Chuka University
info@chuka.ac.ke | 020 231 0512 / 020 231 0518

AGRICULTURE AND ENVIRONMENTAL REVITALIZATION INNOVATIONS

EFFECTS OF LAND FRAGMENTATION AND CROP DIVERSITY ON SMALLHOLDERS' FARM INCOME; CASE OF KISII COUNTY, KENYA

Ibrahim Nyariki Kiprop[1*], Joram Kamau Ngugi[2] & Geoffrey Kipruto Kosgei[1]
[1]Department of Agricultural Economics, Agribusiness Management and Agricultural Education; Chuka University, P. O. Box 109-60400, Chuka Kenya
[2]Department of Agricultural Economics and Agribusiness Management, Egerton University, P. O. Box 536-20115, Egerton, Kenya
**Corresponding Author Email: ropny86@gmail.com; isamoita@chuka.ac.ke; gkosgei@chuka.ac.ke*

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ABSTRACT
With global climate change becoming evident across the continent, agriculture has suffered greatly due to the effects of global warming. Erratic weather conditions and sporadic rainfall patterns which are unpredictable have led to the compromise of food security especially in areas where farmers rely on rain-fed agriculture. The effects of climate change have led to the failure of crops in the field compounded by uncertainty in agricultural planning hence affecting farmer's income across the agricultural value chain. This study conceptualized land fragmentation as the production of different crops in different geographical location by a single farmer. A 3 Stage Least Squares model (3SLS) to estimate how land fragmentation and crop diversity affect smallholder farmers' income was employed. To measure land fragmentation, the Januszewki index (JI) was adopted while crop diversity was captured using the Entropy index method. The results show that land fragmentation has a positive effect on crop diversity. Farm crop diversity affects positively the level of farm income. The findings suggest that land fragmentation, as much as it has had a negative view on its effect, it can be of positive impact especially on farming households with small farms.
Keywords: Land Fragmentation; Crop Diversification; Januszewki index; Entropy index

INTRODUCTION
With the declining agricultural productivity and land efficiency, there has been a renewed focus on the effect of land fragmentation especially in most developing countries. Without any universal approach to understanding land fragmentation, different views have been shared on how to view land fragmentation; a problem or not (Demetriou, 2013). According to van Dijk (2003), land fragmentation is in terms of the number of used units being used, different ownership, internal fragmentation or commonality between ownership and use. In Sub-Saharan Africa, there has been a major decline in farm sizes leading to decreased farm output (Kiplimo & Ngeno, 2016). In Africa, effects of land fragmentation on agricultural production and efficiency have been reported by Okezie *et al.* (2012) in Nigeria, Ayalew and Deininger (2013) in Rwanda, Kiprop *et al.* (2015) and Barasa *et al.* (2019) in Kenya.

Kenya is characterized by both high and medium productive land and Arid and Semi-arid land. In the country, 16% of the total arable land is made up of high and medium agricultural potential that receives adequate and reliable rainfall that can support intensive cropping and dairy production (Kiprop *et al.,* 2015). Over the last 20 years the Western part of Kenya, Kisii County included, has experienced a sharp rise in population. This has greatly led to the subdivision of the vast large scale farms in the areas (Barasa *et al.,* 2019).

From early 1960s major land reforms took place as the British colonials allowed Africans to buy land from them. This

marked the start of land fragmentation problem in Kenya. With the population expected to hit 55 million by 2050, according to the World Bank, pressure on the existing arable land is increasing in the country. The existing laws of land succession, customs and traditions and the coming up of the new constitution that allows daughters to inherit land contribute to a great extent to the problem of land fragmentation (Kiplimo & Ngeno, 2016). Land ownership in Kenya is divided into three; private, communal and government trust. Communal and private ownership are the big influencers of land fragmentation to extents that the land cannot be viable for production through optimal use of inputs (Nyariki *et al.*, 2015). With the lack of adoption of new technologies by smallholder farmers, agricultural productivity and efficiency have been stalled leading to a continuous vicious cycle of poverty and food insecurity (Kassie *et al.*, 2015; Valbuena *et al.*, 2015).

