

*Full Length Research Paper*

# Land fragmentation, agricultural productivity and implications for agricultural investments in the Southern Agricultural Growth Corridor of Tanzania (SAGCOT) region, Tanzania

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There are polarized evidences of the impact of agricultural land fragmentation on land productivity. On the one hand there viewpoints which consider land fragmentation to harm agricultural productivity. On the other hand there are counter thoughts which view land fragmentation as a positive situation which allows farmers to cultivate many environmental zones, minimise production risk and optimise the schedule for cropping activities. We use the case of Ihemi cluster in the Southern Agricultural Growth Corridor of Tanzania (SAGCOT) to investigate the impact of land fragmentation on crop productivity. We furthermore discuss the nature and causes of land fragmentation in the SAGCOT region and its implication on the future structure of agricultural landholdings and welfare of smallholder farmers in the region. The results showed that the nature and level of fragmentation in the study area were the outcome of combined, rather than isolated influences of supply and demand driven factors. Overall, the results did not support the claim that fragmentation reduces land productivity. This then implies that land fragmentation should not always be considered as defective. There were evidences of increasing chunks of land owned by rich farmers and investors which increased the possibility for increased consolidation of agricultural land under large scale farming. However, the landholdings for smallholder farmers might become increasingly more fragmented as poor smallholder farmers continue selling their land holdings to rich farmers and investors. Releasing the SAGCOT region's potential for agricultural development will require that smallholder farmers are helped to secure adequate and suitable land for farming, raise agricultural productivity, diversify their sources of income, and adopt good production practices. This requires setting up a strong base of investor - farmer synergies for inclusive agricultural growth.

**Key words:** Ihemi cluster, land fragmentation, land consolidation, agricultural productivity; agricultural investment.

## INTRODUCTION

Land fragmentation, also known as pulverization, parcellization or scattering (Bentley, 1987), is defined in the literature as the situation in which a single farm consists of numerous spatially separated parcels (Binns, 1950; King and Burton, 1982; McPherson, 1982; Van Dijk, 2003). It is characterised as a fundamental rural spatial problem concerned with farms which are poorly organised at locations across space (King and Burton, 1982).

Four types of land fragmentation are distinguished in the literature: fragmentation of land ownership; land use; within a farm (or internal fragmentation); and separation of ownership and use (Van Dijk 2003; Van Dijk, 2004). Fragmentation of land ownership refers to the number of landowners who use a given piece of land. Fragmentation of land use refers to the number of users that are also tenants of the land. Internal fragmentation emphasizes the number of parcels exploited by each user and considers parcel size, shape and distance as the main issues. Separation of ownership and use involves the situation where there is a discrepancy between ownership and use.

Past studies and substantial literature have examined the relationship between land fragmentation, on the one hand, and land productivity, or efficiency at farm level, on the other (Blarel et al., 1992; Bizimana et al., 2004; Wu et al., 2005; Van Hung et al., 2007; Thomas, 2007; Rahman and Rahman, 2008; Chen et al., 2009; Corral et al., 2011, Austin et al., 2012; Sauer et al., 2012).

There are contradictory considerations regarding whether land fragmentation is a problem or not (Sklenicka, 2016; Sklenicka et al., 2014; Wu et al., 2005; Nguyen et al., 1996). Firstly, there is a viewpoint that sees land fragmentation as the source of ineffective agriculture (Sklenicka et al., 2014; Apata et al., 2014; Latruffe and Piet, 2014; Corral et al., 2011; Di Falco et al., 2010; Rahman and Rahman, 2008; Van Hung et al., 2007; Bentley, 1987). This viewpoint considers land fragmentation as a major threat to efficient production system due to the fact that continuous subdivision of farms would lead to small sized land holdings that may be hard to economically operate. According to this viewpoint, land fragmentation is said to harm productivity in a number of ways: fragmented land holdings can increase transport costs. If the plots are located far from home, and far from each other, there is a waste of time for the workers spent on travelling in-between the plots and home. Management, supervision and securing of scattered plots can also be more difficult, time consuming, and costly. Small and scattered plots

waste land area and require more land for fencing, border constructions, and paths and roads. Land fragmentation might also increase the risk of disputes between neighbours (Mwebaza and Gaynor, 2002).

Small fragmented land holdings might also cause difficulties to grow certain crops, and prevent farmers from changing to high profit crops. More profitable crops, like for example fruit crops, require larger plot areas, so if the farmers only possess small and fragmented plots they may be forced to grow only less profitable crops (The World Bank, 2005).

Other costs associated with land fragmentation include the hindering of economies of scale and farm mechanization. Small and scattered plots hamper the use of machinery and other large scale agricultural practices. In small fields operating machines and moving them from one field to another can cause problems. Small land holdings might also discourage the development of infrastructure like transportation, communication, irrigation, and drainage (Mwebaza and Gaynor, 2002). Finally it is noticed that banks are sometimes unwilling to take small, scattered land holdings as collateral, which prevents farmers from obtaining credit to make investments (ibid). In view of these disadvantages, land fragmentation is thus considered as defective and this has in turn caused several countries to implement land consolidation programs (Sundqvist and Andersson, 2006; Van Hung et al., 2006; The World Bank, 2005). Along the same line Sklenicka (2016) recommends corrective policies in countries with high fragmentation to focus on three different levels: identifying the causes of fragmentation (slowing the process), decreasing current fragmentation (defragmenting ownership), and remedying the effects.

The counter viewpoint sees land fragmentation as a positive situation under which farmers can cultivate many environmental zones, minimise production risk and optimise the schedule for cropping activities (Bentley, 1987). The recognized advantages of land fragmentation in this perspective are closely related to the demand-side causes of fragmentation. One of the benefits associated with land fragmentation is the variety of soil and growing conditions that reduce the risk of total crop failure by giving the farmer a variety of soil and growing conditions. Many different plots allow farmers access to land of different qualities when it comes to soil, slope, micro-climatic variations etc. Fields with high yields one year may the following year generate much lower yields, thus several plots of the same crop also spreads out the risk. In addition, a holding with several plots facilitates crop

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rotation and the ability to leave some land fallow (*ibid*).

Another benefit of land fragmentation is the use of multiple eco zones. Different plots enable farmers to grow a wider mix of crops. Since crops ripe at different times when the plots are in different altitudes, spreading out the agriculture work like harvest and sawing during a longer period of time helps farmers to avoid household labour bottlenecks. This is especially important when the growing season of the crop is short and easily creates seasons of peak labour demand (*ibid*).

