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Implications of Crop and Livestock Enterprise Diversity on Household Food Security and Farm Incomes in the sub Saharan region

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Abstract
Over the years there has been a continual decline in crop and livestock diversity, increasing vulnerability of smallholder farmers to food insecurity. We instituted this study to determine the impact of agro-biodiversity interventions on crop and livestock diversity, smallholder farmers' food security and income generation. Data for this study was obtained from a random sample of 150 households using a single household survey (SHS). Multinomial Logit (MNL) and Ordinary Least Square (OLS) regression models were used to determine the impact of crop and livestock diversity on food security and income, respectively. The results showed that crop diversity significantly increases farm income as well as the probability for the smallholder farmers to be food secure. Further analysis showed that optimal enterprise combination to meet household food security requirements and increase income, farmers should reduce on enterprises with negative gross margins in their farm plans either by among others, perfecting endogenous innovations.
Keywords**:** agro-biodiversity, food security, income, crop, livestock.

Introduction
Past research has shown that agro-biodiversity can increase productivity, food security and economic returns. Agrobiodiversity can also lead to diversity of products and improve income opportunities, human nutrition and contribute to sustainable agricultural production (Thrupp, 1977**).** Studies in western Kenya by Waithaka *et al.* (2003) showed that manure and fertilizers complemented each other in boosting cash and food crop yields in smallholders farming systems. Place *et al.* (2003) showed that 70% of the smallholder households used manure while 41% used compost indicating the importance of manure in mixed farming system. The significance of manure in improving productivity suggests importance of Agrobiodiversity in enhancing food security and income.
Many farmers, especially in marginal areas such as Bondo area in Kenya, where most high-yielding crop varieties and livestock breeds do not do well, rely on a diversity of crop and livestock enterprise. Farmers in Bondo district are mainly mixed crop and livestock subsistence farmers. Their major crop and livestock enterprises are maize, beans, sorghum, cassava, cotton, local cattle, goats, sheep and poultry. A few people are involved in fishing along the lake shore and rivers. More than 80% of the households in Bondo district are food insecure at least in some part of the year in both crop and livestock products. To deal with food shortages 92% of the households buy food from the market (Mungai *et al.*, 2008). Food insecurity has been aggravated by frequent crop failure as result of over reliance on crops that are ecologically unsuitable for the substantial production of crops such as maize. There has been levels of farm enterprise diversification by some farmers to maintain their livelihoods in the face of unfavorable circumstances such as disease infestation, uncertain rainfall, fluctuation in the price of farm inputs and outputs. Crops considered as minor such as cowpeas, sweet potatoes and green grams play an important role in food and livelihood security within the production systems at the local level. Plants that grow in infertile or eroded soils, and livestock that feed on scarce vegetation found on degraded land, are often crucial to household nutritional strategies (FAO, 2005). Furthermore, agrobiodiversity interventions were implemented in Bondo district by FAO-Netherlands partnership programme since 2005. The programme worked with farmer field schools (FFS) to raise awareness on agrobiodiversity issues. It used "learn by doing processes" with a view to enhancing the conservation and sustainable use of Agrobiodiversity. The agrobiodiversity interventions implemented through FFS to enhance crop and livestock diversity were bulking of cassava, sweet potatoes, arrow roots, pumpkins and local vegetables to provide planting materials for the farmer's crop diversity. Other interventions were, intercropping, beekeeping, fish farming, rearing of indigenous goats and poultry, planting of medicinal plants and seed banking. A few commercial crops that were introduced to the farmers such as tissue culture bananas ,onions, tomatoes, chick peas and water melon (Bondo district ABD-FFS Report,2007; Mungai *et al*.,2008). The Agrobiodiversity interventions were expected to generate increased opportunities for enterprise diversification and benefits for farmers and fisher folks in terms of income, food security and sustainable natural resource management (FNPP National Workshop Report, 2005). FFS have been implementing food security related activities in Bondo since 2002. Ten of these FFS comprising an average of 20 farmers each were selected to implement agrobiodiversity activities.
This study assessed the impact of these Agrobiodiversity interventions on crop and livestock enterprise diversity, alongside food security and farm income generation by evaluating the agrobiodiversity farmer field school (ABD-FFS) farmers in relation to Non -ABD-FFS farmers (Erbaugh *et al.*, 2002).

