AN ANALYSIS OF PROFITABILITY AND FACTORS INFLUENCING ADOPTION OF AGRO-ECOLOGICAL INTENSIFICATION (AEI) TECHNIQUES IN YATTA SUB-COUNTY, KENYA

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DECLARATION

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

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ABSTRACT

Decline in soil fertility is considered as one of the most important causes of low agriculture productivity in sub-Sahara Africa. Initiatives to address soil fertility through use of inorganic fertilizers have yielded below average results in increasing productivity. Agro-ecological intensification (AEI) techniques use alternative knowledge and local materials to improve soil fertility and increase productivity. There is, however, little evidence of the economic viability and adoption levels of the AEI technique. There is a gap in understanding of the factors influencing the adoption of AEI techniques and the profitability of this innovation. This study assessed the profitability, level of adoption and factors influencing adoption of agro-ecological intensification technique in Yatta Sub-county, Kenya. Household survey data on demographic characteristic, soil management practices, production and yield from a sample of 140 randomly selected households in Yatta Sub-county was collected. Gross margin analysis and Poisson regression model were used to analyze the data on profitability and factors influencing adoption respectively.

Farmers adopted various components, farm yard (95%), crop diversity (77%), compost manure (76%), utilization of crop residue (72%), cover cropping (57%) and crop rotation (54%). About 40 percent of farmers had adopted at least one component of the AEI techniques while 28 percent of surveyed farmers had fully adopted all components studied. Gross margin analysis showed that farmers practicing AEI technique increased their yield and attained higher profits than farmers without the technique. Results from the Poisson Regression model showed that farm income, age, level of education of household head, and number of extension contacts, among other factors, had significant influence in adoption of the agro-ecological intensification techniques.

These findings give insight into the potential for further development of agro-ecological intensification techniques. Policies that enhance adoption through targeted extension should be encouraged.

Key words; Agro-ecological intensification (AEI) technique, adoption, profitability, Poisson model

1.0 INTRODUCTION

1.1 Background

As the world population increases, demand for food, fibre and other agriculture based products has risen and there is pressure on agriculture to meet the increasing demand. Yet less than half of the world's land is suitable for agricultural production (IDS, 2009, F.A.O, 2003). Some of the main challenges to increasing production include soil degradation, land fragmentation and climate change. In Kenya, increase in population has placed pressure on natural resources especially land (GoK, 2013). Low soil fertility remains a challenge to increasing agricultural production in most of sub-Sahara Africa countries and the problem is most severe in Arid and Semi-Arid areas (Nkonya et al., 2011) which have fragile soils that are easily degraded. Still over 80% of the population, especially those living in rural areas, derive their livelihoods mainly from agricultural related activities (KARI, 2012). Increasing agriculture productivity is therefore important and necessary because of its contribution to food security and poverty reduction for especially for rural households.

In recognition of the important role of soils to production, the 68th UN General Assembly declared the year 2015 the International Year of Soils (IYS). Among the objectives of the year was: to achieve full recognition of the prominent contribution of soils to food security, climate change adaptation and mitigation, essential ecosystem services, poverty alleviation and sustainable development and to promote policies and actions for the sustainable management and protection of soil resources.

Several strategies to increase soil fertility and consequently enhance productivity, such as increasing fertilizer access through targeted input programs like the Agricultural Support Input program (AISP) in Malawi or the National Accelerated Agricultural Input Programme (NAAIP) in Kenya, integrated nutrient management and organic fertilizer have been developed and promoted (Esilaba et al., 2002, Gruhn et al., 2000, Franzluebbers, 1998). However these interventions face various economic and ecological challenges. For example, the use external inputs such as fertilizers to sustain crop productivity on a long-term basis has not been effective as it often leads to a decline in soil organic matter content, soil acidification and soil physical degradation, which may in turn lead to increased soil erosion (Onwu et al., *2008).*

According to Amit, (2006) average fertilizer use in Sub Saharan Africa is still very low at 9 kilograms per hectare, compared to 125 kilograms per hectare in other parts of the world (Amit, 2006). The low fertilizer consumption is despite various interventions. Some of the reasons advanced for this low uptake include high cost of fertilizer, lack of credit access to farmers and poor infrastructure (De Groote et al. 2006). Sustainability of subsidy programs such as Agricultural Support Input program (AISP) in Malawi or the National Accelerated Agricultural Input Programme (NAAIP) in Kenya is therefore uncertain.

Although distribution of subsidized fertilizer in semi-arid areas could contribute positively to fertilizer use, its contribution to yield and smallholders' income is limited due to environmental riskiness and low response rate (Mbuvi, 2000, Kibaara and Nyoro, 2007). In poor soils crop response to fertilizers is low. Hence farmers invest in external inputs only on plots they considered fertile (Marenya and Barrette, 2009). This suggests that fertilizer demand is complementary to the soil physical condition and improving soil condition may be important to stimulate use of fertilizers and market participation.

Other studies showed that poor soils can lock farmers in to a cycle of increasing poverty due to inability to purchase inputs to increase productivity, Kristen et al., (2008). Low soil quality and other challenges facing agriculture for example low investment in the sector, inefficient techniques and institution constraints still need to be addressed in order to encourage small holders to use inorganic input (Kydd et al, 2006).

Considering these challenges alternative sustainable practises, such as the agro ecological intensification of land use, are necessary to improve agriculture productivity in the ASALs. Agro ecological intensification is an approach to farming that blends tradition with innovation to make use of locally available resources, for increased agricultural productivity and natural resource conservation (Miguel and Clara, 2005). Agro-ecological intensification (AEI) is further defined as the harnessing of ecological processes to increase productivity of local resources, labor, off-farm nutrients, and sunlight, to increase production and reduce losses to stresses, while preserving the environment. Effective deployment of AEI needs to be addressed for different production systems and conditions of market and input access.

The Yatta plateau is one of the areas under ASALs in Kenya, which promises good agricultural growth if appropriate interventions are in place. The ongoing project on AEI in Yatta is focused on cassava and sorghum production. Cassava (*Manihotesculenta*) and sorghum (*Sorghum bicolor*), are important crops due to their drought resistance ability, thus more food secure crops. The decline in production of these food crops raises concern for food security. However recent progress in research and development in cassava has developed improved varieties that are high yielding, fast maturing and drought and disease resistant. Sorghum has also been identified a priority crop by the Kenya Agricultural and Livestock Research Organisation, (KALRO). The priority crops are inter cropped and rotated with nitrogen fixing legumes such as pigeon peas and dolichos (*Dolichos lab lab*) in order to increase their yield.

The current study was within the project, 'Towards Increased Agricultural Productivity and Food Security in East Africa through Capacity Building in Agroecological Intensification,' conducted in Yatta Sub County in Kenya and Kamuli District in Uganda. The project aimed at improving agricultural productivity and food security in semi-arid lands through capacity building in agroecological intensification use of land. The focus was on the use of indigenous technical knowledge (ITK) in sustainable soil fertility management. This is achieved through promotion of abandoned food crops, sorghum and cassava and using locally available materials, farm yard manure and compost manure to enhance soil quality. Intercrop and crop rotation cropping systems with indigenous legumes were employed to help achieve the full potential of improved varieties while preserving biodiversity, improving the nutrition diet, food security and livelihoods of households in semi-arid lands. It anticipates that increasing agricultural productivity using these indigenous approaches will significantly reduce food insecurity and improve livelihoods in the area. This will increase the economic opportunities available in ASALs and ultimately contribute to poverty reduction.

1.2 Statement of the problem

Despite the effort taken to subsidize agriculture inputs, fertilizer use remains a high risk for smallholders. This is because, in cases of low rains, which are the norm in ASALs, the crops scorch, making fertilizer a very costly risk for the poor farmer (Mbuvi, 2000). Therefore the effect of price subsidies and greater access to services has resulted in little change in the number of farmers using new technologies, in particular improved varieties and fertilizer. In addition most smallholder farmers still engage in subsistence low production due to several constraints such as lack of credit to purchase input and low soil fertility (De Groote et al. 2006, Marenya and Barrett, 2009).

Several innovative and indigenous ways of improving soil fertility under the agroecological intensification techniques have been developed. The concept has been widely explored but much of the recommendation is on agronomic practices (De Jager et al. 2001, Onwu et al. 2008, Omotayo et al. 2009). The magnitude of the economic benefits is so far not known , whether it has adequate incentive, and the number of farmers who have adopted the approach is also not known. Further the profitability of adoption of agro ecological intensification technique is also not known. Economic theory assumes profit maximization, hence the assumption that a profitable technique is likely to be highly adopted. There is a gap in knowledge of factors affecting the continued adoption of these technologies particularly in arid areas.

1.3 Purpose and objective

The purpose of this study is to evaluate profitability and factors affecting adoption of Agro Ecological Intensification (AEI) techniques in Yatta Sub-county, Kenya.

1.4 Specific objectives

- To assess profitability of adopting Agro Ecological Intensification (AEI) techniques.
- To asses socio-economic factors influencing adoption of AEI technique in Yatta Sub-county Kenya.

1.5 Hypotheses

1. There is no significant difference between gross margin of agroecological intensification technique adopters and that of non-adopters.
2. Socio-economic factors do not influence adoption of agro ecological intensification techniques in Yatta Sub-county.

1.7 Justification

There is increased awareness of the need for sustainable intensification throughout Africa. This has been enhanced by the realisation of the need to preserve the natural environment in order to continue to benefit from the various ecological services it offers. Agroecological intensification technique promises to offer multiple production benefits while still preserving the environment. By measuring the profitability of agro ecological intensification technique, this study will provide farmers with knowledge that will inform their decisions in resource allocation and target return on investment. It will provide them with information which can facilitate them to make decisions based on sound economic analysis. The study will further provide and enhance knowledge to researchers with an economic analysis of technology and provide guidance in the further development of suitable techniques that are more likely to be up scaled to other ASALs.

Further, Kenya, as most countries in Sub-Sahara Africa, lacks soil fertility management policies. This has led to continued soil mining and depletion with little intervention by government and development agencies to reverse the decline in soil quality. Policy design for soil fertility management is particularly difficult because soil is not a tradable commodity and therefore not subject to market policies that are much easier to influence. However by studying the behaviour of the primary users of the soil, we can develop suitable policies so that they have incentive to promote soil management. Empirical evidence of adoption in arid lands is important in order to understand the limitations farmers encounter and the necessary policy amendment.

2.0 LITERATURE REVIEW

2.1 Sustainable agriculture intensification

In the past, agriculture production relied on increasing area of cropped land in order to meet the ever expanding worlds' food demand (Fischer et al., 2015). This was done through clearing forests and uncultivated land; however, there is a limit to the available arable land (Nkonya et al., 2013). Further expansion extended to arid and semi-arid lands which are fragile and more susceptible to climate variations (FAO, 2009, AGRA, 2014, Fischer et al. 2015). In considerations of these limitations to expanding cultivated land, other strategies to increase production became necessary. One such approach was agriculture intensification.

Agriculture intensification relies on increasing production per unit of input used (land, labor, seed) (FAO, 2004). Intensification occurs when there is increased productivity or improved efficiency of inputs (FAO, 2004). An example is mono cropping in tea and coffee, irrigation and specialization. While agriculture intensification is important to improve farming livelihoods (Warren, 2002), it has different and varying impacts on land, biodiversity and other natural resource on which agriculture production is dependent (Harms et al., 1987, Tscharntke et al., 2005, Firbank et al. 2007, Geiger et al., 2010). Agriculture intensification focused on high external input use such as intensive use of fertilizer, pesticide and herbicide often lead to loss of diversity and can create ecological problems that cause further intensification difficult and cause declining yields (ILEA, 1998, Geiger et al., 2010). High cost of inputs and credit availability are also a challenge in high input intensification. This makes high external input intensification unsustainable and unattainable to most small scale farmers. Further, productivity of external inputs decreases in highly degraded soils causing concern for sustainability of agriculture intensification (Marenya and Barrett, 2009). Sustainable intensification requires increasing agriculture production at reduced negative environmental impact (The Royal Society, 2009, Pretty et al., 2011).

To reduce reliance on external inputs and achieve increased yield, approaches such as integrated pest management and integrated nutrient management have been considered (Banabana, 2002, Mugwe et al., 2008, Odendo et al., 2009). However little consideration has been given to the ecological functions and processes involved in agriculture production and the negative effect agriculture can have on natural environment (ILEA, 1998). Soil nutrient may be considered a renewable natural resource. This means it has inflows, outflows and stock. Agro ecological intensification requires consideration of these natural resources environment and ecosystems processes. Agro-ecology, applies ecological concepts and principles to the design and management of agro-ecosystems so that the systems are both environmentally sound and productive (Gliessman, 1998). Some of the agroecological sustainable techniques include, crop rotation, cover cropping, utilization of crop residue, crop diversity, use of compost and farm yard manure. This techniques help enhance soil organic matter, physical, biological and chemical properties of soil and thereby enhancing its ability to function as source of nutrient and water and anchor to crops (Gebremedin and Schwab, 1998). In response to this, soil scientists have quantified, recorded and developed soil replenishment technologies that reverse the adverse effect of agriculture production on soil fertility.

2.2 Theory of agriculture technology adoption

Technological innovations aim at efficient use of scare resources. However, a technology remains economically insignificant unless it is fully adopted and utilized (Feder et al., 1985). Hence, numerous studies have been carried out to identify factors that affect adoption and how they can be enhanced or eliminated depending on their impact on technology adoption.