Previous research by Bardhan (1973) and Monchuk *et al.* (2010) have considered land fragmentation as detrimental to agricultural production. On the other hand, Bentley (1987), Blarel *et al.* (1992) and Goland (1993) among others have viewed that not all forms of land fragmentation have been negative but also beneficial as it helps in managing production risks, ease in allocating available labour and managing the different soil types for different crops (crop diversification). But the full impact or effects of land fragmentation can only be context-specific depending on the geographical, socio-economics and environmental conditions. According to Ciaian *et al.*, (2018), land fragmentation in Albania had led to increased agricultural diversification especially among the subsistence households. Also, land fragmentation has led to improved food quality, security and sustainability in Rwanda (Ntihinyurwa *et al.*, 2019).

Farmers fragment their land into plots depending on soil type or quality to diversify their crops (Tran & Van Vu, 2019). Land fragmentation in a positive way contributes to food security as farmers diversify their crops and therefore more foodstuffs are available. The farmers get the freedom to grow different crops different from the world top four of wheat, rice, maize and potatoes (Ntihinyurwa *et al.*, 2019). In the developing countries like Kenya, with access to the right information, developed research and extension, improved rural financial markets, good distribution of assets coupled with crop diversification, agricultural productivity and efficiency in areas experiencing high land fragmentation can be achieved. With improved productivity of the smallholder farmers, economic development can be achieved (Barasa *et al.*, 2019).

According to Konguka (2013) (cited in Ntihinyurwa *et al.*, 2019), farmers can grow a variety of crops to help reduce over-reliance of limited food crops, especially with the unreliable cropping season. According to FAO and World Bank, crop diversification has been used by small scale farmers as a means of mitigating themselves from market and production risks to achieve food security (Rehima *et al.*, 2013). In most developing countries, crop diversification has been considered as a tool for growth and sustainable agriculture. Farmers can diversify to high- value crops by fragmenting their land into small sizes as evidenced in China and Vietnam (Nguyen, 2017). In the USA, diversified farms have shown a reduction in the cost of production due to diversification (Paul & Nehring, 2005; Nguyen, 2017). Similarly, in Sudan, crop diversification has helped reduce income uncertainties (Guvele, 2001). According to Lin (2011), intensive agricultural production can be achieved through crop diversification as it shields farmers from the effects of climate change. There is little empirical evidence of how land fragmentation and crop diversification affects household income. According to Tran & Van Vu (2019), farmers would diversify to other non-farm activities if they feel that land fragmentation affects their farming efficiency. Other farmers would diversify by fragmenting their land more depending on the variation in inputs use, weather patterns, terrain and location to reduce on risks (Ntihinyurwa *et al.*, 2019; Tran & Van Vu, 2019).

METHODOLOGY

Following the literature, the study employed a 3 Stage Least Squares model (3SLS) to estimate how land fragmentation and crop diversity have impacted the smallholder farmers' income. The first step was to determine how farm income is affected by both fragmentation (fragmentation index is used in this case) and crop diversity. The second step was to find how land fragmentation and other factors have impacted crop diversity given that crop diversity is itself affected by land fragmentation. To measure land fragmentation, the Januszewki index (JI) was adopted (Kiprop *et al.*, 2015). This index should be within the range of 0 to 1. The index was computed as:

$$k = \frac{\sqrt{\sum a}}{\sum \sqrt{a}} \qquad 1$$

Where 'a' represents the parcel size and *k* represents the Januszewki index.

Crop diversity is then calculated using Entropy index and/or Herfindahl index methods. Entropy Index weights the shares of a farm's activity by a log term of the inverse of the respective shares. It takes the value of zero when the farm is completely specialized, and it will approach its maximum when diversification is perfect. Thus, for increasing diversification the index should increase. This index gives less weight to larger activities than the Herfindahl index (HI).