Farmers may also prefer fragmented land holdings when there are diseconomies of scale with respect to the size of the parcels. This phenomenon might be a result of labour market failure. The farmers might be unable to gather enough labour to meet seasonal peaks on large parcels (*ibid*). Labour market failure, that is, the lack of off-farm job opportunities, can also result in a large amount of unproductive family members working on the farm due to their low opportunity cost. The resulting high ratio in labour to land makes the productivity per acre of land high. This could be an explanation of the existence of diseconomies of scale (Heltberg, 1998).

This paper evaluates the impact of land fragmentation on crop productivity in Ihemi cluster of the SAGCOT area in Tanzania using data which were collected during the baseline survey conducted by the LiFELand (Laying the Foundations for Effective Landscape-level Planning for Sustainable Development in the SAGCOT Corridor) project, which runs from April 2015 to December 2017. Funded by the CGIAR/International Water Management Institute (IWMI) Research Program on Water, Land and Ecosystem, the project promotes and facilitates the adoption of sustainable intensification in the Ihemi cluster through provision of robust, evidence-driven processes and strategies.

### The study area

The study was conducted in Ihemi Cluster which is located in the eastern-most part of the Southern Highlands of Tanzania. This together with other six clusters (that is, Ihemi, Kilombero, Sumbawanga, Mbarali, Rufiji, and Ludewa clusters), were identified under the SAGCOT initiative as especially ripe for agricultural investment. The initiative was launched by the Government of Tanzania (GoT) in 2010 as a Public Private Partnership (PPP) dedicated to ensuring food security, reducing poverty, and spurring economic development in the southern part of the country. The corridor stretches from the Indian Ocean to the Zambian border covering a total area of about 300,000 km<sup>2</sup> (approximately one third of total area of Tanzania Mainland) (AGG Team, 2012). The region has considerable agricultural potential which is underutilized and characterized by low productivity, low levels of investment, and high rates of poverty. To release the region's potential, the SAGCOT initiative seeks to attract

more than US \$3 billion of investment to dramatically increase food production, increase annual farming revenues by more than US \$1.2 billion, benefit small-scale farmers and the rural poor, and establish the southern part of Tanzania as a regional food exporter. It will do so by concentrating and linking agricultural investment from the public sector, development partners, and Tanzanian and international investors to kick start the region's latent potential for highly productive agriculture and efficient value chains.

In particular, the Ihemi cluster falls in two regions namely Iringa and Njombe [located between latitudes 6°30' and 11°0' south of the Equator and longitudes 33°30' and 37°0' east of the Greenwich (Figure 1)]. The Iringa region shares borders with Singida and Dodoma regions (towards the north); Morogoro region (eastwards), Mbeya region (westwards) and Njombe region (southwards). Iringa region covers a total area of 35,743 km<sup>2</sup> out of which 2,704.2 km<sup>2</sup> (7.6%) is covered by water bodies of Mtera Dam, the Little and Great Ruaha Rivers. The remaining area (33,038.8 km<sup>2</sup>) is land area (Iringa Regional Commissioner's Office, 2013).

The Njombe Region borders Iringa Region in the North, Morogoro Region in the East and Ruvuma region in the South. It also shares borders with the Republic of Malawi via Lake Nyasa and part of Mbeya Region in the North-West and West. The Region has the total surface area of 24,994 km<sup>2</sup> out of which 21,172 km<sup>2</sup> is covered by land (84.7%) and 3,822 km<sup>2</sup> is covered by water (15.3%) (*ibid*).

## STUDY APPROACH AND METHODOLOGY

### Sampling procedure and data collection

The study districts, wards and villages were purposefully selected based on their location along the cluster landscape, suitability as an average unit for socioeconomic analysis and potential for agricultural investment. A total of five districts were selected, two from Njombe and three from Iringa Region. The sample villages in each of the five sample districts and the respective sample sizes are presented in Table 1.

Prior to the selection of sample households and commencement of questionnaire survey, a range of Participatory Rural Appraisal (PRA) methods, including Focus Group Discussions (FGDs), Key Informants Interviews and Wealth ranking were conducted as a footing step to the study. These helped to identify wealth groups and socio-economic landscapes that acted as the sampling frame for a stratified random sample.

The wealth ranking exercise was conducted in all the twenty sample villages and at least 10% of the total households were chosen in each village (from the village registers) in order to provide a logistically feasible sampling frame. The wealth ranking exercise eventually resulted in identification of three wealth groups ("rich", "medium", and "poor"). Prior to the wealth ranking exercise the participants were asked to list the indicators of wealth which were then used to rank every household in the sample villages.

The "rich" households were relatively a small group, covering only about 11% of the total households. They were food secure all year round and had a fairly secure livelihood base. The "medium" wealth class constituted about 40% of the households, with a