According to Feder et al., (1985), adoption is defined as the degree of use of a new technology in the long-run equilibrium when the farmer has full information about the technology and it's potential. Adoption is separate from diffusion which refers to the aggregate adoption of technology within a society or geographical area (Sunding and Zilberman 2001).

Adoption theories fall in two main categories, cognitive theories and behavioural theories, (Hycenth et al., 2010). Cognitive theories suggest that agents' change of behaviour, adopt new technology and is motivated by the need to solve a current persisting problem. Behavioural theories, however, suggest that behaviour is conditional and therefore is acquired through learning of new skills and ideas. In spite of the different approaches, numerous studies agree that adoption takes place in a process (Rogers, 1995, Neupane et al., 2002, Mugwe et al., 2008). The process begins with awareness, then formation of an attitude about the technology, followed by the decision to adopt or not adopt then intention to implement and finally the implementation of the innovation (Rogers, 1995, Bonabana, 2002).

Several studies have examined adoption of soil fertility management techniques and its importance in increasing productivity and efficiency of external inputs (Côte et al., 2010). Soil fertility replenishment technologies can broadly categorized into those relying on on-farm nutrient recycling generally referred to as organic/renewable (Oluyede et al., 2007, Ayuya et al., 2012), inorganic, such as chemical fertilizer (Omamo et al., 2002) or integrated management technologies combining organic and inorganic fertilizers (Mugwe et al., 2008).

Assuming that farmers are rational they will use the best available technology to produce at the maximum profit or optimize other utility such as food security or increased income. However households are subject to several constrains including environmental such as climate change or socio economic example credit, input and information access (Foster and Rosenzweig 2003).

Limited capacity of smallholder farmer to obtain credit coupled with low returns to soil fertility management technologies have been identified as prominent reasons behind the sub optimal adoption of these technologies (Oluoch-Kosura et al., 2001, De Groote et al., 2006, Marenya and Barrett, 2009). Several studies have also investigated factors that influence soil fertility management decisions by small scale farmers and found that farmers' decision on the level of inorganic fertilizer to use is joint to the decision of the level of organic fertilizer applied Omamo et al., (2002). The studies found that farmers' use inorganic and organic sources of soil nutrients are complementary. However once the effects of cropping patterns, farm-to market transport costs, and labour availability are taken into account, smallholder applications of inorganic and organic fertilizers appear to be substitutes.

Therefore considering farmers to be rational agents and adoption as an optimizing process, farmers adopt a technology if and only if the technology maximizes their utility, (Foster and Rosenzweig 2003). Adoption may therefore be modelled in the random utility framework. Random Utility Theory hypothesize that utility can be expressed a function of factors (x) affecting the decision to adopt or not adopt. These factors include demographic and socioeconomic attributes of the farmer (Adesina and Chianu, 2002), agroecological and institutional variables and preferences about technology specific attributes (Adesina et al. 1995).

Much of the interest in adoption studies is the measure of the rate and intensity of adoption. Rate, generally concerns the time, that is, measure how long it takes for farmers to adopt a new technology while intensity is about the level of adoption at a specific moment in time. Rogers, (1995), noted that people adopted technologies at different times and different rates. In this study adoption refers to the full utilization of agro ecological techniques to improve soil fertility in the long run.

Studies investigating factors that influence soil fertility management decisions by small scale farmers have shown that same factors found to affect adoption were also found relevant in influencing the speed of adoption (Odendo et al., 2010). Further socio environment and resource endowment were shown to influence more than just the decision to adopt but also the intensity of adoption (Otieno et al., 2011). Analysis of intensity of are instructive to policy particularly agriculture extension. Yet, despite several initiatives to enhance soil fertility among small scale farmers' lands, adoption of soil fertility management among small scale farmers has been low. Studies reveal that in most cases adoption is below average (Mugwe et al., 2008, Marenya and Barrett, 2009, Oluoch-Kosura et al., 2001).

The present study will consider adoption of a soil fertility techniques not addressed in any previous study. Agroecological intensification techniques are exceptional in approach; they utilizes indigenous technical knowledge of ecosystems and blends it with innovation in soil science to raise agriculture productivity. This study has also been conducted in semi-arid lands, an area which until recently received little attention. In addition the analysis profitability using trial and household data which is distinctive and will give comparison of gross margins of technology developers and of farmers.

2.3 Profitability of soil management techniques

Profitability is most commonly used on financial analysis of investments. However with modification they can be successfully applied in diverse situations including assessment of technologies. According to Virlanuta et al., (2011) there are two approaches to profitability analysis; economic and financial analysis. Financial analysis consider pure financial returns of investment such as in soil fertility, while economic analysis take account of comparative advantage of investing in an agricultural versus a non-agricultural activity (Kelly et al., 2003, Howard et al., 2005). An economic analysis evaluates best projects in terms of social costs and benefits and recommendations are based on highest return on investment for social cost (Howard et al. 2005). As such, economic analysis differentiates between socio and private cost and benefits. Regardless of the approach used profitability analysis (PA) can be an important tool to identify areas that should be addressed by policy makers, farmers or input prices to increase returns to farmers (Kelly et al. 2003, Duflo et al., 2004).

In this study, profitability analysis assesses the financial viability of soil management techniques applied in a specific farming system. It allows incorporation of socio-economic and on farm incomes analysis in purely biophysical and field trial research and assesses their economic viability (Ajayi and Matakala 2006). The previous studies focused on the role of individual characteristic and socio economic factors in uptake of soil fertility management techniques, but conservation measures impute a cost on production. The critical economic factors such as profit and risk have been ignored. However, profitability and risk are important factors to farmers when considering whether to adopt or not adopt a technology, (Oluyede et al. 2007, Maina, 2008, Karanja, 2010).

2.4 Review of analytical techniques

2.4.1 Adoption of soil fertility techniques

Past studies have applied both probit and logit model in investigating various factors influencing adoption. Mugwe et al. (2008) applied a logistic model on a sample of 106, while Odendo et al. (2009) evaluated adoption patterns of Integrated Nutrient Management (INM) using binary logit model on data collected from a random sample of 331 households in western Kenya. Adolwa et al (2012) applied probit model on a sample of 120 farmers to assess factors influencing uptake of Integrated Soil Fertility Management (ISFM) Knowledge among Smallholder in Western Kenya.

For both probit and logit models, the dependent variable is bound between [0, 1]. The objective is to estimate the probability of adopting a given technology. The choice of model depends on the assumption made on the distribution of the error term. Assuming ε has a normal distribution result in probit model while assuming ε has logistic distribution result in logistic model.

The double hurdle model has been used in consumer studied to show factors influencing decision to consume and then decision on how much to consume and in market participation studies (Wodjao, 2009, Holloway et al. 2000, Burke, 2009). Double-hurdle model is indeed superior to other most commonly used binary dependent variable models, the double-hurdle model is tested against the Tobit and Heckman models using likelihood ratio (LR) and Vuong tests, respectively. The tests reveal that, compared to these two models, the double-hurdle model is the best econometric specification to deal with the single-day diary data (Wodjao, 2009).

The current study will estimate a regression function using the Poisson Regression model. The Poisson is a count data model first used by Bortkiewicz (1898). The method was used by Otieno et al. (2011) to estimate the role of pigeon pea variety attribute on the number of varieties taken by farmers. The method was also used by Chege (2014) to assess factors affecting food security. Food security was measured using the Household Dietary Diversity Index (HDDI) was a count variable. In the current study, the agroecological techniques considered follow a count variable model hence the Poisson Model was considered appropriate to assess adoption.

The utility may be expressed as a linear sum of observable behaviour and a random error term which includes unobservable behaviour and measurement errors.

The condition characterizing the discrete choice about whether to adopt can then be written as;

$y_i = f(X_I),$ ……………………………………………………………..………………… (1)

Where $y > 0$ with adoption and $Y < 0$with no adoption, the indicator variable $y_i^* = 1$ when $y_i > 0$ and the household adopts, with $y_i^* = 0$ under no adoption. Y_i^* is a latent variable, it represents the unobservable behaviour, which is a function of a set of factors $\mathbf{x}_i$. A linear sum of the participation Equation (1) has the form;

$$Yi* = \boldsymbol{\beta} i\, \boldsymbol{x} i + \varepsilon i, \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

Where $Y^*_i = 1$ if $Y_i > 0$ and $Y^*_i = 0$ otherwise, $\boldsymbol{\beta}_i$ is a vector of unknown coefficients controlling the relationship between household-specific characteristics, $\mathbf{x}_i$ and adoption, and $\boldsymbol{\varepsilon}_i$ is a random error. Therefore in the adoption of agro ecological intensification technique, the relevant model assumes farmers in Yatta district have option to improve their soil using AEI technique. Utility derived from the decision to adopt will be denoted asU_{AEI}, which is affected by a vector of socio, economic and physical factors x. Since U_{AEI} is not observable we observe the decision, y_{AEI} which can be presented as;

$$Y_{AEI}(X) = \beta_x x + \varepsilon_{AEI} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

Where $Y_{AEI}(X)$adoption of AEI given X is factors, β_x and ε_{AEI} is the factor coefficient and random error associated with adoption of agro ecological intensification technique.

2.4.2 Profitability of agricultural technologies

Some approaches used in previous studies to analyze profitability include partial budgeting, net present value and gross margin analysis. Partial budgets are used to measure the expected changes in net benefits from individual treatments, (Ngare, 2004). It accounts only changes in returns and costs that result from change in implementing a specific technology or alternative. Incomes and expenses unaffected by the change are ignored, not included in the calculation. The current study compares profitability of applying AEI technique to conventional farming without inputs. Partial budgets only give changes in benefit hence were not used in the study.

Net Present Value (NPV) is also commonly used (Ajayi and Matakala, 2006, Pannell et al., 2014). NPV allows discounting of benefits to present value using a relevant discount factor. NPV may be used to evaluate a benefits accruing from use of a single technology over time or in comparing different technologies. Positive NPV shows that the technology is viable, while the technology with highest NPV is preferred. Due to lack of data to do discounting, the NPV was not used to decide the financial viability of the technology. Instead, current study employs a gross margin analysis. Gross margin gives the difference between the gross income, which is the product of total output and unit price of output, and the total variable cost. Gross margin assist in making managerial decisions. Gross margins are reported per unit which helps evaluate the economic viability of each enterprise (Karanja, 2010). The farm activity with the highest gross margin per unit on the most limiting resource is chosen.

3.0 METHODOLOGY

3.1 Conceptual framework

Agro ecological intensification research acknowledges these farmers constraints and incorporates indigenous knowledge and improves on it by advances in soil science (Tripp, 2005). It is therefore possible to hypothesise that adoption of AEI could be higher than has been in other soil management techniques that omitted indigenous knowledge in their conceptualization. Another limitation is that some farmers have little management skills and often practice farming without proper planning. Consequently many farmers continue in subsistence farming and realize little profit from their farming activities. Planning is important because it allows the farmer to control resources and make adjustments where necessary. Planning makes use of tools such as inventory records and budgets. Such tools help the farmer make efficient resource allocations as well as attain the maximum return from his investment.

The agroecological intensification project was initiated in 2011 in Yatta Sub County Machakos County by the McKnight Foundation. The project aimed at improving agriculture productivity and food security in this the semi-arid region through promoting cultivation of abandoned crops using agroecological techniques. These techniques were crop rotation, incorporating crop residue, intercropping and using cover crops to increase water retention. Inorganic fertilizers specifically farm yard and compost manure were used to improve soil fertility. Sorghum and Cassava were used as the test crop. Trials were conducted on farmers land to encourage participation and adoption in farmers' normal conditions. The conceptual framework in Figure 1, demonstrates the adoption behavioural pattern frequently used to study adoption of technologies (Neupane et al., 2002, Mugwe et al., 2008).