Methodology
The study was conducted in the greater Bondo area in Siaya County in Kenya. The Bondo district is one of the two districts in Kenya where the FAO-Netherlands Partnership Programme (FNPP) - agrobiodiversity project activities were

implemented. Bondo district presents a wide cross section of aquatic and terrestrial biodiversity, which provides a good opportunity for farmers to adopt enterprise diversification as a strategy to enhance Agrobiodiversity. The district lies between longitude 34^oE and $34^o30'E$ and latitude 0^o and $0^o30'S$. The entire South-West boundary is delineated by Lake Victoria while the northern boundary is marked by River Yala. The district has a population of 275,543 (projected based on 1999 census (Bondo district development report, 2007). Bondo district covers a total of 1,972 km^2 out of which 972 km^2 is dry land and 1,000 km^2 is water surface. The total arable land is 796 km^2. The district receives 800-16000mm of rainfall per annum with a bimodal distribution pattern. The soils are mainly Luvisols with low – moderate fertility except Madiany division which has black cotton soils (Vertisols) of relatively high fertility. The district is divided into four agro ecological zones namely Lower Midland Two (LM_2), LM_3, LM_4, M_5 of which LM_3 and LM_4 covers 96 percent of the total area (Jaetzold and Schmidt, 1982). The major farming system was mixed crop and livestock subsistence farming. The major crops were maize, sorghum, cassava, cotton and beans while livestock kept were zebu cattle, indigenous goats, sheep and poultry. Farmers living along the lake shore were involved in fishing and small scale vegetable production which forms a relatively important source of income to the district.

The impact of crop and livestock diversity on farm income and food security was Analyzed in two parts: Ordinary Least Square (OLS) multiple regression model was specified to determine the impact of crop and livestock diversity on farm income(Y) (Lifeng *et al.*, 2007; Thi Mai *et al.*,2007). The OLS model was specified as:

$$Y_i = \lambda_o + \sum_{k=1}^{n} \lambda_{ik} \chi_{ik} + \varepsilon_i \quad \text{..........} (1)$$

Where: Y_i = farm income, λ_o = the mean farm income difference between participating and non-participating group, X_{ik} = a vector of independent variables affecting farm income (Y_i), and ε_i = the unobserved factors affecting farm income. Farm income (Y_i) was determined from the farm income using the equation below:

$$\mathbf{Y} = \sum_{m=1}^{12}\sum_{j=1}^{n} b_j^s \mathbf{p^s} - \sum_{m=1}^{12}\sum_{j=1}^{n} b_j^b \mathbf{p^b} - \sum_{m=1}^{12}\sum_{j=1}^{n} \mathbf{L_h} - \sum_{m=1}^{12}\sum_{j=1}^{n} \mathbf{cp_h} - \sum_{m=1}^{12}\sum_{j=1}^{n} \mathbf{cp_x} \quad \text{..........} (2)$$

Where: Y = Net farm income above household food security, m = months of the year, p= input and output market price, b_j^s = quantity of good j sold, b_j^b = quantity of goods j bought, P^s = price index of good j sold and P^b = price index of good j bought, cp_h = cost of production of h crop enterprises. cp_x = cost of production of x livestock enterprises, ,L_h= labour hired. To determine the impact of crop and livestock diversity on food security (FDSEC), Multinomial Logit (MNL) regression model was used. Given X_i is a vector of explanatory variables, $ß_i$ is the matrix of parameters to be estimated and Z is the response variable, the general MNL model can be stated as:

$$\mathbf{Pr(Z=j/x)} = \frac{e^{B_j X_I}}{\sum_{K=1}^{4} e^{B_I X_I}} \quad \mathbf{j= 1,2,3} \quad \text{..........} (3)$$

Where: Pr is the probability of a household falling in a food security category j and xi is a vector of exogenous variables affecting the probability of a household falling in a food security category j, j = 1 when a household is food insecure in dietary energy consumption, j = 2 when a household is food secure in dietary protein and energy consumption, j= 3 when a household is food insecure in both protein and energy dietary consumption. Z = Food security, which was estimated first from the food security equations (4 and 5) before being used in the food security regression equation. Food security equation comprises of dietary energy constraint and dietary protein constraint with respect to household members. Dietary energy constraint (De) was expressed as:

$$\sum_{i=1}^{m} Q_1 + \sum_{i=1}^{m} Q_2 + \sum_{i=1}^{m} Q_3 + \ldots\ldots + \sum_{i=1}^{m} Q_n \geq \mathbf{D_e} \quad \text{..........} (4)$$

