced Land Agro-usage Structure versus Flat)

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 (Premium Influenced Land Agro-usage Structure versus flat)	1	15174.56	15174.56	205.91	<.001
Vegetable type	3	20722.24	6907.41	93.73	<.001
Plot treatment (premium influenced land agro-usage structure 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 (premium influenced land agro-usage structure 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 (premium influenced land agro-usage structure 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			

11.0 Site variations

Variate: Yield in ha					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Site treatment (Vihiga & 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 & Jinja)	1	7891.4	7891.4	67.17	<.001
Residual	958	112556.8	117.5		
Total	959	120448.2			

12.0: Analysis of the costs and benefits of constructing premium influenced land agro-usage structures

Cost		Figure in Ksh
Amaranthus hybridus		
Land		***
Labour		1000
Pegs		***
Manure		***
Filler materials		***
Purchase of 50 empty sacks @50		2500
Purchase of ropes		300
Fertilizer		200
Total Costs (TC)	**4000**	
Revenue		
total sales for season 1 (82 kg @Ksh 60)		4920
total sales for season 2 (80 kg @Ksh 60)		4800
Total Revenue (TR)	**9720**	
total benefit (TV-TC)	**7240**	
Solanum scabrum		
Land		***
Labour		1000
Pegs		***
Manure		***
Filler materials		***
Purchase of 50 empty sacks @50		2500
Purchase of ropes		300
Fertilizer		200
Total Costs (TC)	**4000**	
Revenue		
total sales for season 1 (90 kg @Ksh 65)		5850
total sales for season 2 (81 kg @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 @50		2500
Purchase of ropes		300
Fertilizer		200
Total Costs (TC)	**4000**	
Revenue		
total sales for season 1 (85kg @Ksh 65)		5525
total sales for season 2 (77 kg @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 @50		2500
Purchase of ropes		300
Fertilizer		200
Total Costs (TC)	**4000**	
Revenue		
total sales for season 1 (60kg @Ksh 30)		1800
total sales for season 2 (70 kg @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, and Total Vegetable Crop benefits 19265

13.0: Analysis of the costs and benefits of constructing Flat beds

Cost		Figure in Ksh
<u>Amaranthus hybridus</u>		
Land		***
Labour		1000
Manure		***
Fertilizer		200
Total Costs (TC)	**1200**	
Revenue		
total sales for season 1 (60 kg @Ksh 60)		3600
total sales for season 2 (67kg @Ksh 60)		4020
Total Revenue (TR)	**7620**	
total benefit (TV-TC)	**6420**	
<u>Solanum scabrum</u>		
Land		***
Labour		1000
Manure		***
Fertilizer		200
Total Costs (TC)	**1200**	
Revenue		
total sales for season 1 (63 kg @Ksh 65)		4095
total sales for season 2 (55 kg @Ksh 65)		3575
Total Revenue (TR)	**7670**	
total benefit (TV-TC)	**6470**	
<u>Cleome gynandra</u>		
Land		***
Labour		1000
Manure		***
Fertilizer		200
Total Costs (TC)	**1200**	
Revenue		
total sales for season 1 (53kg @Ksh 65)		5525
total sales for season 2 (62 kg @Ksh 65)		5005
Total Revenue (TR)	**7475**	
total benefit (TV-TC)	**6275**	
<u>Daucas carota</u>		
Land		***
Labour		1000
Manure		***
Fertilizer		200
Total Costs (TC)	**1200**	
Revenue		
total sales for season 1 (45kg @Ksh 30)		1350
total sales for season 2 (53 kg @Ksh 30)		1590
Total Revenue (TR)	**2940**	
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

14.0: Analysis of the Net Present Value of Premium Influenced Land Agro-usage Structure and flat bed

Years	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Premium Influenced Land Agro-usage Structure (Amaranthus 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 (Amaranthus 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**													
Premium Influenced Land Agro-usage Structure (Solanum 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 (Solanum 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**													
Premium Influenced Land Agro-usage Structure (Cleome 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 (Cleome 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**													
Premium Influenced Land Agro-usage Structure (Daucas carota)														
Total benefits	3900	3900	3900	3900	3900	3900	3900	3900	3900	3900	3900	3900	3900	3900
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 (Daucas 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
Premium Influenced Land Agro-usage Structure (Amaranthus 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 (Amaranthus 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

Premium Influenced Land Agro-usage Structure (Solanum 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 (Solanum 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

Premium Influenced Land Agro-usage Structure (Cleome 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

Flat (Cleome 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

NPV

PREMIUM INFLUENCED LAND AGRO-USAGE STRUCTURE (Daucas 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

NPV

Flat (Daucas 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

15.0: Analysis of the Satisfaction Index

Farmer	Crop performance	Construction costs	Time of construction	Durability	Income generation
1	8	4	5	5	8
2	7	3	5	6	7
3	9	5	5	4	8
4	8	6	6	5	8
5	6	4	4	6	8
6	7	4	6	4	9
7	8	3	4	4	6
8	9	4	5	5	7
9	8	5	7	6	7
10	9	6	3	4	6
Total	7.9	4.4	5	4.9	7.3