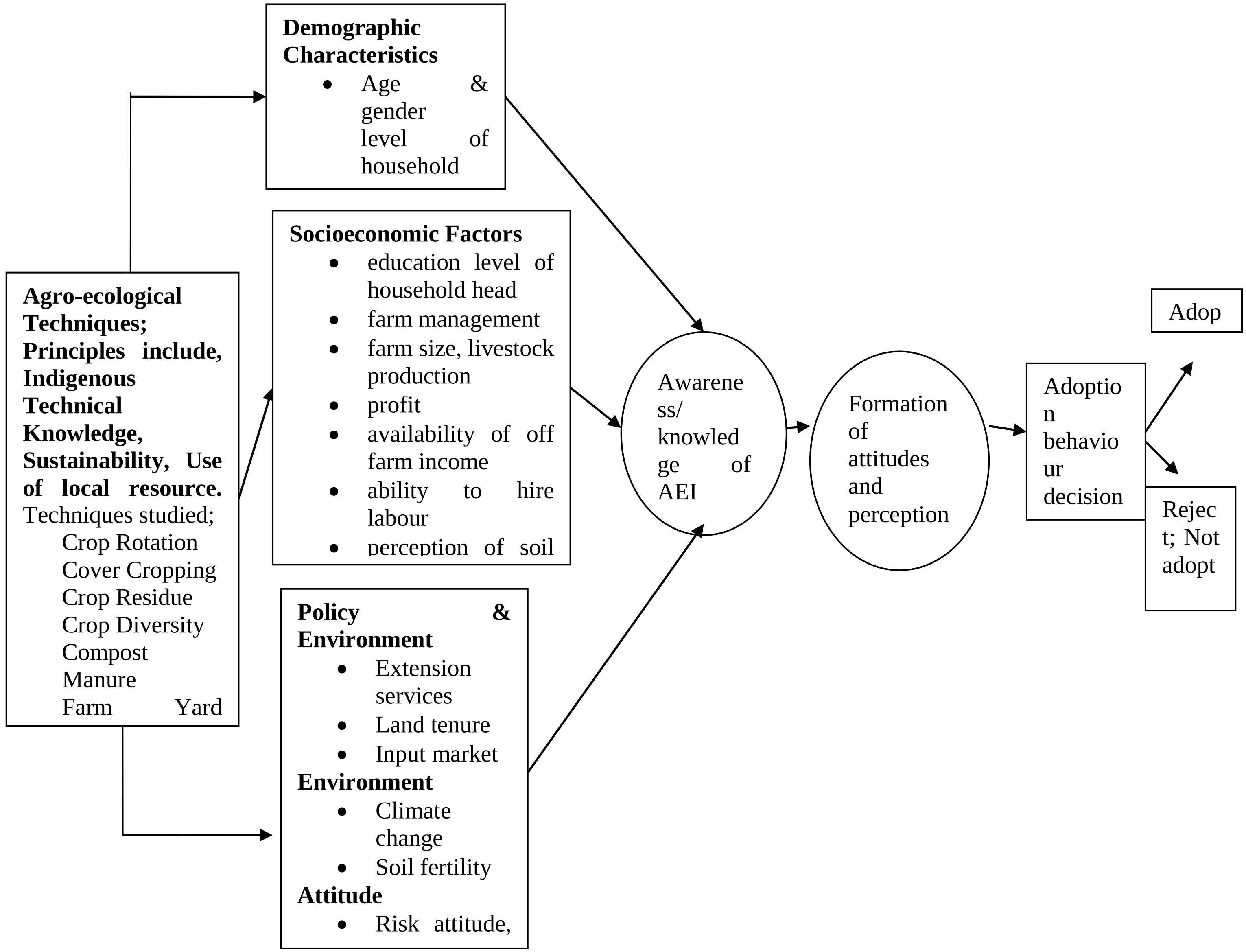

Figure 1: Conceptual framework for farmers' adoption decision of AEI techniques in Yatta. Adapted from Neupane et al.,(2002).

The concept describes the innovation- adoption process where farmers begin by being aware of new technology then form an attitude, negative or positive, then make a decision to adopt or not. This is based on based on the principle describe by Rogers, (1995). Figure 1 show the framework used to study adoption decision by farmers in this study. Several factors affect adoption, this include, demographics, socio economic, policy and environmental factors and farmers' own risk attitude. Conceptually a profitable technique should be attractive to farmers due to the accruing benefits associated with its adoption (Karanja, 2010). However various macro and microeconomic factors may influence the decision to adopt a technique. As such an adoption study may be viewed as an investigation of the opportunities and constraints influencing adoption and how such identified factors may be enhanced (if enhancing) or eliminated (if limiting) adoption. In this study, the following broad categories are assumed to influence adoption, Policies and markets, demographic and socio economic factors, physical environment, perception and behavioral attributes of the agent.

Policies and markets factors provide the institutional framework within which economic agents function. For example, land tenure systems, if secure; provide incentive for effective investment in land and infrastructure. Market factors include the availability of input market and output market. Availability of markets facilitates exchange of benefits accruing from adoption of AEI technique hence encourage adoption among farmers.

Demographic and socio economic factors considered in this study include; age of farmer, education level, gender, income and main occupation and resource endowment. Age reflects on the experience of the farmer (CIMMYT, 1993). Older farmers are assumed to be more experienced and hence less likely to take risk to adopt new techniques. However the advantage of AEI technique is that it uses indigenous knowledge and hence acceptable to more experienced farmers. Education levels reflect the managerial skill that a farmer may have. With higher education a farmer is more likely to better understand the benefits of AEI and evaluate the alternatives between adoption and non-adoption. Gender influence may not be well defined and is subject to research, but it is known that each gender will likely take up a technology that favors their role. Income level and main occupation have varying influence. At high off-farm income level the farmer is less likely to adopt than if the main occupation is farming. Physical environment characteristics such as climate condition and soil physical qualities influence the adoption of AEI. In areas with more variability in climatic condition and poor soil AEI technique is likely to be most appropriate and therefore more likely adopted.

Behavioral attitude towards risk can also influence the adoption of technology by a farmer. Risk loving farmer may be more willing to adopt a technology and be an early adopter so as to gain the potential benefits the innovation. However a risk averse farmer may be slower to adopt and prefer to observe others and learn before taking it up themselves. Hence such a farmer will be a late adopter. Risk neutral farmer will adopt after learning the risk involved.

The combined effects of all the above factors result either in adoption or non-adoption of AEI techniques of land use. In places where adoption is optimal decision by farmers, the increased income and improved livelihoods are some of possible outcomes. Farmers will only adopt if the technology is profitable hence the need for profitability analysis.

3.2 Study area

The study was carried out in Yatta Sub-County of Machakos County. Yatta Sub-county is a semi-arid area classified in agro-ecological zone IV and V (Jaetzold and Schmidt, 2006). Yatta Sub-county lies between 1º37’ S and 1º45’ S latitude and 37º15’ E and 37º23’ E longitude (Fig 1). Yatta has a population of 147,579 consisting of 48 percent male and 52 percent female. It has

33, 162 households (KNBS, 2013). The area is a semi arid region experienced low soil fertility and low agriculture productivity caused by the poor soil. Yatta Sub-county is generally arid, with a mean annual rainfall of 500-750mm and mean temperature 29^0C. It has a bimodal rainfall distribution. The long rains occur between March and May, while the short rains are received between October and December. The Sub-county lies on a plateau at an elevation of 1700m, it has an approximate area of 1059 square kilometres. The area is of moderate agricultural potential (Munyao et al. 2013). The soils are mainly Acrisols, Luvisols and Ferralsols (USDA 1978, WRB, 2006). They are well drained, moderately deep to very deep, have high moisture storage capacity but low nutrient availability (Kibunja et al. 2010). Machakos County has 52 percent urban population. The main town in Yatta Sub County is Matuu town most economic activity being trade in agricultural products. Farmers practice mixed farming, keeping indigenous cattle and small stock and growing drought tolerant crops mainly maize sorghum and cassava **(**Macharia, 2010).

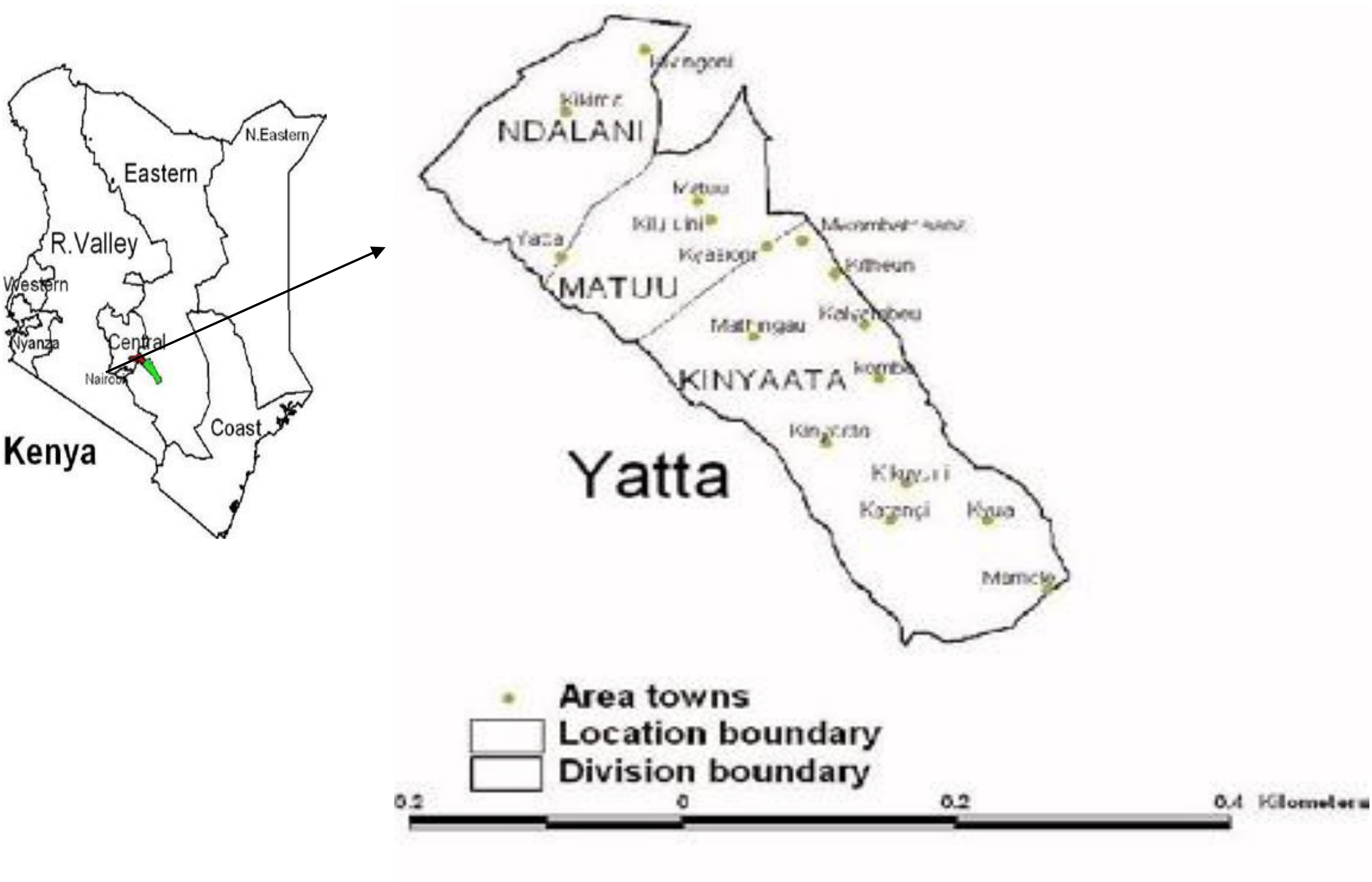

Figure 2: Map of Yatta sub-County

3.3 Data Analysis

3.3.1 Descriptive statistics

Descriptive statistics were used to describe and characterize the demographics, socio economic characteristics and resource access and endowment of the sampled farmers. This was to give more insight into the structure of sample used. Descriptive were also used to illustrate the different levels of adoption and technique use. The summary statistic used mainly focused on means and frequencies.

3.3.2 Profitability analysis

This study considered profitability with reference to agro-ecological intensification technique applied in arid area of Yatta. Gross margin was used to compare performance of enterprises that have similar requirements for capital and labour. In order to conduct a comparative study of the cropping system, identification of each system and its associated practices was necessary. Gross margin were calculated as the difference between the income from the enterprise and the variable costs incurred in the enterprise. For each specific case, costs, prices and managerial assumptions are made. The following variable cost items were identified: land preparation, planting, soil improvement, pest, disease and weed control and harvesting cost. Details of the expenses are listed below. Costs are calculated per unit area.

Land preparation costs: land preparation was by hoe or ox-plough. Labour cost associated with land preparation, which is clearing, ploughing and making furrows were considered. It was calculated by multiplying the wage rate by the number of man hours used. In cases where ox-plough was used, cost was calculated as hiring rate per hectare.

Planting costs: these include two costs, Seed cost and labour cost. Seed cost is amount of seed used as measured in kilogram multiplied by the price per kilogram. Labour costs are wage rate multiplied by number of man hours used for planting. Costs were valued at the market price.

Soil amendment cost: soil amendment being organic that is farm yard manure and / or compost manure. Cost of manure was calculated by multiplying quantity by price. Cost of compost was difficult to approximate due to missing markets. All these include application labour cost.

Pest, weed and disease control cost: This was calculated as the cost of all insecticide, fungicide and herbicide and application labour cost. It was calculated by multiplying number of sprays by cost per hectare. In most cases weed control is by weeding so includes labour cost.

Harvesting: this includes labour for harvesting, packaging material and processing cost. It is calculated by multiplying number of units per hectare by cost per hectare. Cropping is rain fed hence the exclusion of irrigation cost. Management cost is also excluded since most farmers managed their own farms, there was low level specialization and opportunity cost was difficult to measure.

In summary; Average yield multiplied by price gives the gross value product;

$$\text{Gross Value product (GVP)} = \text{Avg. Yield} * \text{price(p)}$$

Average input plus labour give the variable cost; $\text{Variable cost (VC)} = \text{Avg input cost} + \text{labor Cost}$

Gross margin per hectare;

$$\text{Gross Margin/ hactare} = \frac{\text{GVP} - \text{Variable Cost (VC)}}{\text{No. of hactares}}$$

The calculate formula used was; $GM = \sum_{j=1}^{n} Q_j P_{xj} - c$

Where; Q_j is the output of j^{th} product per unit area of land

P_{xj} is the unit price for the j^{th} product and

C is the total variable cost of producing the output.

Expected benefits; increase in yields, food security and improved likelihoods. Gross value product was calculated for total production without deduction of household consumption. Input and output prices were valued at the prices in the market during the survey period. Calculations were done for the main cereal and root crops as identified in literature and survey data. This crops were; sorghum, cassava, pigeon peas, and dolichos. This is because of their relative importance to food security in the study area. Two approaches are used; farm trial data and survey data results.

The empirical specification of revenue and costs used is illustrated in the next section. Gross margin analysis for each experiment treatment and combination of management practices for farmers was calculated and compared using an analysis of variance (ANOVA) test. The Least significant difference (LSD) at 5% was used to detect difference among means. The hypothesis that there is no difference in average gross margin between adopting and not adopting AEI technique was rejected for any difference below 5 percent level of significance.