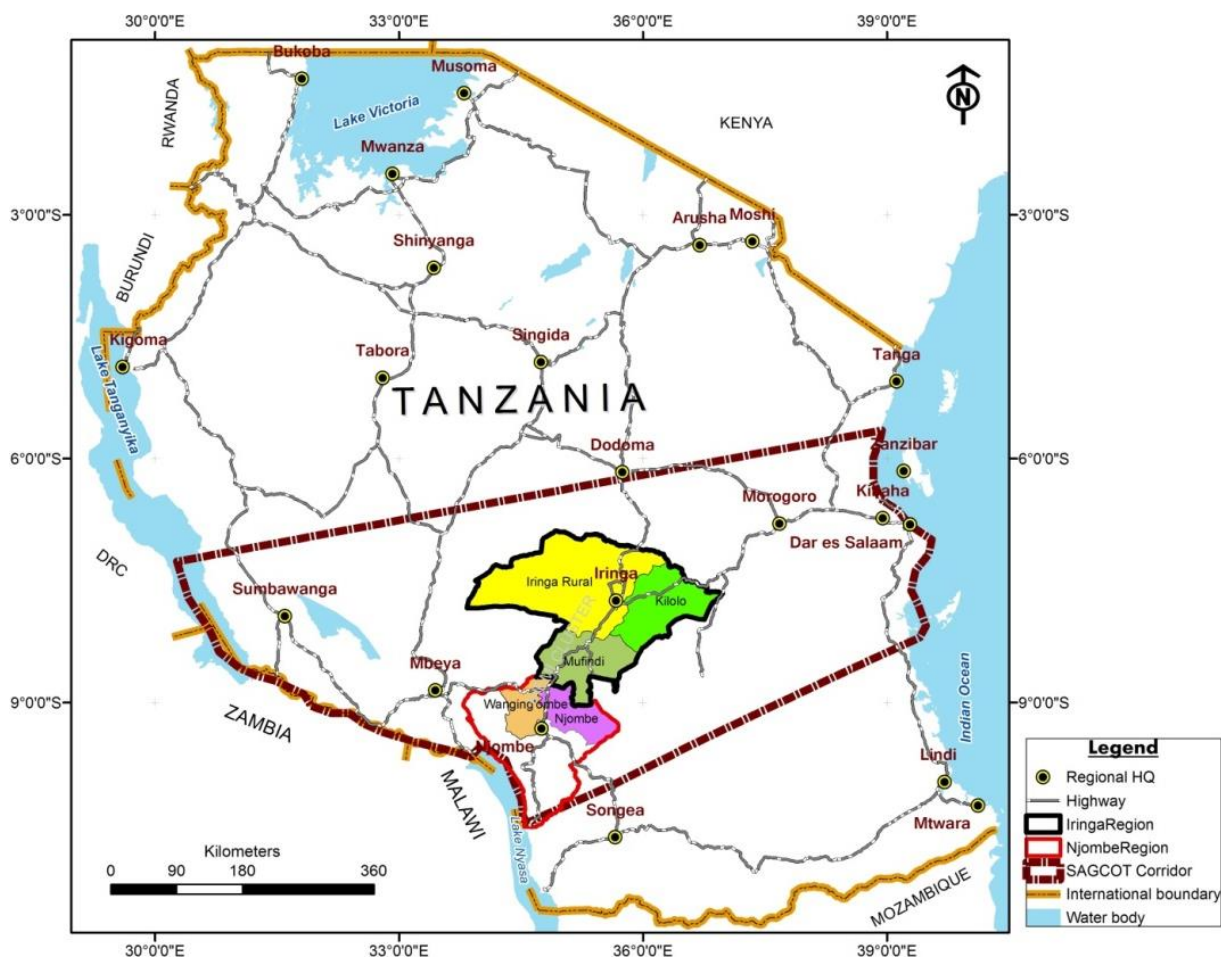


Figure 1. Map of Tanzania showing the location of Iheri cluster and SAGCOT region.

Table 1. Levels of fragmentation of operated land in the two regions of Iheri cluster, 2014/15 (%).

Measure of dispersion	Region		Total
	Iringa	Njombe	
Simpson index			
0.0 - 0.5	35.6	11.1	23.3
0.5 - 0.7	64.4	77.8	71.1
Over 0.7	0.0	11.1	5.6
Mean*	0.6	0.7	0.6
Median*	0.6	0.7	0.6
Number of parcels			
0	6.3	3	4.7
1	19	20	19.5
2	32.7	34	33.3
3	28	26.5	27.3
4	8.3	10.5	9.4
5	3.7	4.5	4.1
6 and above	2	1.5	1.8
Mean*	2.9	3.5	3.2
Median*	3.0	3.0	3.0

smaller base of assets to draw on, but the majority of the households in this class were still food secure all year round. The "poor" households constituted about half of the total households (49%). In total, 607 households were interviewed in twenty villages from five study districts namely Iringa, Kilolo and Mufindi district councils (in Iringa region) as well as Njombe and Wanging'ombe district councils (in Njombe region).

### Data analysis

Data gathered using FGDs, key informants and audio recorded interviews were transcribed and organised into discussion topics. A content analysis of transcribed data was then carried out using Excel spreadsheet. The data were first sorted into themes and later patterns were generated across themes to show the relationships across key issues such as farm/parcel sizes, soil and water conservation practices, and income sources just to mention few.

The questionnaire for household survey was pre-coded prior to actual data collection. The open ended questions were coded and generated during the compilation of responses to ensure consistency in the use of codes for open ended questions. A coded template was designed in SPSS and the information contained in the questionnaire was transferred into the software for data analysis. Data cleaning was performed to ensure that data values are complete, accurate correct and free from outliers.

The analysis of data entailed mainly the production of descriptive statistics such as means, standard deviation, analysis of variance, and t-tests. In addition, a linear regression analysis was used to assess the effects of land fragmentation on productivity. The study assumed a linear relationship between dependent and independent variables. Land fragmentation was analysed using a combination of measures including the size and number of parcels, average distance to parcels and the Simpson index. These measures and the alternative approaches to assess farm fragmentation are presented in the next section.

### Measures of land fragmentation

Land fragmentation is a spatial phenomenon which depends on many parameters. King and Burton (1982) cite the following six relevant factors: Holding size; number of parcels belonging to the holding; size of each parcel; shape of each parcel; the spatial distribution of parcels; and the size distribution of parcels.

Most authors who tried to measure fragmentation have used a simple average of the number of parcels per holding (either regional or national), an average of holding size and an average of parcel size. Some other authors developed more complicated descriptors. In particular, Edwards (1961) calculated a fragmentation index as the percentage of a holding's land which is not adjacent to the farmstead. In addition, Simmons (1964) proposed a land fragmentation index which took into account the number of parcels in a holding and the relative size of each parcel. The formula for Simmons's land fragmentation index is as follows:

$$FI = \frac{\sum_{i=1}^n a_i^2}{A^2} \quad (1)$$

Where  $FI$  is the fragmentation index,  $n$  is the number of parcels belonging to a holding,  $a$  is the size of a parcel and  $A$  is the total holding size. An  $FI$  value of 1 means that a holding consists of only one parcel and values closer to zero mean higher fragmentation. The Simmons index becomes the Simpson index if it is subtracted

from 1 (Shuhao, 2005).