Where**:** Q_n = minimum consumption of **n** energy sources in **m** months. D_e = Minimum dietary energy requirement. Minimum Protein dietary requirement is given by:

$$\sum_{i=1}^{m} Q_1 + \sum_{i=1}^{m} Q_2 + \sum_{i=1}^{m} Q_3 + \ldots\ldots + \sum_{i=1}^{m} Q_p \geq \mathbf{D_{pr}}. \quad \text{..........} (5)$$

Where: Q_p = Minimum consumption of **p** protein source in **m** months, D_{pr} = Minimum dietary protein requirement. The food security empirical model is specified as:

$$Z_{ji} = ß_j + \sum_{k=1}^{k} \beta_{jk} x_{ik} + \mu. \quad \text{..........} (6)$$

Where: Z_{ij} is the logs odd ratio, β_{jk} is the parameters to be estimated, X_{ik} a vector of independent variables affecting the probability of a household falling in a food security category j, **μ =** other factors affecting the probability of a household falling in a food security category j. The response of food security to Agrobiodiversity was compared for ABD-FFS Farmers and Non- ABD-FFS Farmers (Lifeng *et al.,* 2007). The variables that were included in the model are as shown in Table 1.

Table 1: Food security model variables

Variable	Description	Measurement	A Priori Assumptions
FDSEC(Z)	Food security	(Energy Secure=1,Protein and Energy secure=2.protein and energy insecure=3)	+
CD	Crop diversity	Index	+
LVD	Livestock diversity	Index	+
FARMSIZE	The size of the Farm in Acres	Acres	
TECH	Technology	Index	+
HHSIZE	Household size	No.	_
GENDER	Gender	(Male=1 Female= 0)	indeterminate
NFI	None farm Income	Kshs	+
NFE	Non- food items Expenditure	Kshs	_
	Participation		_
PART.	Age of Household Head	PART=1,Non PART=0	+
AGHED	Education Level(Years of	Years	Indeterminate
EDUC	Schooling)	Years	+
DMKT	Distance of Household to nearest major Market(km)	km	indeterminate

Results

Impact of crop and livestock diversity on farm income

Ordinary Least Square (OLS) multiple regression model used to determine the impact of crop and livestock diversity on farm income(Y) showed the results of the analysis Table 2 below.

Table 2: Analysis of the impact of crop and livestock diversity on farm income

Independent Variables	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	-33591.636	16172.729		-2.077	.040**
Participation (ABD-FFS/NABD-FFS)	8922.346	7445.048	.096	1.198	.233
Crop diversity index	75152.596	19301.698	.301	3.894	.000**
Livestock diversity index	33161.898	29057.788	.086	1.141	.256
Household Size of the Respondent(HH members)	-3459.638	1539.104	-.186	-2.248	.026**
Age of Household Head	-11781.405	6773.780	-.136	-1.739	.084*
Distance of Household to nearest major Market(km)	417.403	2732.401	.011	.153	.879
Gender of Head of Household(Male/Female)	-12647.787	7603.359	-.135	-1.663	.099*
The size of the Farm in Acres	1320.281	919.985	.112	1.435	.154
Education Level(Years of Schooling)	2160.849	1215.640	.160	1.778	.078*
Household Non-Food Expenditure	-.246	.154	-.134	-1.596	.113
Household Non - Farm Income	.111	.042	.205	2.631	.010**
Household Agric. Prod. Technology Level	80.391	36.612	.160	2.196	.030**

Dependent Variable: Household Net Farm Income, R^2 = 0.353. F= 5.91(0.000), condition index (CI) = 16.7, **Significant at (p<0.05), *Significant at (p< 0.1)

Impact of Crop and Livestock diversity on food security

To evaluate the impact of crop and livestock diversity on food security (FDSEC), the multinomial Logit (MNL) regression model was used since the dependent variable food security had three categories. The three categories included the probability of the household being energy secure, both protein and energy secure and then both the protein and energy insecure. The three categories of household food security status were analysed, of which energy insecure was the reference category while protein and energy secure was taken as the category of interest. Protein and energy secure category represents the status of the household being food secure. Table 3 shows the results of multinomial logistic regression to examine which variables affected the probability for households in a particular food security category. The Variables included those representing household characteristics [Age(AGHED), Gender, Education years of the head, Nonfood income (NFI), Nonfood expenditure (NFE) , household size (HHSIZE)], Participation in ABD-FFS, Crop diversity(CD),Livestock Diversity (LVD),farm size, Distance to market(DMKT), Technology use (TECH).