3.3.3 Poisson regression

The Poisson regression is a count data model in which the dependent variable is a non-negative integer valued random variable and is assumed to have a Poisson distribution. The Poisson distribution makes the assumption that the conditional mean equals conditional variance. The Poisson model gives the probability that an event denoted as Y is at level y at a give time t. For example the probability that a farmer will contact (Y) an extension office at least five (y) times in a year can be expressed as a Poisson distribution. Hence assuming the dependent variable Y has a Poisson distribution, the following model is specified;

$$Pr(Y = y) = \frac{e^{-\mu}(\mu)^{y}}{y!} \quad \text{.................... Equation 1}$$

Y is a discrete variable and can only take one value y at any given time t. Where μ is the mean value and it represents the level, intensity or rate parameter, $\mu > 0$. The time value is normalized to 1, $t = 1$ hence the above specification.

The current study explores the level of uptake of agro-ecological intensification technique components introduced. Farmers were presented with six different components of agroecological intensification technique. The level of adoption was then defined as the number of agro-ecological components that a farmer adopts. This definition has been used in Otieno et al., (2011). In that study farmers were presented with different varieties of pigeon peas each with different varietal traits. The level of adoption was then defined by the number of new varieties a farmer adopted rather than by the land area dedicated to the new technology.

Suppose farmers' adoption decision can be analyzed as a function of farmers' demographic factors, resource endowment and farmer's subjective judgment. Assuming y, is a count variable denoting the level of adoption, μ is a function of several observed characteristics x_i, the Poisson regression may be specified as;

$$f(y_i; x_i) = \frac{e^{-\mu(x_i;\beta)}\mu\,(x_i;\beta)^{y_i}}{y_i!} \quad \text{Equation 2}$$

y_i is the level of adoption observed at time t, μ, represents the mean level of adoption which must be greater than 0, μ>0 and is a function of x_i, where x_i represents the independent/ explanatory variables and β is the estimated parameter. e is the exponential function given approximately as 2.71. Hence y_i = 0, 1, 2,..n, where zero means no adoption while numbers 1, 2,...,n represent the number of techniques adopted by the i^{th} farmer.

Estimation of β can be done using the Poisson regression. The log-likelihood for poisson regression follows:

$$L = \sum_{i=1}^{N} y_i\, x_i^{\,b-e^{x_i b}} - Iny_i! \quad \text{Equation 3}$$

The equation is estimated using the maximum likelihood method; the first order condition gives the matrix of coefficient, β, of the explanatory variables. However, a limitation of the Poisson regression model is, if the dependent variable Y has a Poisson distribution, $y \sim Po(\mu)$, the model assumes conditional variance of Y equals its conditional mean (Green, 2007). It assumes;

$$E(y_i; x_i) = Var(y_i; x_i) = \mu(y_i; x_i) \quad \text{Equation 4}$$

So if the adoption has a mean 4.34 and variance of 1.595^2 suggesting over dispersion of the data. It is therefore erroneous to apply a Poisson regression to the data. But such comparison of mean and variance to indicate over dispersion can tend to overstate its degree. Therefore we first test for over dispersion using Cameron and Trivedi (1998) formula where if $\frac{Var\,[y_i]}{E\,[y_i]} > 2$, then over dispersion is an issue. In case of over or under dispersion, we correct the situation by specifying an alternative distribution such as the negative binomial and apply the maximum likelihood estimates.

3.3.4 Model variables

Following the model, the following set of variables was selected for this study. The choice of variables to include in the model is inferred from literature. Three broad categories were included; Household characteristics that include age, education, gender, main occupation and total household size, resource endowment and characteristic that include land holding, area of cultivated land, income, livestock ownership, group membership and institutional factors example access to agricultural extension

Table 1 : Variable definition and expected signs of determinants of AEI adoption

Variable	Description of Variable	Expected Sign
Dependent Variable		
AEI technique	Total Number of AEI technique components farmers adopts	
Independent Variables		
Household head Age	Age of household head (Years)	+/-
Household head Gender	Gender of the household head, dummy Male=1, Female=0	+/-
Household head Education	Household head number of years of formal education	+/-

Livestock Unit	Number of livestock equivalent units owned by the household	+
Off-Farm Income	Total income earned without the farm in the last year. Units (Ksh)	+
Farm Income	Total income from farming activities in the last year. Units (Ksh)	+
Group Membership	Farmer belong to a social group, dummy 1 if yes zero otherwise	+
Soil Fertility	Perception of farmer about fertility of the soil in his farm, dummy, 1 if fertile, zero otherwise	+
Gradient	Farmers perception of the slope of their land, dummy 1 if steep zero otherwise	+/-
Crop rotation Training	Whether the farmer had training on crop rotation, dummy 1 if yes zero otherwise	+
Cover crop Training	Whether the farmer had training on cover cropping, dummy 1 if yes zero otherwise	+
Improved Sorghum	Whether the farmer cultivates improved sorghum variety, dummy 1 if yes zero otherwise	+
Crop Failure	Whether crop failure is a constraint to crop production, dummy 1 if yes zero otherwise	+

Age: The influence of age on adoption is not clear in literature. Older farmers may have more experience in farming and therefore better able to access technologies yet older farmers may be more risk averse than younger farmers hence less likely to adopt. Age could therefore have a positive or negative effect on adoption (CIMMYT, 1993, Ayuya et al. 2012). There is therefore no prior effect hypothesised for age.

Education: Education gives farmers ability to access, assess and evaluate information disseminated about technology, and influence decision making. It is hypothesised that the probability of adopting technology would be greater for more educated farmers since education allows them learn faster (Marenya and Barrett, 2007).

Gender: Gender effect on adoption can either be positive or negative depending on the technology being promoted and resource distribution between men and women.

Size of household: measured by the number of dependents in a household, Larger households have greater pressure to meet on subsistence production. So they are more likely to adopt soil management technique that enhances production (Odendo, 2010).

Resources endowment: Resource endowment and characteristics include, land size, area of cropped land and livestock ownership capture the resource endowment (Otieno et al., 2011). Manure comes from animal excreta therefore the possession of livestock is important for adoption since there exist no market for manure in rural areas acquisition of manure is related not to economic status of farmer but rather to ownership of livestock. Households with more livestock units are expected to have higher adoption level of use of farm yard manure for fertility enhancement.

Group membership: Group membership is expected to have positive effect on adoption because group membership ensure a farmer has interactions with other farmers hence can share information through farmer to farmer exchange (Kiptot et al., 2006).

Income: Off-farm and farm income were included to capture the financial liquidity of farmer to explain ability of farmer to acquire necessary inputs including labour. Households with higher incomes are expected to adopt more techniques hence positive sign (Maina, 2008). However since AEI technique uses locally available material lack of income may not influence adoption.

Perception: Subjective preference for product characteristic and demand for products can be affected by farmers' perception of the product attribute (Adesina et al., 1995). Similarly, Marenya and Barret, 2009 showed farmers' perception of soil condition affect their demand for soil fertility management techniques. Effect of farmers' perception of soil condition on adoption of AEI technique is expected to be positive.

Gradient: it refers to measure of the degree of steepness of the land; it is based on the farmers' subjective judgment. It is graduated from flat to very steep. More steep land are at risk of soil erosion therefore gradient is expected to have positive response on adoption.

Access to extension service: Access to extension services is important for adoption of technologies. Extension program are important for creating awareness, dissemination of correct information about technologies and ensuring accurate expectations about outcomes of those innovations (Lambrecht et al., 2014). Frequency of access to extension services is therefore expected to have positive effect on adoption.

The hypothesis tested was that socio economic variables include in the model have no effect on adoption of agroecological intensification technique. The coefficient for each variable is zero, i.e $\beta_i = 0$. The hypothesis is rejected if the P value of the matching variable is less than 10 percent level of significance. Otherwise fail to reject the hypothesis and conclude that the effect of that variable is not significant or not statistically different from zero. The empirical model is specified by taking the logarithm of Equation 3 and adding random error term to yield Equation 4 below which is then estimated;

$ln\text{L}=\ln k + \beta_1 \ln X_1 + \beta_2 \ln X_2 - \beta_3 \ln Y + \varepsilon_{ij}$ .... Equation 4

3.4 Data sources and sampling procedure

3.4.1 Data sources

The study is a quantitative design and uses cross sectional data. The study used primary data from on-farm trial and farmer data. On farm trials conducted over two years (from October 2010 to August 2012) capturing four seasons were conducted in Ikombe and Katangi wards of Yatta Sub-county. The experimental setup was a Randomized Complete Block Design with a split plot arrangement. Three cropping systems; mono cropping, intercrop and crop rotation with legumes were arranged. The split-plots were incorporated with organic inputs farm yard manure (5 tonnes per hectare), compost (5 tonnes per hectare) and a control (nothing applied). The test crops were sorghum and cassava with Dolichos and pigeon pea grown either as intercrops or in rotation. The resulting design is fifteen plots for each test crop with different treatment or no treatment for each. Each crop was grown respectively on plots treated with FYM, compost or control giving a total of 15 plots for each test crop.. Sorghum and dolichos were harvested three months after planting while cassava and pigeon pea was harvested eleven months after planting. On farm trial data was used to calculate gross margins for the experimental fields.

The farmers' data was collected in Yatta, Ikombe and Katangi wards in June 2013 by household survey. Primary data collected included household demography data, farms budgets and assets, household incomes and expenditure, access to extension and training, market participation, and farming practise. Farmers were asked which combination of techniques they practiced. They were then asked to recall data from the previous season. Farmers were assumed to gather information from their own experience gained on initial adoption and from the experience of others and update their knowledge and perception about an innovation. They then adopt the new technology if it is perceived more profitable than their current practice (Feder et al., 1985). Some farmers did not have production records for the previous season hence data was based on how much the farmer could remember. As such approximations were made for data that was deemed inaccurate or insufficient. Such extrapolations lead to inaccuracy but however give overall trend of gross margin for the enterprise (Irungu, 1999). The following variable cost items data were collected: land preparation, planting, soil improvement, pest, disease and weed control and harvesting cost for both farm trial and farmer data.

3.4.2 Sampling methods

The sampling frame was smallholder farmers from Ikombe, Katangi and Yatta wards of Yatta Sub-county. Yatta has a population of 147,579 consisting of 48 percent male and 52 percent female. It has 33, 162 households (KNBS, 2013). A stratified random sampling method was used to select the sample. The study site was divided into three stratums based on administrative units, Ikombe, Katangi and Yatta wards. In each ward, locations were randomly selected. From the locations, villages were selected. In the village, a list of farmers was generated with the assistance of village heads, from which the households were selected. Probability proportional to size sampling technique was used to decide the number of households to interview from each ward. The allocation was arrived at using the following formula;

$$n_i = N/ n$$

Where; n_i is the sample size from the i^{th} ward. N is the total population in Yatta Sub-county and n is the population in ward *i* according to the Kenya National Bureau of Statistics, KNBS, 2010 census. In each case, a computer random number generator was used to generate random numbers and select the households to be interviewed in each village. The technique eliminates sampling bias and ensures that each household has an equal chance of being sampled. This guarantees the sample is normally distributed, every element of the population is sufficiently represented and the sample estimates obtained will be efficient (Ndambiri et al., 2013). A sample of 140 households was sufficient and cost efficient for the study. Previous similar studies have used samples of at least 120 households (Mugwe et al., 2008).

4.0 RESULTS AND DISCUSSION

4.1 Farmer demographic characteristics and adoption levels

4.1.1 Socio economic characteristics of farmers in Yatta Sub-County.

The summary statistics of socio-economic characteristics of 140 households interviewed in the study are presented in Table 2.

Table 2 : Descriptive statistics of farmer characteristics for agro-ecological intensification survey in Yatta, Sub-County

Characteristic	Description	Mean	Std. Dev
Age	Age of household head (yrs)	52.30	13.70
Gender (1, Male)	Gender of the household head	0.80	0.39
Education	Number of years in formal school (yrs)	6.75	3.90
Household size	Number of household members	5.62	1.79
Main Occupation Head	Is farming main occupation of HHLD (1, yes, 0, No)	0.68	0.46
Resources			
Farm size	Land size (acres[1])	6.86	5.24
Cropped land	Area of cultivated land (acres)	0.83	1.20
Off farm Income	Amount of off farm income (Ksh)	38,537	7,174
Farm income	Amount income earned from farm (Ksh)	22,624	31,501
Livestock	Livestock equivalent unit Owned (LU)	5.30	3.75
Asset Value	Asset value (Ksh)	113,200	140,443
Institutional Factors			
Extension contact	Frequency of information access (per yr)	6.94	17.242

[1] 2.5 acres =1 hectare

Group membership	Percentage no. of households	0.85	0.35
Soil fertility	Rank of soil fertility (1= good, 2= average, 3=bad)[2]	1.92	0.576

[1] Soil fertility; this is based on farmer's subjective judgment of their soils.

Average age of household head was 52.30 years which is above the national average age of 19 years. The farmers are still in productive age, and may imply that they have long experience in farming could therefore have opportunity to improve their productivity through application of improved technique. Kariyasa and Dewi (2013) argue that experience could provide an opportunity to support promotion of new technology.

Most farmers had basic education with approximately an average of seven years of formal schooling. This suggests mostly farmers learnt through informal learning. Education, whether formal or informal, plays an important role through the development process (Alene and Manyong, 2007). With just basic education farmers' are able to access information and enhance their decision making.