HI has a weakness in that it is insensitive to minor secondary activities as it only focusses on major farm activities (Theil, 1967). Let Z_i be the crop acreage in activity *i*. Then: $\sum Z_i$ = total farm acreage cropped will show the proportions

Therefore: Entropy index= $\sum_{i=1}^{N} P_i \log \frac{1}{P_i}$ 2

Where N is the total number of crops and P_i represents an area proportion of the *i-th* crop in the total cropped area.

$$Farm\ Income = \beta_0 + \beta_1 cropdiversity + \beta_2 Fragmentationindex + \beta_3 Fertilizeruse + \beta_4\ non\text{-}farmincome + \beta_5 Knowledge + \beta_6 LandSize + \beta_7 farmilysize + \varepsilon_1 \quad 3$$

Equation 4 depicts the role of fragmentation and amount of crop diversity on farm income.

Farm crop diversity = $\alpha_0 + \alpha_1$*fragmentationnindex* + α_2*experience* + α_3*land size* + α_4*fertilizer use* + ε_2 4

Because the error terms might be correlated, seemingly unrelated regression is used alongside the 3SLS. Seemingly Unrelated Regression (SUR) has a cross-equation error correlation. Also, the Durbin-Wu-Hausman test was done to test for endogeneity of the crop diversity index.

Sampling Method

Kisii County was purposively selected based on vast information from literature review on land fragmentation in the region. The sampling criterion for sample distribution was based majorly on the area's population distribution. The required sample size was determined by proportionate to size sampling method (Kothari, 2004).

$$n_2 = \frac{Z^2 \hat{P}(1-\hat{P})}{e^2} \quad 6$$

Where n = sample size, $\hat{P}$ = proportion of the population containing the major interest, Z= confidence level (α = 0.05), δ = acceptable/allowable error. Since the number of households that had fragmented their land was not known, $\hat{P}$ =0.5, Z = 1.96 and e = 0.05. Survey data was collected from smallholder farmers who were randomly selected from various regions to give a sample size of 196 farmers.

RESULTS AND DISCUSSIONS

Factors that influence land fragmentation among households

In the context of this study, the first step was to determine factors that influence land fragmentation among households. Hence, the JI results were regressed on specific household characteristics using the Tobit model in STATA software. The limited dependent variables (results of JI are bounded between 0 and 1) were used in the regression. Since the Tobit model parameter estimation is by maximum likelihood, it provides consistent and asymptotically efficient estimators for parameters and variance (Greene, 1997). For the dependent variable, the JI index calculated was chosen as it shows clearly the level of fragmentation. Thus, the overall fragmentation level was regressed against the different explanatory variables.

Table 1 shows the results of the factors influencing land fragmentation among households in Kisii County. This was achieved by the use of censored Tobit model as the limit of the Januszewki Index lies between 0 and 1. The smaller the fragmentation index value, the higher the degree of land fragmentation. Among the sampled households, the factors identified as significant influencers of land fragmentations were age and education level of the household head, generation, farm income, land size and number of women.

Table 1: Factors influencing land fragmentation among households

Level of land fragmentation (Januszewski Index)	Coefficient	Std. Err.
Age	0.0046**	0.0019
Education	0.010**	0.0050
Number of men	0.018	0.0168
Number of women	0.027*	0.0161
Number of generations	-0.058*	0.0306
Yield	0.017	0.0286
Land size	0.081***	0.0075
Farm income	0.016***	0.0051
Group membership	0.086	0.0634
Access to extension	0.035	0.0658
Constant	-3.868***	0.2217
Sigma	0.278	0.0156

Number of Obs =161, LR chi2 (12) = 132.49, Pseudo R2 = 0.7359, Log likelihood = -23.780327, Prob>chi2= 0.0000
*** Significant at 1%; ** significant at 5%; and * significant at 10%

A year increase in the age of the household head increased land fragmentation index by 0.0046. This was significant at 5% among households especially if the household head is female (0.027 times). This implies that the older a household head becomes, the less likely he is to subdivide his landholding to his children. Older members of the

household tend to be less involved in agriculture, depending more on their more energetic children. With the absence of a male head, the children tend to demand a share of their land because the female head cannot hold the land for them. Kisii has a more traditional cultural setup where women are not landowners.