Furthermore, Dovring (1965) computed fragmentation by measuring the distance which a farmer would have to travel to reach each of his parcels, returning back to his farmstead after each visit although it ignores the number of actual visits per year and the potential that any parcel could be visited without returning back to the farmstead. Moreover, Januszewski (1968) developed a similar fragmentation index to Simmons, combining the number of parcels per holding and their size distribution into a  $K$  index as follows:

$$K = \frac{\sqrt{\sum_{i=1}^n a_i}}{\sum_{i=1}^n \sqrt{a_i}} \quad (2)$$

Where  $n$  is the number of parcels and  $a$  is the parcel size. The  $K$  values range from 0 to 1. As values tend to zero,  $K$  indicates a high degree of fragmentation. This index has three main properties: the degree of fragmentation increases proportionally with the number of parcels; fragmentation increases when the range of parcel sizes is small and fragmentation decreases as the area of large parcels increases and that of small parcels decreases. Blarel et al. (1992) note that Januszewski and Simmons indices are the most popular. Igozurike (1974) suggested a 'relative index of land parcellization'. In contrast to the above indexes, this measure is based on the average size of the parcels and the distance travelled by a farmer to visit all his parcels sequentially (that is, in one round trip). This index is given by the following equation:

$$P_i = \frac{1}{S_i} Dt \quad (3)$$

Where  $P_i$  is the fragmentation (or parcellization) index of holding  $i$ ,  $S_i$  is the size of each parcel and  $Dt$  is the total round-trip distance covering all parcels. King and Burton (1982) criticized this index because distance has not been clearly defined by the researcher and is overemphasized, without taking into account the number of parcels. An example is quoted based on a holding with two parcels with size  $S$ ; and a distance of 10 km apart, which would give a  $P_i$  twice as high as a holding with 10 parcels of size  $S$ , each 1 km from its neighbours. Schmook (1976) defined a fragmentation index called  $P_o$ , which is the ratio between the area of a polygon which circumscribes all the parcels of a holding, to the area of that holding. Values of this index are always above 1; a high  $P_o$  value indicates intense fragmentation. Schmook (1976) also suggested another fragmentation coefficient which is calculated by dividing the average distance to parcels by the mean parcel size.

This study employed a mixture of measures of fragmentation including the size and number of parcels, average distance to parcels and the Simpson index. The latter is widely used because it is sensitive to both size of parcels and number of parcels. The Simpson index can arithmetically be defined as (Equation 4):

$$SI = \frac{\sum_{j=1}^J A_j^2}{A^2} \quad (4)$$

Where,  $SI$  = the Simpson index;  $A_i$  = the area of the  $i$ th plot;  $A =$

$$\sum_{i=1}^J A_i = \text{the total farm area.}$$

A value of zero indicates complete land consolidation (one parcel only), while the value of one is approached by holdings of numerous parcels of equal size.

To examine the impact of land fragmentation on productivity a two stage least squares (2SLS) analysis was used. The 2SLS procedure was purposefully used in order to tackle the problem of "misspecification" of variables. Three models were formulated (Equations 5 to 7). These were basically of the same nature but differentiated by either excluding both the observed and predicted values for average distance to parcels ( $T$  and  $T_p$ ), or including only one of them. In other words, equation 5 served as a control model by which the evaluation of explanatory powers in Equations 6 and 7 was facilitated.

$$Y_a = f(E_p, X_6, D). \quad (5)$$

$$Y_a = f(E_p, T, X_6, D). \quad (6)$$

$$Y_a = f(E_p, T_p, X_6, D). \quad (7)$$

$$X_6 = f(G, C, L_a, S)$$

Where:  $Y_a$  = crop productivity;  $T$  = average distance from homestead to parcels;  $E$  = number of parcels;  $L$  = household labour equivalent;  $G$  = age of head of household;  $S$  = sex of head of household;  $C$  = education level of head of household;  $D$  = regional dummy;  $E_p$  = predicted values for number of parcels;  $T_p$  = predicted values for average distance to parcels

The implicit assumption underlying the formulation was that the models were correctly specified in the first place. A number of OLS formulations were tried before adopting the 2SLS model.

## RESULTS AND DISCUSSION

### Parcel sizes and land fragmentation

Generally, crop parcels are very small - 60% to about 86% had sizes ranging from 0.25 to 2 acres (Figure 2) compared to average farm size in Africa of 2.5 ha; North America (121 ha), Latin America (67 ha) and Europe (27 ha) (Kanu et al., 2014).

The results of analysis of land dispersion using the Simpson Index (SI) and number of parcels (Table 2 and Figure 3) as well as the average time spent by farmers to walk from their homesteads to parcels (Figure 4) suggest high levels of land fragmentation for both the two regions and districts of Ilemi cluster. Relatively however, the land holdings were more fragmented in Njombe region than in Iringa region. This can partly be explained by the difference in relative per capita land size between the two regions, which supports the argument that fragmentation

is a supply driven factor. On average our results showed relatively smaller per capita cropland for Njombe region (0.16 acres/person) than Iringa region (0.21 acres per person).

Although the median number of parcels (Table 1) was the same for both regions (3.0), the median value of the Simpson Index was greater for Njombe region (0.7) compared to that of Iringa (0.6) and the difference was significant at  $P < 0.01$ . In Njombe region, about 20% of farmers operated four or more parcels, whereas for Iringa it was only 16.9%.

Most parcels were located at distances of 1 km<sup>2</sup> and more from homestead (Figure 4). The correlation between Simpson Index and the average distance to parcels was -0.281, and this relation was significant at 0.01 level. The t-test results on both the mean number of parcels and the Simpson Index supported the assertion that land consolidation increased with land scarcity and market access. Land consolidation was relatively higher in Iringa than Njombe district at  $P < 0.01$  with t-values equal to 3.08 and 3.28 respectively. In this test, fragmentation (Simpson Index or number of parcels) was used as the inverse measure of consolidation.

It is important to note that the disparity in land fragmentation between farmers in the two regions of Ilemi cluster (Iringa and Njombe) was not necessarily an outcome of only supply driven factors (higher population density in this case) or demand drive factors. The disparity seemed not to originate purely from constraints in land acquisition or from limited choice of parcel location. A number of both side supply - and demand driven factors seemed to interact together to define the prevailing levels of fragmentation. We evaluate and discuss some of these factors in our analysis of the effects of land fragmentation on productivity in the next subsection.

### Land fragmentation and productivity

The regression results for the three models specified in the analysis (Equations 5 to 7) are summarized in Tables 2 to 4, respectively. In Tables 2 and 3, only age of the head of household, labour equivalents per hectare, and regional dummies were statistically strongly significant. The rest of predictors were non-significant. In Table 4 however, only two predictors remained consistently non-significant (education level and sex of head of household). The predicted values for the number of parcels were significant at  $P < 0.05$ , and the rest were all significant at  $P < 0.01$  level, as expected.