Majority of household heads were male suggesting decisions were largely controlled by men. Distribution of productive assets among gender influence preference of production processes and hence the type of technology adopted (Kelsey, 2013). Each gender will adopt technologies that are appropriate for them. So where men hold the land right they are more likely to adopt technology that is assets specific and of long term investment in the land.

The mean household size was 5.62, which is approximately same as the national average size of 5.1 per household. The large household size implies the availability of labour but also number of persons supported by the farming activity. Similarly, Baiono (2007), found positive correlation between household sizes with decision to adopt soil conservation measures. Larger households could also reduce the need for hired labour therefore reduces the cost of production.

Average land owned was 6.86 acres and the average land under cultivation 0.83 acres. The difference in land owned and cultivated suggests unutilized capacity therefore more crop production is possible. However it may indicate there are constraints limiting crop production.

Average annual farm income was Ksh 22, 624 and off-farm income Ksh 38,537. At least 68percent of the household heads reported farming as their main occupation. However, off-farm income still was important source to 28 percent of households as alternative income. This suggests there are diversified economic activities in the area that agriculture can provide with labour and resources.

The sampled households had at least 6.9 contacts with extension per year and at least eighty five percent of households belonged to a group. Access to extension translates to access to information that in turn improves crop production. Farmers may form groups to assist each other in with credit but the group also serve as a platform for exchanging knowledge. Group membership therefore can help increase productivity in rural areas. Average total livestock units was 5.3 and average asset value Ksh 113,200. It is expected that the availability of such resources would enable a farmer to implement soil management practices that depend on nutrient recycling within the farm.Perception of soil fertility was that soils were of average fertility suggesting that farmers are aware of the quality of soils. Previous studies show that perception of soil quality may influence farmers' approach on soil management technique (Marenya and Barrette, 2009).

4.1.2. Level of adoption of soil management technique

Six agroecological practices were considered in this study, these were crop rotation, cover cropping, crop diversity, compost manure, animal manure and use of crop residue. The analysis show that the most common cropping system was inter cropping (45.7%), mixed cropping (40%) crop rotation (8.6%), and mono cropping (5.7%) being least practiced. The main crops grown in the area were; maize, sorghum, cassava, green grams, cow peas, pigeon pea, beans, chick pea, millet and dolichos.

Farmers are at different levels of adopting the techniques, table 3 show the various levels of adoption. At least 2 farmers representing 1.4 percent adopted one of the components while 10.0 percent adopted at least three components and 27.9 fully adopted all the six AEI techniques being investigated. Mean level of adoption was 4.34, std. dev (1.595).

Table 3: Proportion of farmers adopting AEI technique

No. of Components	% of farmers adopting
0	4.3
1	1.4
2	8.6
3	10.0
4	20.7
5	27.1
6	27.9

Further analyses were conducted to identify the most adopted components. Summary of component uptake is presented in Table 4. The results show livestock manure was the most commonly adopted technique with 95.7 percent farmers adopting it. This may be due to the availability of the manure from the livestock which, most farmers kept. At least 77 percent of farmers practised crop diversity, mainly because of diversifying production to spread risk as well as family diet. Compost manure was use by 76 percent of farmers, while 73 percent used crop residue to manage soil fertility while 57 percent used cover crops in soil fertility management. Crop rotation was least adopted with only 54.3 percent of sampled farmers adopting the technique, this could be because of small land sizes.

Table 4: Percentage of components adopted

Components Adopted	% of farmers adopting
Farm Yard Manure	95
Crop Diversity	77
Compost Manure	76
Crop Residue Utilization	72
Cover Cropping	57
Crop Rotation	54

Farmers were also questioned about specific constraints to crop production. The results are given in Table 5. About 75 percent of the farmers indicated that soil fertility was a constraint in their farming. However, only eight percent of farmers had ever had their soils scientifically tested in the laboratory. At least 76 percent of the sampled farmers considered soil erosion a constraint, crop failure was rated a problem by 71 percent of the farmers, while 87 percent of farmers also considered water shortage a constraint. Pest and diseases were rated as constraints by 94 percent and 84 percent of the farmers respectively. Previous studies comparing pest and disease incidence of different regions in the country show Machakos County with lower incidences than other regions (FAO, 2014, Mwang'ombe, 2007). Nonetheless yield reduction due to pest and disease may occur because farmers take no control measure for the pest (F.A.O, 2012). In addition Kiprotich et al., 2015 reported increased rate of pest and diseases incidence in the county. At least 95 percent of farmers showed evidence of using organic strategies to address these limitations.

Table 5 : Farming constraints

Constraint	% of positive response
Pest	93
Diseases	94
Water Shortage	87
Soil Erosion	76
Soil fertility	75
Crop Failure	54

Most farmers adopted more than one component. This shows there is an awareness and adoption of various components of agro-ecological technique. The results imply that there is potential for further diffusion of the technique. However, farmers face various constraints. The main constraints to crop production relate to ecological issues. These can be addressed using correct management practices such as agroecological intensification technique. AEI technique harnesses ecological process to reduce losses due to stress, increase production and preserve the environment. Further adoption of agroecological intensification technique can therefore assist realise maximum crop production from Arid and Semi-arid lands.

4.2 Profitability of agro-ecological intensification techniques in Yatta, Sub-County, Kenya

Results for calculated gross margin from field experiment are presented in Table 6 and 7. For the purpose of comparing yields, experiment yields were presented in kilograms per hectare. Results shows mean gross margins for sorghum in Ikombe and Katangi under different crop systems and organic inputs in sorghum based system.

4.2.1 Mean gross margin per hectare for Sorghum

In Ikombe, highest (Ksh 61,708) gross margin was attained in sorghum - dolichos intercrop and the least (Ksh -9,333), was in sorghum dolichos rotation with no organic input (Control). The results show that addition of organic input yield positive returns on the investment except sorghum dolichos rotation that had negative returns.

In Katangi the highest gross margin per hectare (Ksh 108,933) was in sorghum dolichos intercrop using farm yard manure while the least (Ksh – 8,283) was in sorghum dolichos rotation with no organic input (Control). The highest gross margin in Katangi (Ksh 108,933) is higher than in Ikombe (Ksh 61,708). Both sites compare favourably to other arid area Turkana, which had gross margin of Ksh 60,000 (FAO, 2013). The intercrop system was shown to give the highest (1.69 and 3.71) return on investment in both site Ikombe and Katangi respectively.

Table 6: Mean gross margin per hectare for sorghum in Ikombe

Ikombe	Variable Cost					Gross Value	Gross Margin		
Crop.Sys	**Seed**	**Org Fertilizer**	**Labor**	**Land Prep**	**Total**	**Total**	**Gross Margin per Ha**	**Return to Labour**	**Return on investment**
Sor FYM	1875	5000	14150	4000	25025	38917	**13,892**	0.98	0.56
Sor COMP	1875	3500	14150	4000	23525	35250	**11,725**	0.83	0.5
Sor CTRL	1875	0	14150	4000	20025	30000	**9,975**	0.7	0.5
Sor+Dol FYM **(Inter)**	4125	5000	16250	4000	29375	91083	**61,708**	3.8	2.1
Sor+Dol CMP **(Inter)**	4125	3500	16250	4000	27875	74950	**47,075**	2.9	1.69
Sor+Dol CTRL **Inter)**	4125	0	16250	4000	24375	65583	**41,208**	2.54	1.69
Sor+P.P FYM **(Inter)**	3750	5000	16250	4000	29000	78060	**49,060**	3.02	1.69
Sor+P.P CMP **(Inter)**	3750	3500	16250	4000	27500	69920	**42,420**	2.61	1.54
Sor+P.P CTRL **(Inter)**	3750	0	16250	4000	24000	63530	**39,530**	2.43	1.65
Sor-Dol FYM **(Rot)**	2250	5000	12400	4000	23650	16217	**-7,433**	-0.6	-0.31

Sor-Dol COMP **(Rot)**	2250	3500	12400	4000	22150	13217	**-8,933**	-0.72	-0.4
Sor-Dol CTRL **(Rot)**	2250	0	12400	4000	18650	9317	**-9,333**	-0.75	-0.5
Sor- P.P FYM **(Rot)**	1875	5000	12400	4000	23275	38243	**14,968**	1.21	0.64
Sor- P.P COMP**(Rot)**	1875	3500	12400	4000	21775	36683	**14,908**	1.2	0.68
Sor- P.P CTRL **(Rot)**	1875	0	12400	4000	18275	31683	**13,408**	1.08	0.73

Sor (Mono); Sorghum Monocrop, Sor+Dol (Inter); Sorghum Dolichos Intercrop, Sor-Dol (Rot); Sorghum Dolichos Rotation, Sor+P.P (Inter); Sorghum Pigeon Pea Intercrop, Sor-P.P (Rot); Sorghum Pigeon Pea Rotation, FYM; Farm Yard Manure COMP; Compost Manure CTRL; Control

Table 7 : Mean gross margin per hectare for sorghum in Katangi

Katangi	Variable Cost					Gross Value	Gross Margin		
Crop. Sys	**Seed**	**Org Fertilizer**	**Labor**	**Land Prep**	**Total**	**Total**	**Gross Margin per Ha**	**Return to Labour**	**Return on investment**
Sor (Mono) FYM	1875	5000	14150	4000	25025	40,500	**15,475**	1.09	0.62
Sor (Mono) COMP	1875	3500	14150	4000	23525	34,417	**10,892**	0.77	0.46
Sor (Mono) CTRL	1875	0	14150	4000	20025	27,701	**7,676**	0.54	0.38
Sor+Dol FYM **(Inter)**	4125	5000	16250	4000	29375	138,308	**108,933**	6.7	3.71
Sor+Dol CMP **(Inter)**	4125	3500	16250	4000	27875	125,777	**97,902**	6.02	3.51
Sor+Dol CTRL **(Inter)**	4125	0	16250	4000	24375	109,200	**84,825**	5.22	3.48
Sor+ P.P FYM **(Inter)**	3750	5000	16250	4000	29000	103,613	**74,613**	4.59	2.57
Sor+ P.P CMP **(Inter)**	3750	3500	16250	4000	27500	83,713	**56,213**	3.46	2.04
Sor+ P.P CTRL **(Inter)**	3750	0	16250	4000	24000	72,760	**48,760**	3	2.03

Sor-Dol FYM **(Rot)**	2250	5000	12400	4000	23650	18,317	**-5,333**	-0.43	-0.23
Sor-Dol COMP **(Rot)**	2250	3500	12400	4000	22150	20,867	**-1,283**	-0.1	-0.06
Sor-Dol CTRL **(Rot)**	2250	0	12400	4000	18650	10,367	**-8,283**	-0.67	-0.44
Sor- P.P FYM **(Rot)**	1875	5000	12400	4000	23275	37,400	**14,125**	1.14	0.61
Sor- P.P **(Rot)**	1875	3500	12400	4000	21775	32,813	**11,038**	0.89	0.51
Sor- P.P CTRL **(Rot)**	1875	0	12400	4000	18275	27,868	**9,593**	0.77	0.52

Sor (Mono); Sorghum Monocrop, Sor+Dol (Inter); Sorghum Dolichos Intercrop, Sor-Dol (Rot); Sorghum Dolichos Rotation, Sor+P.P (Inter); Sorghum Pigeon Pea Intercrop, Sor-P.P (Rot); Sorghum Pigeon Pea Rotation, FYM; Farm Yard Manure COMP; Compost Manure CTRL; Control

The test of mean differences was done using GENSTAT; results are shown in table 8. Results are shown for differences at five (p<o.o5) percent level of significance. Mean difference between the farming systems, intercrop, and rotation was Ksh 25, 020.20 and was significant. The profit difference between compost and farmyard manure was also significant and was Ksh 2,570.10. Interaction of sites, farming systems and organic inputs was Ksh 37, 354.70 and significant. There was no significant difference in gross margin observed between Ikombe and Katangi sites.

Table 8 : Mean gross margin results for sorghum based cropping system in Ikombe and Katangi

	Ikombe				**Katangi**			
Farming system	**COMPOST**	**CONTROL**	**FYM**	**Means**	**COMPOST**	**CONTROL**	**FYM**	**Means**
Sorghum	11,725	9,975	13,892	11,864	10,892	7,767	15,475	11,378
Sorghum+Dolichos (Inter)	47,075	41,208	61,708	49,997	97,092	84,825	108,933	96,950
Sorghum+ Pigeon Pea (Inter)	42,420	39,530	49,060	43,670	56,213	48,760	74,613	59,862
Sorghum- Dolichos (Rot)	-8,933	-9,333	-7,433	-8,567	-1,283	-8,283	-5,333	-3,367
Sorghum-Pigeon Pea (Rot)	14,908	13,408	14,968	14,428	11,038	9,593	14,125	11,586
Means	**21,439**	**19,270**	**26,127**	**22,279**	**34,790**	**28,532**	**42,523**	**35,282**
%C.v	17.1							
L.s.d Site	37663.3**Ns**							
L.s.d Farming System	25020.2*							
L.s.d Input	2570.1*							
L.s.d Site x Farming System x Input	37354.9*							

Least Significant Difference (LSD) * 5% level of error Intercrop (Inter), Rotation (Rot)

Reject the hypothesis that there is no significant difference in profit in adoption of agroecological intensification technique and conclude that AEI techniques result greater revenues.