The number of years of schooling had a positive influence on the household's decision to fragment land into smaller portions for either his children or selling portions for upkeep purposes. An extra year of schooling for the household head increases fragmentation index by 0.07 times and this was significant at 5%. This implies that a well-educated household head is less likely to subdivide his land but rather centralize homesteads leaving a large portion for production purposes. Land size of the household was a significant factor in decision making concerning land fragmentation. Increase in size of landholdings will increasing land fragmentation index by 0.081 times, which implies a reduction in the probability of fragmenting the available land. This can be explained by the fact that less fragmented land allows for the cultivation of crops on large scale thus allowing for economies of scale to exist. Some farmers are trying to make most out of the small parcels of land to produce more. With a small piece of land, when it comes to inheritance of the land by male children, the level of fragmentation will tend to increase more and household land end up being less than the standard land size of 2 hectares.

An extra generation in a family lineage decreases the land fragmentation index by 0.058 times. This implies that additional generation will increase land subdivision making land that was once large be subdivided into smaller portions for several households. This means that with one more generation coming of age, land fragmentation will increase. This is because the new generation will also want to own property of their own especially land in their ancestral homes. Household farm income had a significant influence on farm fragmentation among households in Kisii County. Extra Shilling in household income increases land fragmentation index by 0.016 times implying a reduction in probability to subdivide land into small portions as incomes improve overtime. This was significant at 1%. An increase in land size, that is below 0.5 hectares per capita, is influenced by an increase in household income.

SLS regression results

Table 2 shows the results from the Three Stage Least Squares (3SLS) analysis and Seemingly Unrelated Regression (SUR) to show consistency of the regression results.

Table 2: Regression using Entropy Index

Variables	3SLS (A)		SUR (B)	
	Coeffs	Std Errors	Coeffs	Std Errors
Dependent variable: Farm Income				
Crop diversity	3.95**	5.31	4.28***	0.75
Experience	-0.11	0.07	-0.10	0.07
Family size	0.04	0.15	0.04	0.14
Fragmentation	19.58	13.88	17.54	12.08
Labour(days)	0.05*	0.03	0.04**	0.02
Fertilizer	1.07**	0.41	1.07**	0.32
Land area	-0.31	0.93	-0.25	0.35
Non-farm income	-0.14*	0.08	-0.14**	0.07
_cons	1.92	4.43	1.75	1.41
Dependent variable – Farm crop diversity				
Experience	-0.01	.01	-0.01	0.01
Land area	-0.07***	0.02	0.16***	0.03
Fertilizer use	-0.04	0.03	-0.06**	0.03
Fragmentation	8.98***	2.25	-0.90	1.15
_cons	0.45***	0.14	0.81***	0.11

N=177; significance levels: * at 10%, ** at 5% and *** at 1%,

The 3SLS and SUR analysis used the same variables for consistency of the regression results. Results of the SUR show that farm crop diversity is significant at 1% level. This shows that farm crop diversity is correlated with farm income. Farms that manage to grow different crops on separate fragments of land tend to earn more than those that don't. This is consistent with Di Falco and Perrings (2005) and indicates the economic benefits that are associated with crop diversification. Also on the 3SLS column, farm crop diversity is significant at 5% level. Growing a variety of crops to match the different agro-ecological conditions of the area will tend to be more beneficial than growing

only one type of crop. This can also help reduce production risks and price fluctuations as farmers can be able to trade throughout the year on the different crops grown. According to Ciaian *et al.* (2018) land fragmentation leads to increased farm diversification in Albania as households with fragmented land grow different type of crops as they try to be sustainable and improve their farm efficiency.

Fertilizer use is also significant indicating that it has a positive effect on farm income. This result gives a different perspective on intra-specific crop diversity (Di Falco and Chavas, 2006). Increasing the number of crops increases the use of fertilizer and pesticides and in the long run, more income is expected from the sale of farm products. Fertilizer use tends to improve productivity of farms and farmers get more produce.