The regression results for Equation 7 (Table 4) show that fragmentation has a positive impact on land productivity (crop yield) when predicted values ( $T_p$ ) are used instead of observed values of average distance to parcels ( $T$ ). When both these values are excluded (Table 2), and when only observed values of average

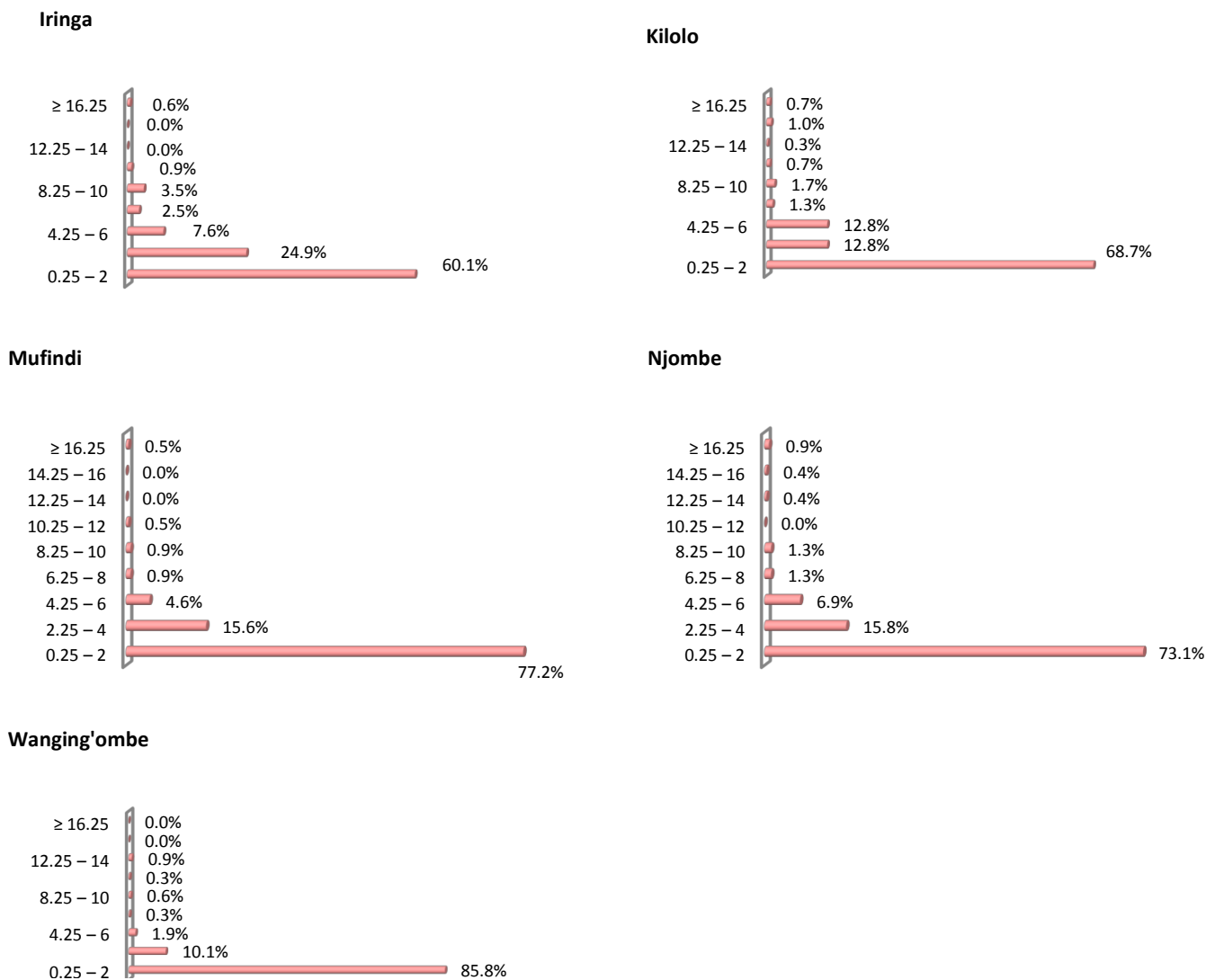


Figure 2. Parcel sizes (acres).

Table 2. Regression results of second stage – 2SLS for the control fragmentation-productivity model.

Term	Coef.	StDev	T	P
Constant	88717.0	53926.0	1.65	0.104
$E_p$	-10660.0	8500.0	-1.25	0.213
Age of head of household	2792.5	732.2	3.81	0.000***
Education level of head of household	2262.0	2031.0	1.11	0.269
Labour equivalent/Ha	-71725.0	15127.0	-4.74	0.000***
Sex: 1	-3508.0	10057.0	-0.35	0.728
Region: 0	29744.0	7575.0	3.93	0.000***
S	64667			
R <sup>2</sup>	43.3%			
Adj R <sup>2</sup>	39.2%			
F	10.56			
P	0.000***			

$E_p$  = predicted values of number of parcels; \*\*\*significant at 0.01% level.