4.2.2 Mean gross margin per hectare for cassava

Results for gross margins for cassava in Ikombe and Katangi under different crop systems and organic inputs in sorghum based system are shown in Table 9 and 10. In Ikombe the highest (Ksh 89,008) gross margin per hectare was using cassava dolichos intercrop with farm yard manure while the least (Ksh 7,825) was in cassava pigeon pea rotation with compost organic input. In Katangi, the highest gross margin per hectare (Ksh 434,135) was in cassava pigeon pea intercrop with farm yard manure and the lowest (Ksh 10,895) was in cassava pigeon pea rotation with on organic input (Control).

Cassava root is tolerant to poor soils and adverse weather conditions. Yield per unit of land is high compared to other crops including sorghum hence greater gross margins from cassava. It is also adapted to wide range of agroecological zones.

Table 9 : Mean gross margin per hectare for cassava in Ikombe

Ikombe	**Variable Cost**					**Gross Value**	**Gross Margin**		
Crop. System	**Seed**	**Org. Fertilizer**	**Labour**	**Land Prep**	**Total**	**Total**	**Gross Margin/ ha**	**Return on Lb**	**Return on investment**
Cassava (Mono) FYM	95000	5000	29000	4000	133000	220095	87,095	3	0.65
Cassava (Mono) COMP	95000	3500	29000	4000	131500	177436	45,936	2	0.35
Cassava (Mono) CTRL	95000	0	29000	4000	128000	196209	68,209	2	0.53
Cass+Dol FYM **(Inter)**	97250	5000	33900	4000	140150	229158	89,008	3	0.64
Cass+Dol COMP **(Inter)**	97250	3500	33900	4000	138650	197170	58,520	2	0.42
Cass+Dol CTRL **(Inter)**	97250	0	33900	4000	135150	159741	24,591	1	0.18
Cass+ P.P FYM **(Inter)**	96875	5000	33900	4000	139775	211588	71,813	2	0.51
Cass+ P.P COMP **(Inter)**	96875	3500	33900	4000	138275	205525	67,250	2	0.49
Cass+ P.P CTRL **(Inter)**	96875	0	33900	4000	134775	186435	51,660	2	0.38
Cass-Dol FYM **(Rot)**	2250	5000	12900	4000	24150	78600	54,450	4	2.25

Cass-Dol COMP **(Rot)**	2250	3500	12900	4000	22650	87900	65,250	5	2.88
Cass-Dol CTRL **(Rot)**	2250	0	12900	4000	19150	63900	44,750	3	2.34
Cass- P.P FYM **(Rot)**	1875	5000	12900	4000	23775	36118	12,343	1	0.52
Cass- P.P COMP **(Rot)**	1875	3500	12900	4000	22275	30100	7,825	1	0.35
Cass- P.P CTRL **(Rot)**	1875	0	12900	4000	18775	27520	8,745	1	0.47

Mono; Monocrop, Cass+Dol (Inter); Cassava Dolichos Intercrop, Cass-Dol (Rot); Cassava Dolichos Rotation, Cass+P.P (Inter); Cassava Pigeon Pea Intercrop, Cass-P.P (Rot); Cassava Pigeon Pea Rotation, FYM; Farm Yard Manure COMP; Compost Manure CTRL; Control

Table 10 : Mean gross margin per hectare for cassava in Katangi

Katangi	Variable Cost					Gross Value	Gross Margin		
Crop. System	**Seed**	**Org. Fertilizer**	**Labour**	**Land Prep**	**Total**	**Total**	**Gross Margin/ ha**	**Return on Labor**	**Return on investment**
Cassava FYM	95000	5000	29000	4000	133000	325880	192,880	7	1.45
Cassava COMP	95000	3500	29000	4000	131500	266791	135,291	5	1.03
Cassava CTRL	95000	0	29000	4000	128000	248030	120,030	4	0.94
Cass+Dol FYM **(Inter)**	97250	5000	33900	4000	140150	264700	124,550	4	0.89
Cass+Dol COMP **(Inter)**	97250	3500	33900	4000	138650	198265	59,615	2	0.43
Cass+Dol CTRL **(Inter)**	97250	0	33900	4000	135150	148020	12,870	1	1.1
Cass+ P.P FYM **(Inter)**	96875	5000	33900	4000	139775	573910	434,135	13	3.11
Cass+ P.P COMP **(Inter)**	96875	3500	33900	4000	138275	483546	345,271	10	2.5
Cass+ P.P CTRL **(Inter)**	96875	0	33900	4000	134775	479756	344,981	10	2.56
Cass-Dol FYM **(Rot)**	2250	5000	12900	4000	24150	95850	71,700	6	2.97

Cass-Dol COMP **(Rot)**	2250	3500	12900	4000	22650	78750	56,100	4	2.48
Cass-Dol CTRL **(Rot)**	2250	0	12900	4000	19150	46350	27,200	2	1.42
Cass- P.P FYM **(Rot)**	1875	5000	12900	4000	23775	42570	18,795	1	0.79
Cass- P.P **(Rot)**	1875	3500	12900	4000	22275	36980	14,705	1	0.66
Cass- P.P CTRL **(Rot)**	1875	0	12900	4000	18775	29670	10,895	1	0.58

Mono; Monocrop, Cass+Dol (Inter); Cassava Dolichos Intercrop, Cass-Dol (Rot); Cassava Dolichos Rotation, Cass+P.P (Inter); Cassava Pigeon Pea Intercrop, Cass-P.P (Rot); Cassava Pigeon Pea Rotation, FYM; Farm Yard Manure COMP; Compost Manure CTRL; Control

Test for mean differences in gross margin under cassava based system in Ikombe and Katangi are shown in Table 11. The results show significant difference at five (p<o.o5) percent level of error. The difference in gross margins between Ikombe and Katangi sites was Ksh 190, 043.10, between farming systems Ksh 110,904 and between inputs, farmyard and compost was 41, 585.40. The difference in effect of interaction of site, farming system and organic inputs was 196,883.20. These differences were all significant at five percent.

Table 11: Mean gross margin results for cassava based cropping system in Ikombe and Katangi

		Ikombe				Katangi		
Farming system	**COMPOST**	**CONTROL**	**FYM**	**Means**	**COMPOST**	**CONTROL**	**FYM**	**Means**
Cassava	45,936	68,209	87,095	67,080	135,291	120,030	192,880	140,400
Cassava + Dolichos (Inter)	58,520	24,591	89,008	57,373	59,615	12,870	124,550	65,678
Cassava + Pigeon Pea (Inter)	67,080	51,660	71,813	63518	345,271	344,981	434,135	374,795
Cassava – Dolichos (Rot)	65,250	44,750	54,450	54,817	56,100	27,200	71,700	51,666
Cassava – Pigeon Pea (Rot)	7,825	8,745	12,345	9,638	14,705	10,895	18,795	14,798,
Means	**35,906**	**39,591**	**62,942**	**56,742**	**122,197**	**103,195**	**168,412**	**129,467**
%C.v	32.2							
L.s.d Site	190043.1*							
L.s.d Farming System	110904*							
L.s.d Input	41585.4*							
L.s.d Site x Farm System x Input	196883.2*							

Least Significant Difference (LSD) * 5% level of error Intercrop (Inter), Rotation (Rot)

Again reject the null hypothesis that there is no significant difference in profit between agroecological techniques and conclude that there is difference in gross margin.

The results confirm findings of Place et al., (2003) and Pannell et al., (2014) that showed that application of crop management vary across agroecological conditions. Different site, systems and organic inputs combinations yield unique results. Interventions for soil management practices need to be designed to address the unique inputs and systems farmers may use.

4.2.3 Mean gross margin based on farmers' data

Table 12 shows results for average gross margin in sorghum at for farmers' different levels of AEI techniques. At zero (0) level, the farmer adopted none of the components of AEI while at level six the farmer adopted all six components.

Table 12 : Farmers' mean gross margin for sorghum under AEI techniques in Yatta

Level of AEI	0	1	2	3	4	5	6
Revenue							
Yield kg ha-1	**20.0**	**70.86**	**69.81**	**91.09**	**102.04**	**155.77**	**180.72**
Total revenue (Ksh ha^{-1})	**445**	**1559**	**1536**	**2004**	**2245**	**3427**	**3976**
Variable Costs							
Seeds	40.50	58.30	91.10	141.70	83.00	89.50	100.00
Fertilizers	0.00	0.00	0.00	103.20	57.90	0.00	0.00
Chemicals	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Manure	0.00	200.00	260.70	485.80	688.30	299.60	330.00
Labour	323.90	603.20	300.00	313.00	446.60	384.00	550.00
Total Variable cost (Ksh ha^{-1})	364.40	861.50	651.80	1043.70	1275.70	773.10	980.00
Gross margin (Ksh ha^{-1})	**80.63[a]**	**697.46[b]**	**884.15[c]**	**960.28[c]**	**969.29[d]**	**2653.93[e]**	**2996.00[e]**

N=32 Significant of mean difference [a,b,c,d,e] =1%

Table 12.1: ANOVA Results for differences in gross margins of sorghum for farmers at different levels of adoption

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2.789E7	6	4647768.472	1927.502	.000
Within Groups	320701.738	133	2411.291		
Total	2.821E7	139			

There was a significant (p<o.o1) difference in gross margins for sorghum between groups of farmers at different levels of AEI adoption. However for farmers that applied between three or four practices of AEI technique in sorghum no difference in gross margin was noted. Farmers that applied at least five or six practices accrued significantly ($p<0.01$) higher Ksh 2653 ha^{-1} and Ksh 2996ha^{-1} profits respectively. The high incomes attained by farmers applying several components of AEI maybe due to the enhanced soil moisture and organic carbon content due to the practices. However, compared to trial results, farmers earn lower gross margins from sorghum. The gap may suggest lack of knowledge by farmers on the proper application of AEI technique.

Table 13 shows farmers' average gross margins for cassava at different levels of AEI technique. In Cassava, profits were significantly (p<o.o1) different between farmers at different levels of AEI technique. Farmer that practiced at least one technique attained Ksh 448 ha^{-1} compared to Ksh 152 ha^{-1} for farmers that applied none.

Table 13 : Farmers' mean gross margin for cassava under AEI techniques in Yatta

Level of AEI	0	1	2	3	4	5	6
Revenue							
Yield kg ha^{-1}	**9.00**	**21.86**	**33.19**	**46.96**	**51.52**	**54.50**	**89.06**
Total revenue (Ksh ha^{-1})	**242.91**	**546.56**	**829.96**	**1174.09**	**1295.55**	**1362.14**	**2226.72**
Variable Costs							
Seeds	0.00	16.60	0.00	121.46	100.40	150.00	101.21
Fertilizers	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chemicals	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Manure	0.00	0.00	80.97	161.94	147.37	146.96	779.35
Labour	91.09	80.97	125.91	193.52	242.91	170.85	377.33
Total Variable cost (Ksh ha^{-1})	91.09	97.57	206.88	476.92	490.69	467.81	1257.89
Gross margin (Ksh ha^{-1})	**151.82[a]**	**448.99[b]**	**623.08[c]**	**697.17[c]**	**804.86[d]**	**894.33[e]**	**968.83[f]**

N= 45 Significant of mean difference [a,b,c,d,e,f] =1%

Table 13.1 ANOVA results for differences in gross margins of cassava for farmers at different levels of adoption

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	2.883E7	6	4805031.860	1698.981	.000
Within Groups	376148.525	133	2828.184		
Total	2.921E7	139			

When farmers chose from several technically feasible cropping sequences, the decision criterion should be based on the impact on soil quality and fertility, environmental quality and farm profitability. Both researcher and farmers data show that agroecological technique is profitable. The explanation for the gap in yield and profit suggest that farmers lack information on application of technique necessary to increase their yields.

In ASAL areas inclusion of neglected traditional crops such as sorghum and cassava that are drought resistance and tolerant to low soil fertility can enhance the competitiveness of the system. In a study on sorghum based systems nutrient balances in Yatta Namoi et al., (2014), found significantly lower Nitrogen (N) and Phosphorus (P) balances. This may explain the lower incomes in sorghum systems compared to the cassava systems. Hence the choice of crop and organic input combination in a system is important when deciding the enterprise the farmer should operate.

4.3 Adoption of agroecological intensification technique in Yatta, Sub- County

The empirical results of the regression model are presented in Table 14. Test for multicollinearity was done using the correlation matrix and the variance inflation factor (VIF). In presence of high collinearity, the standard errors are often inflated and estimated coefficients can be unreliable. Although the pair-wise correlations give guide to presence of multicollinearity, high zero-order correlations are a sufficient but not a necessary condition for the existence of multicollinearity because it can exist even though the zero-order or simple correlations are comparatively low, say, less than 0.50, Gujarati (2007). Therefore several tests are employed to test multicollinearity. According to Gujarati (2007), the rule of thumb is if the VIF of a variable exceeds 10, which will happen if R^2_j exceeds 0.90, that variable is said be highly collinear. The VIF of the variables was less than 10 and the pair-wise correlation less than 0.7.

The chi-squared value was significant at 1%, implying that all the variables jointly determine the dependent variable. McFadden R^2 of 10.88%, is sufficiently high. However, the Poisson Model produces no natural counterpart to the R^2 in linear regression model, (Green, 2007). It is therefore difficult to assess the goodness of fit of the model based on the R^2. Poisson were measure the test for over dispersion. Test for over dispersion was done. The result showed there was equal-dispersion hence the Poisson regression was correctly applied.