Labour days were also significant at 10% and positively affect farm income. For most of the farmers, their income tends to increase when they work on their farms with the help of the family members. The more days they spend on their farms, the more farm income they get. Non-farm income is also significant at 10% level on the 3SLS and 5% level in the SUR equations. As the total non-farm income increase in the household, the total farm income will end up reducing. This is because non-farm income may influence the farmers not to engage themselves in farming activities. This is mainly because in Kenya, the income obtained from the farming sector is comparatively lower and inconsistent than that from the non-farming sector.

On the second equation, the land area of the households affects the farm crop diversity. In the 3SLS column, land area is shown to have a negative influence on the farm crop diversity. Having a bigger piece of land will tend to decrease the crop diversity as more farmers prefer to do large scale farming of commercial potential crops like maize or beans. Pope and Prescott (1980) found that large and rich farms tend to specialize more than smallholder farms because they can have access to better inputs, mechanized labour and better management skills. Other studies have found different results to this. Rehima *et al.* (2013) found a positive effect of land fragmentation on farm crop diversity in Ethiopia.

Land fragmentation also has an effect on crop diversity as shown by the 3SLS results. The 3SLS coefficient is largely different from that of the SUR which is statistically insignificant. The widespread level of land fragmentation has led to increased crop diversity in the area and most parts of the country. According to Rehima *et al.* (2013), an increase of one plot increases crop diversification by 47.7% in Ethiopia. With different agro-ecological and soil conditions within the farm, farmers tend to increase more diversity in the farm. Other studies like Abay *et al.* (2009) and Mesfin *et al.* (2011) show evidence that fragmented land and fragmentation index increase agricultural diversification. Farm input use is also significant as shown in the SUR column.

CONCLUSION AND RECOMMENDATIONS

Kisii County presents a good case of extreme land fragmentation in Kenya due to the land policy reforms made after independence. Although there have been many studies on how land fragmentation has had an influence on household's farm income and how also it has influenced agricultural production, no concrete evidence has shown how a relation of both land fragmentation and crop diversity has affected farm incomes.

To answer the question as to whether the two factors affect household income, the study examined the effects of both on crop income. The results show that land fragmentation has a positive effect on crop diversity. On the other hand, farm crop diversity affects positively the level of farm income. The findings suggest that land fragmentation, as much as it has had a negative view on its effect, it can be of positive impact especially on farming households with small farms. They diversify their farm production with other factors in mind for them to reduce certain production risks hence improve their level of farm income or sustenance. By fragmenting their land, they can diversify the number of crops grown hence participate in commercial agriculture to earn more and be food secure.

The study also identifies other factors that affect or contribute to household farm income. Crop diversity, labour and fertilizer use contributes to smallholder farmers earning more from their farms. All this contribute more to the households' food sustainability and food security. With multiple plots to grow different crops (early maturing, perennial, cash crops, cereals, vegetables, tubers or disease-resistant crops) to be grown, farmers can be able to meet their household food demands and also for the market. On the other hand, factors that affect crop diversity were land area and fragmentation. Different theories support this result such as the FAO theory on land fragmentation which is taken as a strategy for risk management and driver to food security. To understand the different types or levels of land fragmentation a more elaborate study needs to be undertaken to avoid a vague view of it due to methodological

limitations from the study area and indexes for measurement. From this, the study does not view fragmentation as a negative phenomenon but a risk mitigation strategy to deal with food insecurity, land shapes and overpopulation in some areas. This contributes to Sustainable Development Goals (SDGs) and Vision 2030. Therefore, the study recommends more generalized research to cover issues of land fragmentation using globally recognized land fragmentation and crop diversity measures. The study also recommends for land use consolidation measures based on the variation in comparative advantage across the country. Factors like the physical nature of land, agro- ecological variability and socio-economic factors should be put into consideration, especially in the Kenyan context.

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