Table 3: Impact of crop and livestock diversity on food security

IndependentVariables	Food Security Status of the Households							
	Both Protein and Energy secure				Both Protein and Energy insecure			
	B	Std. Error	Sig.	Exp(B)	B	Std Error	Sig.	Exp(B)
Intercept	-.897	.972	.356		.802	1.798	.542	
PART	1.011	.436	.020**	2.748	-.144	.956	.522	.542
CD	2.827	1.283	.028**	16.902	-7.617	2.576	.011**	.001
LVD	1.251	1.771	.480	3.495	-1.443	4.072	.678	.184
HHSIZE	-.184	.094	.050**	.832	.424	.210	.368	1.208
AGHED	.036	.399	.929	1.036	.138	.712	.560	1.515
DMKT	.141	.178	.429	1.151	.365	.344	.526	1.243
GENDER	-.165	.444	.711	.848	-1.539	.942	.317	.390
FARMSIZE	.166	.090	.067*	1.180	-.291	.289	.175	.676
EDUCLEV	.012	.069	.856	.988	-.007	.143	.489	.906

Reference category – Energy insecure -2Log Likelihood = 205.4, *Chi-Square = 49.7, Cox and Snell =0.282, Nagelkerke = .345, McFadden = 0.195, Number of observations = 150, Energy insecure = 46, Both protein and energy secure =93, Both protein and energy insecure = 11, **Significant at ($p<0.05$), *Significant at ($p<0.1$), B = Variable coefficient (Log odds ratio), Exp (B) = Exponential of B.

Discussions and Conclusion

The results show that crop diversity has a significant positive impact on farm income. A unit change in crop diversity would increase net farm income by Kshs 75152 per acre per annum. ABD-FFS farmers had a higher income of Khs 8922 per annum than NABD-FFS farmers though not significantly different ($p<0.05$). Similar results were obtained by Erbaugh *et al*. (2002). The mean net income over and above household subsistence requirements was Kshs -24669 per annum for ABD - FFS and Kshs -33591 per annum for NABD-FFS households. Though ABD-FFS farmers diversified their crop enterprises most of their net incomes were still negative due to low productivity. The farmers will need to enhance the impact of crop diversity on income by applying productivity improvement technologies on their farm. Results in Table3 shows that increase in technology use has a positive impact on net farm income. The use of improved technology in terms of fertilizers, quality seeds, pesticides and farm machinery was insignificant for both the ABD-FFS and NABD-FFS farmers. The mean working capital use per farmer per annum was Ksh 4009. The mean difference in capital use for ABD-FFS and NABD-FFS was insignificant (Kshs 249).

Agrobiodiversity is the result of the interaction between the environment, genetic resources and management systems and practices. Thus, agrobiodiversity encompasses the variety and variability of animals, plants and micro-organisms that are necessary for sustaining key functions of the agro-ecosystem, including its structure and processes in support of food production and food security (FAO, 1999). Farmers in Bondo have carefully selected and raised many different animals and plants adapted to their local environments and needs over the years. However, intensification and commercialization of agriculture, particularly over the last 30 years has led to a continual decline in agrobiodiversity among smallholder farmers (Kooten *et al.*, 2000; Nijkamp *et al.*, 2008). Loss of agrobiodiversity has undermined the ability of agriculture to provide food and income leading to food insecurity.

The results of crop and livestock diversity on food security analysis showed that the coefficients for Crop Diversity (CD), Livestock diversity (LVD), Participation in ABD-FFS (PART), were positive for both protein and energy secure food security category. It implies households with high Crop and Livestock Diversity and Participation in ABD-FFS will have a high probability of being food secure. The coefficient for crop diversity is significantly positive for both protein and energy secure food security category while significantly negative for both protein and energy insecure category. This suggested that crop diversity had a significant positive impact on food security. This is plausible because Increase in crop diversity enhances the probability of a household being food secure. These findings are in line with the aspirations FAO Netherlands Partnership Programme (FNPP) - Agrobiodiversity project. The project aimed at sensitizing the smallholder farmers in Bondo district to enhance agro-biodiversity on their farms so as to reduce vulnerability to food insecurity ((FNPP project document, 2005).