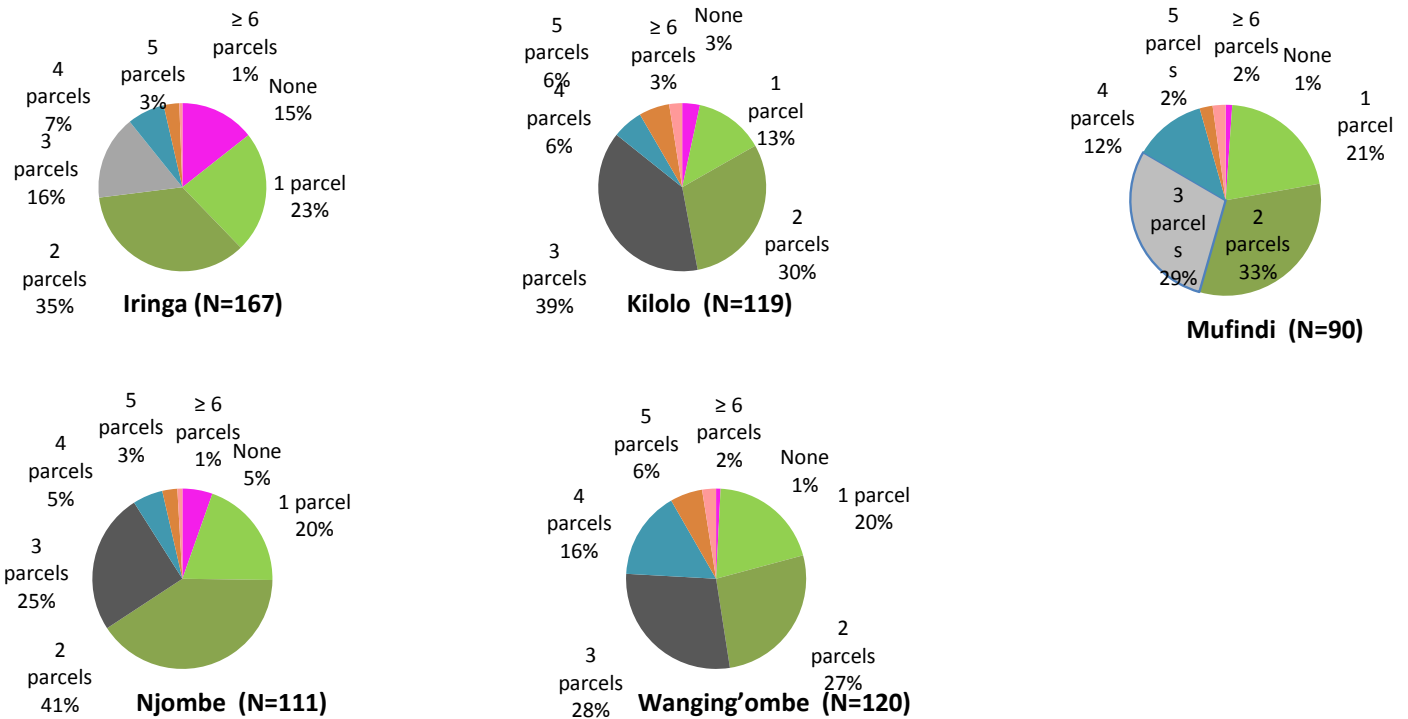


Figure 3. Land ownership by number of parcels.

distances to parcels are included – an approach which is considered to ignore the effects of variables specified as exogenous (Table 3), the results support a contrary explanation: that is, fragmentation has a negative impact on land productivity. When subjected to correlation coefficient test (in isolation) the observed values of number of parcels correlated negatively with observed values of land productivity ( $r = -0.269$ ) at 0.05 significant level. The correlation coefficient between predicted values of number of parcels and observed values of land productivity was also negative ( $-0.269$ ) and significant at 0.01 level. In addition, many smaller parcels were generally close to homesteads in Njombe region (Figure 4), whereas, only few, larger parcels were far away from houses in Iringa region (Iringa, Kilolo and Mufindi district councils in the same figure). This would support Fenoaltea (1976)'s and Blarel et al. (1992)'s argument that, greater fragmentation does not necessarily result in greater average distances for farmers.

It is important to note that these results make a deceptive but interesting point which tends to be overlooked frequently in the analysis. The point is that analyzing the factors hypothesized as affecting land productivity in isolation rather than in an integrated or comprehensive manner may be too hypocritical to draw any tangible conclusion. The opposite appears to be an appropriate approach, particularly when one evaluates the causes and persistence of land fragmentation prevailing in most smallholder production systems in developing countries. Several socioeconomic factors are

interlinked together and are more likely to have a combined, rather than separable, effect on land productivity.

The positive impact that the average distance to parcels has revealed on land productivity can partly be explained by the fact that distant parcels are comparatively the more currently cleared or developed ones. It therefore becomes logical when one considers them as less suffered from continuous cultivation and hence less degraded.

### Implication for agricultural investment in the SAGCOT

The findings presented and discussed in the foregoing subsection raise particular questions regarding the future of smallholder landholdings as agricultural investments expand in the SAGCOT region. These include among others the following two key questions: (a) Will the agricultural landholdings become more fragmented or more consolidated? (b) What will be the likely impact on access to land and productivity as well as welfare of smallholder farmers at large?

Obviously, we expect several chunks of land owned by rich farmers and investors to sprout which is more likely to result in increased consolidation of the agricultural land in the cluster. However, the landholdings for smallholder farmers will become more fragmented as poor smallholder farmers are increasingly selling their small