Table 14 : Results for Poisson regression for adoption of AEI techniques in Yatta

	Co. Efficient	**Std errors**	**P>IzI**
HHHead Age	0.6200	0.027	0.023**
HHHead Age2	-0.0006	0.000	0.018**
HHHead Gender	0.0944	0.116	0.419
HHHead Education (Yrs)	-0.0336	0.015	0.027**
Group membership	0.0933	0 .092	0.315
InOffFarm Income	0.0133	0 .009	0.167
Infarm Income	0.0228	0.012	0.065**
Improved Sorghum	0.3272	0. 093	0.000***
Gradient	0.0677	0.116	0.559
Perception on Soil Fertility	0.1779	0 .150	0.233
Crop Failure (Constraint)	-0.0830	0.092	0.370
Crop Rotation (Extension)	0.1725	0.107	0.100*
Cover cropping (Extension)	0.0681	0. 104	0.514
Total Livestock Unit	0.0090	0.011	0.452
Constant	-0.5899	0.722	0.414

Notes: N= 140, Mc Fadden R^2 0.1088, Probability $\chi2$ 0.0000, ***, ** and * indicate significance at 1%, 5% and 10% levels respectively.

The following variables were found have significant influence on adoption; age and education level of household head, farm income, and extension training on crop rotation, and cultivating improved sorghum.

Age was found to positively influence adoption of agroecological intensification technique and was statistically significant at 5 percent level. However, since the sample average age high, the function age squared was included to help model more accurately the influence of age. This was necessary because result show that older farmer was more likely to adopt the technique. To test whether the effect of age is linear for all ages, age squared was included. The result showed that at much higher age the level of adoption was negatively and significant at five percent level of error. Hence we conclude that the influence of age is not infinite and much older farmers are less likely to adopt. This may suggest that AEI should be targeted at farmer at the average age.

Number of years of formal education of the household head was found significant at 5 percent but the influence on adoption negative. This is contrary to the priori expectation that education would enhance adoption. Education enhances farmers' management skills, and improves ability to access and evaluate information (Wozniak, 1984). These should enhance adoption. However technology attributes can affect adoption. According to Lancaster (1979) a consumer considerers the bundle of attributes of a commodity rather than a commodity itself. Assuming that educated farmers are consumers of technology, the Lancaster theory may help explain the observed effect of education on adoption of AEI techniques. The AEI technique relies on indigenous knowledge and is perceived to have increased demand for labour (Tripp, 2005). This attributes may not be attractive to educated farmers who may prefer modern innovations and less labour intensive techniques compared to traditional techniques.

Level of farm income was found positively affect adoption and significant at 10 percent. Studies have shown that farmers seek alternative income to supplement farm income (Fernandez-Cornejo, 2007). It allows for farm resources to be available for reinvestment into the farm. The results here suggest that farm households not only depend on off farm income but also on farm income. Farm income therefore provides farmers incentives to invest in the soil management technology. The positive and significant influence on adoption can be used a proxy for resources available to farmer to practice the AEI technique.

Extension training on crop rotation was found positive and significant at 10 percent while cultivating improve sorghum variety positively and significantly affected adoption at 1 percent. This is consistent with other studies that show extension accelerates adoption (Odendo, 2010, Otieno et al. 2011). Farmers are more likely to adopt technology once they have full information about a technique. Training enhances skill and supplements farmers' traditional/indigenous knowledge. Cultivation of improved sorghum varieties may enhance adoption as farmers would like to exploit the full potential of the cultivars. This can motivate them to address the soil fertility through uptake of better management practices.

In conclusion we reject the hypothesis that socio economic factors do no influence adoption. We conclude socio economic factors: age, education, farm income resources and access to extension affect the adoption and intensity of uptake of agro-ecological intensification technique.

5.0 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary

The purpose of this study was to evaluate profitability and factors affecting adoption of Agroecological Intensification Techniques in Yatta Sub-County, Kenya. Six agroecological intensification techniques; crop rotation, cover cropping, crop residue incorporation, crop diversity, compost manure and farm yard manure were considered in the study. Out of a sample of 140 households, twenty nine percent adopted all six techniques considered in this study. The average number of techniques adopted was four. Farm yard manure was the most adopted by ninety five percent of households, then crop diversity at seventy seven percent, compost manure seventy six percent, incorporation of crop residue seventy two percent, cover cropping fifty seven percent and crop rotation was least adopted with only fifty four percent of households taking it up.

To assess profitability gross margin analysis were calculated and then ANOVA was conducted to assess difference in mean gross margins between different categories of farmers. Two sets of data used; on-farm trial and farmer field data. In farm trials for Sorghum, the highest mean gross margin, Ksh 108,933ha^{-1}, was attained in Katangi in sorghum dolichos intercrop system with addition of farmyard manure. In cassava based system the highest Ksh 434,135ha^{-1} in Katangi with pigeon pea intercrop treated with farmyard manure. In survey mean gross margin was Ksh 2996ha^{-1} and Ksh 968ha^{-1} in Sorghum and Cassava for farmers adopting all six techniques studied. Test of difference show a significant (p<o.o1) difference in gross margin between farmers at different levels of adoption.

A Poisson regression model was estimated to measure the influence of socioeconomic factors on adoption. The factors found to influence adoption were age, education, farm income, extension training and cultivation of improved sorghum. Therefore as contrary to the hypothesis socioeconomic factors affect the uptake of the AEI technique.

5.2 Conclusion

Both on-farm trials and farmers' gross margin analysis showed higher revenue were the agroecological intensification technique was applied. Farm yard manure results were higher than cultivation without addition of organic inputs. In sorghum intercropping with dolichos gave higher revenue than in rotation or with pigeon pea. In cassava system result show that cassava dolichos intercrop with farmyard manure in Ikombe and cassava pigeon pea intercrop with farm yard manure in Katangi gave the highest revenue. Farmers' gross margins for both sorghum and cassava were highest when the farmer applied all the techniques including farmyard manure, compost, cover cropping, crop rotation, incorporating crop residue and intercropping. This lead to rejection of the hypothesis, there is no significant difference in gross margins between application and non-application of agroecological intensification technique. The conclusion is agroecological intensification technique is a profitable approach to soil management.

To increase farmers' yields and incomes, it is important that information appropriate technique and crops to use is availed through researcher's collaboration during technique development. The gap in revenue between farmers at different levels of adoption and between farmers and controlled research experiments reveal that there is potential for higher incomes. Greater collaboration between farmers and researchers could help improve productivity and increase incomes. Combination of enterprises should be also considered when deciding on crop rotation and intercrop systems.

Targeting farmers of average age and access to information provide the most excellent platform for further uptake of agroecological technique. Farm income and cultivation of improved sorghum was found to enhance adoption, hence creating markets for these commodity may further motivate farmers to adopt soil conservation techniques. Lack of formal education is found not limiting to the adoption of AEI technique. While education is important these result suggest that these technique is available to all farmers despite their education level.

5.3 Recommendations

5.3.1 Policy recommendations

Following these findings the study recommends: Investments in sustainable soil management activities need to be targeted; different AEI technique for different agroecological zones. Inclusion of legumes in crop rotation and intercropping systems helps to attain higher returns. In sorghum systems it should be encouraged to intercrop with dolichos in both Ikombe and Katangi. In cassava systems in Ikombe it should be intercropped with dolichos while in Katangi it should be intercropped with pigeon peas. In all systems addition of farm yard manure would improve the yields hence incomes. Extension training on agroecological intensification technique should target individuals within the average age of fifty four years, and those with less than less education. Trainings on each technique that addresses soil fertility challenge e.g. training on crop residue/rotation to address soil fertility should be done separately rather than collectively. Improved crop varieties should be encouraged because it enhances farmers have incentive to address soil fertility. For instance improved seed varieties could be promoted together with an appropriate legume intercropping variety.

5.3.2 Recommendations for further research

Further research areas in the agroecological technique may model different management scenarios of AEI techniques and assess profitability under the different combination. Research may also assess the returns over time for the different combinations. The study recommends cost benefits analysis where discounting can be done. The finding would provide insights about possible techniques combinations under different resource abundance and farmers' objectives. Similar studies may also be carried out in other arid and semi-arid areas and acess whether such studies yield same results allowing for genitalization. It would also provide farmers with information on how they can be combine approaches to reduce cost and increase economic efficiency.

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APPENDICES

Appendix 1: Research Survey Questionnaire

Household Questionnaire

Dear respondent, this questioner is designed to seek your response on factors affecting adoption of agro ecological technique. The response will be used for academic purposes only. Your participation will be highly appreciated.

<u>INTERVIEW BACKGROUND</u>

Date Of the interview		Interviewer
Time Started		Time ended
Date checked		
Date entered		

County	
District	
Division	
Location	
Sub location	
Village	

Respondent's name:	
Contact (Mobile number)	
Age	
Farming experience (Yrs)	

HOUSEHOLD IDENTIFICATION, COMPOSITION AND LABOR CONTRIBUTION (Objective 2 & 3)

Household members= people who live together and share meals including hired labour, children living away but supported by the household but excluding visitors.

Member code	Name of household member (start household head)	Sex **Code A**	Age	Marital Status **Codes B**	Education (Years) **Codes C**	Number of months lived in the household	Occupation (Time spent) **Codes D**		Household Farm labour contribution **Codes E**
							Main	Secondary	
1									
2									
3									
4									
5									
6									
7									
8									

Code A	Code B	Code C	Code E	Code E
1. Female 2. Male	1. Married living with spouse 2. Married but spouse away 3. Divorced 4. Widow/widower 5. Single 6. Other (specify)….	1. None/illiterate 2. Adult education or 1 year of education *Give other education in years	1. Farming (Crop livestock) 2. Salaried employment 3. Self employed off-farm 4. Casual labourer on-farm 5. Casual labourer off-farm 6. Scholl/college child 7. Non-school child 8. Herding 9. Household chores 10. Others (specify)…	1. 100% 2. 75% 3. 50% 4. 25% 5. 10% 6. Not a worker

LAND HOLDING AND USE IN THE LAST CROPPING SEASONS (Objective 2 & 3)

1) What is the total size of your land? ____________________________Acres

2) What is the type of land tenure? **Code A** ________________________

Codes A

1. Own with title deed
2. Own without title deed
3. Family land
4. Communal
5. Rented/ Hired
6. Others (Specify) ……

3) How did you use your land during in the last two seasons?

Land Category	March –May 2010 Long rain		Oct- Dec 2010 short rains		March- May 2011 long rains		Oct- Dec 2011 short rains		March- May 2012 long rains		Oct- Dec 2012 short rains	
	Cultivated (annual + permanent crops)	Uncultivated	Cultivated (annual + permanent crops)	Uncultivated	Cultivated (annual + permanent crops)	Uncultivated	Cultivated (annual + permanent crops)	Uncultivated	Cultivated (annual + permanent crops)	Uncultivated	Cultivated (annual + permanent crops)	Uncultivated
Own land												
Rented in land												
Rented out land												
Borrowed in land												
Borrowed out land												

SOCIO CAPITAL AND NETWORKING (Objective 2 & 3)

4) Do any of the household members belong to a group? Yes (1) No (0); Please describe the group.

Does any member of the household currently belong to any group? **0=N0 1=Yes**						
Member Code (from module 2)	Type of group the household member is registered: **Codes A**	Three most important functions of the group: **Codes B**			Year joined (YYYY)	Role in the group **Codes C**
		1st	2nd	3rd		

Codes A

1. Input supply/farmer coops/union
2. Crops/seed producer and marketing group/coops
3. Farmers' Association
4. Women's Association
5. Youth Association
6. Church/mosque association/congregation
7. Saving and credit group
8. Funeral association
9. Government
10. Water user's association
11. Others (specify)….

Codes B

1. Produce marketing
2. Input access/marketing
3. Seed production
4. Farmer research group
5. Savings and credit
6. Funeral group
7. Tree planting and nurseries
8. Soil & water conservation
9. Church group/congregation
10. Input credit
11. Others (specify)…

Codes C

1. Official
2. Ex-official
3. Ordinary member

<u>ACCESS TO EXTENSION SERVICES (Objective 2 & 3)</u>

5) How do you access agricultural training or information?

Rank	Source Name/Description	**Code A**	Frequency of information access **Code B**	Reliability of source **Code C**	Relevance of information **Code D**
1					
2					
3					
4					
5					

Code A

1. Government extension officers
2. Radio
3. Newspaper, Bulletins
4. Agro vets/ Seed dealers
5. Farmers' organization
6. Neighbours
7. NGO e.g. church
8. Research institutions e.g. KARI, Universities
9. Demonstration farms
10. Mobile phone, Internet
11. Indigenous knowledge

90. Others (Specify)……..

Code B

1. Daily
2. Weekly
3. Bi-weekly
4. Monthly
5. Quarterly
6. Half-annually
7. Annually
8. Others (Specify)…..

Code C

1. Fully reliable
2. Very reliable
3. Fairly reliable
4. Somewhat reliable
5. Unreliable

Code D

1. Fully relevant
2. Very relevant
3. Fairly relevant
4. Somewhat relevant
5. Irrelevant

6) Did you receive training on the following issues in the last three years?

Issue	Received training or information on […] since 2010 **0=N0 1=Yes**	Main source of information for […] Number of interactions during 2011/2012 **Codes A**					
		1st	Number of contacts	2nd	Number of contacts	3rd	Number of contacts
New crop varieties							
Crop rotation							
Field pest and diseases							
Leaving crop residue							
Soil and water management							
Cover crops							
Crop diversity							
Manure production /use							
Compost use							
Adaptation to climate change							
Livestock production							
Tree planting/ Agro forestry							

Code A 1. Government extension officers 2. Radio 3. Newspaper, Bulletins 4. Agro vets/ Seed dealers 5. Farmers' organization 6. Neighbours	7. NGO e.g. church 8. Research institutions e.g. KARI, Universities 9. Demonstration farms 10. Mobile phone, Internet 11. Indigenous knowledge 90. Others (Specify)……..