The coefficient for age of head of household (AGHED) is negative though not statistically significant. This implies that the young households are more food secure than the old ones. Older households are likely to be food insecure due to rural urban migration and other competing off- farm sectors that take away the youthful household labour from the farms leaving the households with old less energetic people tending the land. In Bondo a lot of youthful labour is taken away from the farm by off -farm sectors such as fishing, bicycle and motorcycle tax business. The findings of this study showed that in Bondo district 68% of the household heads were 30-60 years old while 25% were above 60 years old

Distance from the market center (DMKT) and by implication urban center had a positive coefficient implying that farmers who stay far away from the market centre are likely to diversify their crop enterprises and hence more likely to be food secure (Table 8). In Bondo district the main market centers are situated along the Kisumu – Bondo road. As you move away from these market centers, you get close to the lake or the river. The farmers along the river or the lake are likely to produce additional crops especially cash crops like tomatoes and kales using irrigation. The additional crops enable them to have additional income to supplement their food security requirements.

The coefficient for livestock diversity is positive though not significant (Table 3). This implies that households with enhanced livestock diversity are likely to be food secure. The livestock complements crops as well as provide additional income to meet the household food security needs.

Household size has a negative coefficient though not significant implying large households are less likely to be food secure despite diversifying their crop and livestock enterprises due to their high food security demand. A policy targeting crop diversity as a strategy to increase smallholder farmers' household food security in order to be effective has to address the need to maintain small households.

The ABD- FFS farmers had higher level of crop diversity compared to NABD-FFS farmers implying the project interventions had a positive impact on agrobiodiversity. However the NABD-FFS farmers had higher level of livestock diversity compared to ABD-FFS farmers. This difference was associated with the tradeoff between livestock and crop diversity due to ABD-FFS farmers specializing in crop production. This is plausible especially where land is limited and use of pasture improvement practices and alternative feeds is minimal. However the significance of the trade off on food security and income is an area which requires further research as is beyond the scope of this study. The study further found out that increase in agrobiodiversity increases the probability of a household being food secure. This finding implies that smallholder communities in Bondo district need to enhance Agrobiodiversity on their farms to ensure food security. However household size had a strong negative effect on the probability of the household being food secure. Recent studies indicated that household income has a statistically significant positive effect on smallholder farmer access to credit. This implied that the higher the households' monthly income, the more likely that a credit agent will lend to it. (Baiyegunhi and Fraser, 2014). Hence, households in Bondo district in their efforts to attain food security would need to maintain small household size. This study showed that the mean household size in Bondo District was six people with a mode five and a maximum of fourteen. This outcome compares favourably with the Siaya County household mean of five people per household (Bondo District Farm Management Guidelines, 2009).

Furthermore, national food security policy will need to integrate strategies that will bring about small household size among the smallholder communities in order to ensure food security. The increasingly complex nature of the agricultural industry in Africa has necessitated an urgent need for the use of a systemic rather than a traditional approach in solving problems in agriculture. The African agricultural system is characterized by complex challenges such as; famine, erratic rains, food insecurity, poor soil and quality standards, political instability, inappropriate agricultural practices, reliance on rain fed agriculture, lack of specialization on specific few rotational crops (Banson et al., 2014). According to the UN Economic Commission for Africa (2013), most governments of Africa have not be very good in maximizing productivity of their agricultural sector because they overlook key policies to maximize sectorial linkages. Hence broadly we have economic, social, political, cultural and environmental complexity in the African agricultural systems set ups. Agricultural practices and policies of the sector have also contributed to land degradation and destruction of the ecosystem with numerous challenges that have hindered its capacity to spur economic growth. Notably, among these are: climate change, increased pressure on the natural resource base, unfavourable external market conditions, poor rural infrastructure, weak institutions, low research and access to innovative technologies, low productivity of smallholders, reduced investment by governments and official development assistance and the limited engagement by the private sector (UNDP, 2012). It is these interactions that can be used to explain why agricultural production in Africa has been increasing while productivity has in general, been decreasing (The World Bank, 2013).

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