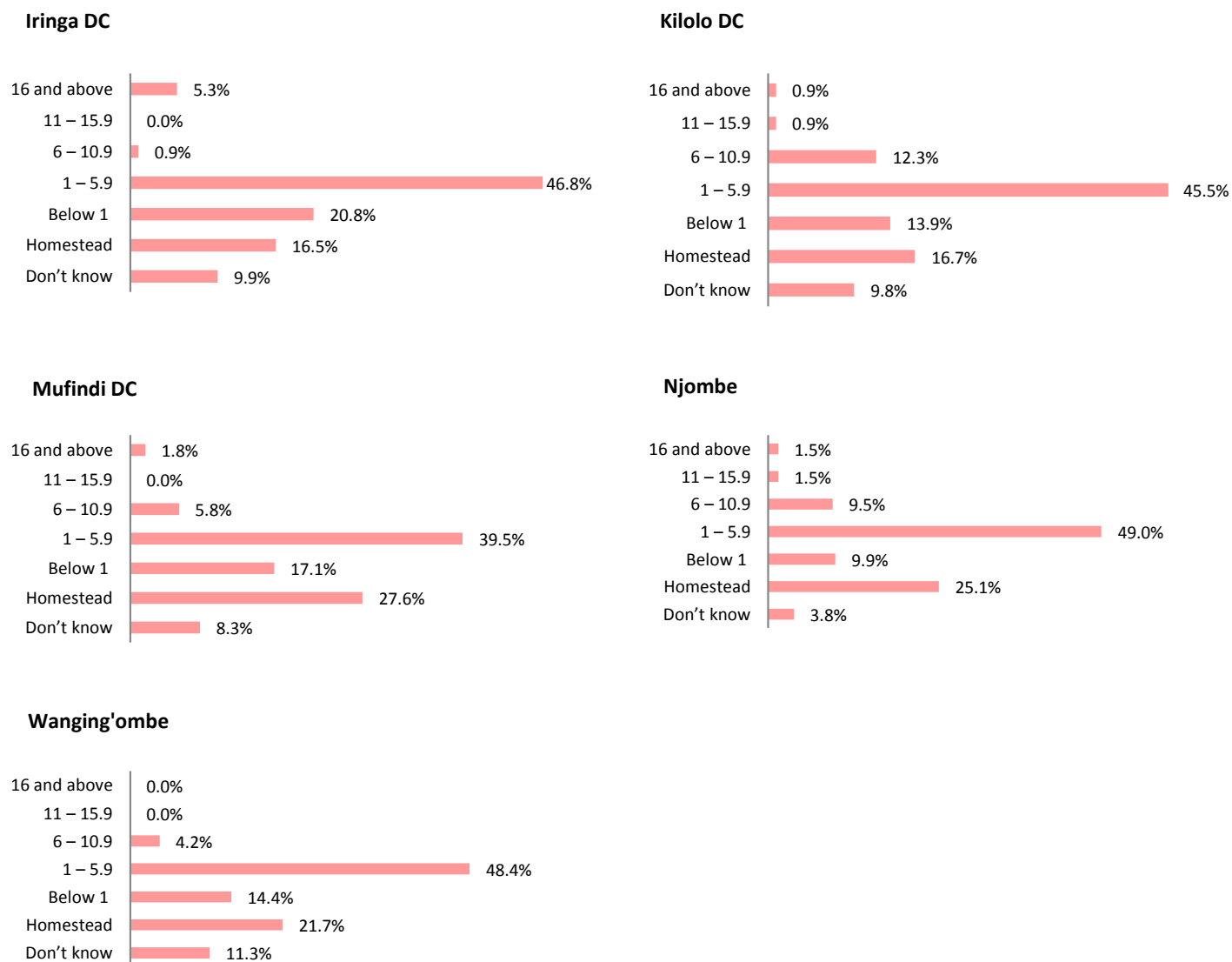


Figure 4. Distance to crop parcels (km).

Table 3. Regression results of second stage - 2SLS with  $T$  variable included in the fragmentation-productivity model.

Term	Coef.	StDev	T	P
Constant	64574.0	67751.0	0.95	0.343
$E_p$	-8257.0	9448.0	-0.87	0.385
$T$	1277.0	2154.0	0.59	0.555
Age of head of household	2776.1	735.6	3.77	0.000***
Education level of head of household	2186.0	2043.0	1.07	0.288
Labour equivalent/Ha	-70769.0	15272.0	-4.63	0.000***
Sex: 1	-3610.0	10098.0	-0.36	0.722
Region: 0	29645.0	7607.0	3.90	0.000***
S	64921			
$R^2$	43.5%			
Adj $R^2$	38.7%			
F	9.03			
P	0.000***			

$E_p$  = predicted values of number of parcels;  $T$  = average distance to parcels; \*\*\*significant at 0.01 per cent level.

**Table 4.** Regression results of second stage - 2SLS with  $T_p$  variable included in the fragmentation-productivity model.

Term	Coef.	StDev	T	P
Constant	-797431	297087	-2.68	0.009***
$E_p$	79580	30881	2.58	0.012**
$T_p$	47404	15653	3.03	0.003***
Age of head of household	2666.1	699.8	3.81	0.000***
Education level of head of household	-826	2189	-0.38	0.707
Labour Equivalent/Ha	-75835	14497	-5.23	0.000***
Sex: 1	-5658	9622	-0.59	0.558
Region: 0	26542	7304	3.63	0.000***
S	61701			
R <sup>2</sup>	49.0%			
Adj R <sup>2</sup>	44.6%			
F	11.25			
P	0.000***			

$E_p$  = predicted values of number of parcels;  $T_p$  = predicted values of distance to parcels; \*\*\* = significant at 0.01 per cent level; \*\* = significant at 0.05% level

parcels to rich farmers and investors. This trend is likely to continue and may result in increased number of landless farmers.

Climate change and lack of funds to purchase inputs will also continue to impact negatively the agricultural productivity of smallholder farmers. Frequent droughts and crop losses resulting in unreliable rainfall increasingly force smallholder farmers to cultivate crops on fragile lands like the bottom valleys (*vinyungu* farming) leading to degradation of existing water sources in the SAGCOT region. Releasing the region's potential will require that these issues are appropriately addressed and smallholder farmers are helped to secure adequate and suitable landholdings for farming, raise agricultural productivity, diversify their sources of income to reduce overreliance on crop production, and adopt good agricultural practices. This has to be achieved by promoting strong investor - farmer synergies for inclusive agricultural growth.

There are already some good examples of investor - farmer engagement emerging in the region. The Rutuba farm for example undertakes training of farmers in good agricultural practices through the Clinton Foundation Program at Gongwa area. Early lessons from this model suggest that small farmers can triple their yields if helped to intensify their agricultural practices (personal conversation with the management of the farm). Smallholder farmers in the SAGCOT region can harvest more crops per unit area provided that they are helped to access right seeds at the right time, own good storage facilities, given the right education and assisted to access competitive markets.

Another example in the region is the Silverlands' model of agri-intensification. Silverlands is a private company which has invested in a big poultry project at Ihemi village that produces three poultry breeds namely the Highland

brown, Cobb 500, Sasso - French bird breeds. The company has a hatchery unit and produces vegetarian and high quality; scientifically formulated poultry feeds and buys crops (maize, soybeans and sunflower) from smallholder farmers in the cluster and in other areas outside Iringa and Njombe regions.

The company normally buys the produce through NGOs who work for the interest of small-scale farmers by so doing bypassing the middlemen node and shortening the value chain or marketing channels of these crops. The company was also piloting a selling mall for poultry products and had selling points in different parts of the country notably the Southern Highlands, Morogoro, Dodoma, and Dar es Salaam regions. In addition the company has established a poultry training college for farmers and other entrepreneurs.

## Conclusions

Land holdings in Ihemi cluster were generally highly fragmented. The pattern of dispersion is however contrary to the explanation given by many analysts of the causes of land fragmentation attributing it to supply driven factors. The population density in Iringa region was relatively higher (174 people per ha) than in Njombe (145 people per ha) yet the land holdings in the latter region were more fragmented than in the former.

In addition, land fragmentation was declining with farm size, and parcels located closer to homestead were more fragmented than the ones located far. It was increasing with land scarcity. The results in this study show a positive relation between land fragmentation and productivity.

We draw the following key lessons from the study of land fragmentation in the Ihemi cluster of SAGCOT: (a)

Land fragmentation should not be considered as undesirable; b) it should also not be viewed as purely originating from, and/or made persistent by the influences of only a single type of factor (e.g. population density – a supply side factor) but a result of interaction between both the supply – and demand – driven factors. Which type dominates the other will depend on the farming environment prevailing in a specific area.

### Conflicts of Interests

The authors have not declared any conflict of interests.