ACCESS TO FINANCIAL CAPITAL, INFORMATION AND INSTITUTIONS (Objective 2 & 3)

7) Did you apply for credit in the last one year? Yes (1) No (0)………………….
8) If yes, please fill the table below, if no, skip to Question 9.

Reason for loan	Needed credit for [..]**0= No 1=Yes**	Did you get the credit **0=N0 1=Yes**	Source of credit **Code A**	Did you get the amount you applied for? **0=N0 1=Yes**	How much did you get? **(Ksh)**	Monthly interest rate **(%)**	Repayment period (months)
1. Buying seeds							
2. Buying fertilizer							
3. Buying other inputs							
4. Labour wages							
5. Buy food							
6. Others specify ….							

Code A

1. Money lender
2. Farmer group/coop
3. Merry go round
4. Microfinance
5. Bank
6. SACCO
7. Relative
8. AFC
9. Others (specify)……

9) Who decides what inputs to buy?

	Household member code or Do not buy **(Code 99)**
1. Fertilizer	
2. Seed	
3. Pesticides	
4. Farm implements	

HOUSEHOLD ASSETS (Objective 2 & 3)

10) Household item owned.

	Assets	**Total Number owned**	**How much would you sell it in its current state? (Ksh) (if >1 take average)**
1	Fork jembe		
2	Hoe		
3	Spade		
4	Axe		
5	Knapsack sprayer		
6	Ox plough		
7	Panga		
8	Slasher		
9	Donkey/ Ox cart		
10	Push Cart (mkokoteni)		
11	Bicycle		
12	Motorbike		
13	Truck/car		

14	Wheelbarrow		
15	Posho mill		
16	Improved charcoal/ wood store		
17	Kerosene stove		
18	Gas cooker		
19	Electric stove		
20	Radio, cassette player		
21	Mobile phone		
22	TV		
23	Land		

AWARENESS OF AGRO ECOLOGICAL INTENSIFICATION TECHNIQUE (Objective 2)

11) Are you aware of agro ecological intensification of land use techniques? (Enumerator prompts by defining AEI technique)

	Agro ecological technique	Are you aware of **[…] Yes (1) No (0)**	Do you apply […] technique	Have you ever attended an on-farm demonstration on […]**Yes (1) No (0)**	If yes continue …			
					Main source of information **Codes A**	If yes how many training sessions did you attend?	Did you try any of the practices taught on […?]	How many years have you practiced […?]
		11a	**11b**	**11c**	**11d**	**11e**	**11f**	**11g**
1	Crop rotation							
2	Crop diversity							
3	Cover cropping							
4	Compost manure							
5	Crop residue use							
6	Manure							
7	Improved cassava variety							
8	Sorghum variety							

Code A 1. Government extension officers 2. Radio 3. Newspaper, Bulletins 4. Agro vets/ Seed dealers	5. Farmers' organization 6. Neighbours 7. NGO e.g. church 8. Research institutions e.g. KARI, Universities 9. Demonstration farms	10. Mobile phone, Internet 11. Indigenous knowledge 90. Others (Specify)……..

17) Which of the following was a constraint in your farm?

Issue	Is […} a constraint in your farm? **0=N0 1=Yes**
1. Pest	
2. Diseases	
3. Soil fertility	
4.Soil erosion	
5. Crop failure	
6. Lack of water	
7. Others (specify)…	

20) FARMING SYSTEMS <u>(Objective 2)</u>

A. **Inter cropping:** What crops did you grow in the last six seasons in intercrop?

Season **Code A**	Crop Grown	Crop Code **(Crop annex)**	Acreage (Acres)	Plant spacing **Codes B**	Average Yield Per unit area	Reason For Growing Crop **Codes C**
	1 2 3 4 5. Others (Specify)……					
	1 2 3 4 5. Others (Specify)……					
	1 2 3 4					

	5. Others (Specify)……					
	1 2 3 4 5. Others (Specify)……					
	1 2 3 4 5. Others (Specify)……					

Codes A
1. Long rains 2010
2. Short rains 2010
3. Long rains 2011
4. Short rains 2011
5. Long rains 2012
6. Short rains 2012

Codes B
1.Broadcasting
2.Mixed spacing
3.Row planting
4.Strip spacing
5.Hill planting

Codes C
1. Consumption
2. Income
3. Food diversification
3. Soil fertility management
4. Integrated pest management (IPM)
4. Fodder
5. Others (specify)…

B. Crop rotation: What crops did you grow in the last two seasons on crop rotation?

Season **Code A**	Crop Grown	Crop Code **(Crop annex)**	Acreage (Acres)	Plant spacing **Codes B**	Average Yield Per unit area	Reason For Growing Crop **Codes C**
	1 2 3 4 5. Others (Specify)……					
	1 2 3 4 5. Others (Specify)……					
	1 2 3 4 5. Others (Specify)……					
	1 2 3 4 5. Others (Specify)……					
	1 2 3					

	4 5. Others (Specify)……					

Codes A
1. Long rains 2010
2. Short rains 2010
3. Long rains 2011
4. Short rains 2011
5. Long rains 2012
6. Short rains 2012

Codes B
1.Broadcasting
2.Mixed spacing
3.Row planting
4.Strip spacing
5.Hill planting

Codes C
1. Consumption
2. Income
3. Food diversification
3. Soil fertility management
4. Integrated pest management (IPM)
4. Fodder
5. Others (specify)…

C. **Mono cropping:** What crops did you grow in the last two seasons in Monocrop?

Season **Code A**	Crop Grown	Crop Code **(Crop annex)**	Acreage (Acres)	Plant spacing **Codes B**	Average Yield Per unit area	Reason For Growing Crop **Codes C**
	1 2 3 4 5. Others (Specify)……					
	1 2 3 4 5. Others (Specify)……					

	1 2 3 4 5. Others (Specify)……					
	1 2 3 4 5. Others (Specify)……					
	1 2 3 4 5. Others (Specify)……					

Codes A
1. Long rains 2010
2. Short rains 2010
3. Long rains 2011
4. Short rains 2011
5. Long rains 2012
6. Short rains 2012

Codes B
1.Broadcasting
2.Mixed spacing
3.Row planting
4.Strip spacing
5.Hill planting

Codes C
1. Consumption
2. Income
3. Food diversification
3. Soil fertility management
4. Integrated pest management (IPM)
4. Fodder
5. Others (specify)…

PERCEPTION ON SOIL FERTILITY **<u>(Objective 2 & 3)</u>**

18) Please rank the soil fertility of your farm. **Codes A**

Codes A
1. Good 2. Medium 3. Poor

19) Please evaluate the gradient of your farm. **Codes B**

Codes B

1. Flat
2. Gently slope
3. Medium Slope
4. Steep slope

20) Have you ever had soil test done on the soil? **Yes (1) No (0)**

RESOURCE REQUIREMENT (Objective 1 & 3)

21) Compared to conventional means, how do the farming systems compare?

	Crop rotation	Intercropping	Mono cropping	Organic Manure	Others (specify)…
Management Time					
Cost of production					
Land					
Labour					
Land					
Knowledge					
Others (specify)					

Codes A
1. More
2. Equal
3. Less
90. Don't know

FARM PRACTICE (Objective 1 &2)

22) What soil amendments do you apply of your soils?

	Amendment **Codes A**	Cost	Unit	Quantity per unit area	Frequency **Codes B**	Source
1						
2						
3						
4						
5						
6						

Codes A 4. Ash **Codes C**

1. Fertilizer	5. Mulching	1. Per season
2. Manure	6. None	2. Annually
3. Compost	7. Others (specify)…	

CROP PRODUCTION INPUT USE (Objective 1)

Cost of crop production in the last two seasons?

Season						Seed				Fertilizer			Labour use in man/days					Manure			Pesticide		Harvest	
	Plot code	Plot size	Crop Name	**Crop code**	Intercrop **o=No 1=Yes**	Source **Code B**	Qty in Kgs	Price /unit	**Total seed Cost**	Qty	Price per unit	**Total Fertilizer cost**	Land preparation	Planting	Weeding	Harvesting	**Total labour cost**	Own Kg	Bought Qty	**Total Cost**	Qty litre	**Total Cost**	Qty	**Price /unit**

Codes A

1. Long rains
2. Short rains

Codes B

1. Own seed
2. family/ neighbour
3. Farmer to farmer seed exchange
4. On farm trials/ extension demonstration plots
5. farmer group
6. Agro- dealers/agro-vets
7. Provided free by NGOs
8. Government subsidy program
9. Government/ research institutions
10. Others (specify)…

UTILIZATION OF CROP RESIDUES FROM MAIN CROPPING SEASON (%) (Objective 1 & 3)

23) Note that percentages need to add up to 100% for every row

Crop Code Annex 1	Burnt in the field (%)	Used as firewood (%)	Left on land for soil fertility (%)	Feed for livestock (%)	Used for construction (%)	Sold (%)	Used to make compost (%)	Others uses (%)

LIVESTOCK AND LIVESTOCK PRODUCTS (Objective 2 & 3)

24) Please describe your household's livestock assets

	Livestock	Number owned	Average selling price **Ksh/unit**	Who makes decisions on livestock? Eg.sell	Main livestock product **Codes A**		
					1st	2nd	3rd
1	Dairy cattle						
2	Indigenous cattle						
3	Bulls						
4	Calves						
5	Small animals						

	e.g. Goats, sheep						
6	Poultry						
7	Donkey						
8	Camel						
9	Rabbit						
10	Others (specify) …						

Codes A	**Codes B**
1. Milk 2.Manure 3. Blood 4. Eggs 5. Hides 6. Others (specify)…	1. Household 2. Spouse 3. Others (specify)…. **Member codes module 2**

MARKETING (Objective 1 & 2)

Marketing: one row per crop per season

Season **Code A**	Crops Code (Crops annex)	Crops Variety **Code B**	Market type **Code C**	Quantity sold (kg)	Who sold (HH member code)	Price (Ksh/Kg)	Total marketing cost

Codes A
1. Long rains
2. Short rains

Codes B
1. Improved variety
2. Local Variety

Codes C
1. Farm gate
2. Village Market
3. Main/district market

HOUSEHOLD INCOME FOR THE LAST 12 MONTHS (Objective 3)

25) Source of income for the last 12 months

		Type of Income	Did you or any household member earn from this last year? **0=N0 1=Yes**	Number of days worked per year	Average income per unit		Total income earned
					Cash (Ksh)	Payment in kind – cash equivalent	
1		Agricultural labour					
2		Casual labour					
3		Salary					
4		Pension					
5		Remittance income/gifts					
6		Rent					
7		Small business					
8		Sale of wood and charcoal					
9		Sale of forest products e.g. wild fruits					
10		Sale in shop, petty trade					
11		Transport					
12	Sale of farm products	Crops					
13		Animal manure					
14		Crop residue					
15		Animal fodder					
16		Sale of cows					
17		Sale of poultry					
18		Sale of animal products					
19		Others (specify)…					

Appendix 2: Variable Correlation Matrix

	HHLDH Age	HHLDH Age2	HHLDH Gender	HHLDE duYrs	Per.Soil Fert	InOffFar mInc	Gradient	InFarm Inc	CropRot (Ext)	CoverCro p(Ext)	Improv edSor	T.Livest ockU	Group Mem	Crop Failure
HHLDHeadAge	1													
HHLDHeadAge2	0.9909	1												
HHLDHeadGender	-0.2223	-0.211	1											
HHLDEduYrs	-0.6357	-0.65	0.2629	1										
PerceptionSoilFertility	-0.007	-0.013	0.0286	0.08	1									
InOffFarmIncome	-0.0264	-0.04	0.1098	-0.041	-0.089	1								
Gradient	0.1583	0.133	-0.167	-0.1	0.1634	0.0022	1							
InFarmIncome	0.0006	0.005	0.0652	0.14	0.1336	-0.0572	-0.0947	1						
CropRotation Ext	0.0687	0.063	0.1477	-0.022	0.2029	0.0701	0.1696	0.169	1					
CoverCrops Ext	0.0983	0.076	0.0239	-0.057	0.2472	-0.0169	0.2546	0.086	0.4945	1				
ImprovedSor	-0.0112	-0.027	0.1215	0.057	0.224	0.0814	0.1997	0.09	0.4103	0.3816	1			
TotalLivestockUnit	0.0577	0.048	0.133	0.011	0.1537	-0.0486	0.0867	0.132	0.1933	0.2159	0.1541	1		
GroupMembership	0.0637	0.078	-0.0189	-0.011	0.0617	0.0075	-0.0161	0.156	0.034	-0.0344	0.0653	0.1172	1	
CropFailure Constraint	0.0605	0.067	0.0037	-0.02	-0.2	-0.0166	-0.1066	0.166	-0.086	-0.1809	-0.04	-0.118	0.0715	1

Appendix 3: Variable Variance Inflation Factor (VIF)

Variable	VIF	1/VIF
HHHEdu Yrs	1.81	0.55
HHLDHeadAge	1.77	0.57
HHLDHeadSex	1.19	0.84
CoverCrops	1.53	0.65
CropRot	1.51	0.66
ImprovedSorghum	1.34	0.74
Perception	1.18	0.84
Gradient	1.18	0.84
InFarmIncome	1.17	0.85
InOffFarmIn	1.05	0.95
CropFailure	1.14	0.87
TotalLivestockU	1.13	0.88
GroupMember	1.06	0.94
Mean VIF	1.31	