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### REFERENCES

- Apata T, Sanusi A, Olajorin V (2014). Small Farms and Agricultural productivity in Nigeria: Empirical analysis of the effects of land tenure, fragmentation and property rights. Paper prepared for presentation at the 2016 World Bank Conference on Land and Poverty, March 14-18, 2016. The World Bank - Washington DC.
- Austin OC, Ulunma AC, Sulaiman J (2012). Exploring the Link between Land Fragmentation and Agricultural Productivity, *Int. J. Agric. For.* 2(1):30-34.
- Bentley W (1987). Economic and ecological approaches to land fragmentation: In defense of a much-maligned phenomenon. *Ann. Rev. Anthropol.* 16:31-67.
- Binns O (1950). The Consolidation of Fragmented Agricultural Holdings. Washington DC: FAO Agricultural Studies P 11.
- Bizimana C, Nieuwoudt WL, Ferrer S (2004). Farm size, land fragmentation and economic efficiency in southern Rwanda. *Agrekon* 43(2):244-262.
- Blarel B, Hazell P, Place F, Guiggin J (1992). The economics of farm fragmentation—evidence from Ghana and Rwanda. *World Bank Econ. Rev.* 6(2):233-254.
- Chen Z, Huffman W, Rozelle S (2009). Farm technology and technical efficiency: Evidence from four regions in China. *China Econ. Rev.* 20:153-161.
- Corral J, Perez J, Roibas D (2011). The impact of land fragmentation on milk production. *J. Dairy Sci.* 94:517-525.
- Di Falco S, Penov I, Aleksiev A, van Rensburg T (2010). Agrobiodiversity, farm profits and land fragmentation: Evidence from Bulgaria. *Land Use Policy* 27:763-771.
- Dovring F (1965). Land and labour in Europe in the twentieth century (3rd ed.). Hague: The Nijhoff.
- Edwards D (1961). An economic study of small farming in Jamaica. University College, West Indies.
- Fenoaltea S (1976). Risk, transaction costs, and the origin of medieval agriculture. *Expl. Econ. Hist.* P 13.
- Heltberg R (1998). Rural Market Imperfections and the Farm Size-Productivity Relationship: Evidence from Pakistan. *World Dev.* 26:10.
- Igozurike MU (1974). Land tenure, social relations and the analysis of spatial discontinuity. *Area* 6:132-135.
- Iringa Regional Commissioner's Office (2013). Iringa Region Investment Profile. Available online at: [www.iringa.go.tz/en/information-centre/documents.html](http://www.iringa.go.tz/en/information-centre/documents.html)
- Januszewski J (1968). Index of land consolidation as a criterion of the degree of concentration. *Geogr. Polon.* 14:291-296.
- Kanu BS, Salami AO, Numasawa K (2014). Inclusive Growth: An imperative for African agriculture. Agriculture and Agro-Industry Department (OSAN). Development Research Department (EDRE). African Development Bank Group. Available at: [http://www.afdb.org/fileadmin/uploads/afdb/Documents/Publications/Inclusive\\_Growth\\_-\\_An\\_imperative\\_for\\_African\\_Agriculture.pdf](http://www.afdb.org/fileadmin/uploads/afdb/Documents/Publications/Inclusive_Growth_-_An_imperative_for_African_Agriculture.pdf)
- King R, Burton S. (1982). Land fragmentation: Notes on a fundamental rural spatial problem. *Progr. Hum. Geogr.* 6(4):475-494.
- Latruffe L, Piet L (2014). Does land fragmentation affect farm performance? A case study from Brittany, France. *Agric.Syst.* 129:68-80
- McPherson MF (1982). Land fragmentation: a selected literature review. Development Discussion Paper No. 141. Harvard Institute for International Development, Harvard University.
- Mwebaza R, Gaynor R (2002). Land sector analysis; land market, land consolidation, and land re-adjustment component, Rural Development Institute, The Government of the Republic of Uganda.
- Nguyen T, Cheng E, Findlay C (1996). Land fragmentation and farm productivity in China in the 1990s. *China Econ. Rev.* 7(2):169-180.
- Rahman S, Rahman R (2008). Impact of land fragmentation and resource ownership on productivity and efficiency: The case of rice producers in Bangladesh. *Land Use Policy* 26:95-103.
- Sauer J, Davidova S, Gorton M (2012). Land fragmentation, market integration and farm efficiency: empirical evidence from Kosovo. Contributed Paper prepared for presentation at the 86th Annual Conference of the Agricultural Economics Society, University of Warwick, United Kingdom. 16 - 18 April 2012.
- Schmook G (1976). The spontaneous evolution from farming on scattered strips to farming in severalty in Flanders between the sixteenth and twentieth centuries: A quantitative approach to the study of farm fragmentation. In R. H. Buchanan, R. A. Butlin, & D. McCourt (Eds.), *Fields*. Belfast: Ulster Folk and Transport Museum. Farms Settle. Eur. pp. 107-117.
- Shuhao T (2005). Land fragmentation and rice production: a case study of small farms in Jiangxi Province, P.R. China. PhD Thesis, Wageningen University.
- Simmons AJ (1964). An Index of Farm Structure, with a Nottinghamshire Example. *East Midlands Geogr.* 3:255-261.
- Sklenicka P (2016). Classification of farmland ownership fragmentation as a cause of land degradation: A review on typology, consequences, and remedies. *Land Use Policy* 57:694-701.
- Sklenicka P, Janovska V, Salek M, Vlasak J, Molnarova K (2014). The farmland rental paradox: extreme land ownership fragmentation as a new form of land degradation. *Land Use Policy* 38:587-593.
- Sundqvist P, Andersson L (2006). A study of the impacts of land fragmentation on agricultural productivity in Northern Vietnam. Bachelor Thesis. Department of Economics. Uppsala University.
- The World Bank (2005). Land Consolidation Issues in Northern Vietnam – Institutions, Implementation, Impacts. Working Paper, The World Bank.
- Thomas J (2007). Property rights, land fragmentation and the emerging structure of agriculture in Central and Eastern European countries. *Elect. J. Agric. Dev. Econ.* 3(2):225-275.
- Van Dijk T (2003). Dealing with Central European Land Fragmentation. Delft: Eburon.
- Van Dijk T (2004). Land consolidation as Central Europe's Panacea reassessed. In: Proceedings of Symposium on Modern Land Consolidation, September 10–11, Volvic (Clermont-Ferrand), France. Available from URL: [http://www.fig.net/commission7/france\\_2004/papers\\_symp/ts\\_01\\_van\\_dijk.pdf](http://www.fig.net/commission7/france_2004/papers_symp/ts_01_van_dijk.pdf)
- Van Hung P, MacAulay TG, Marsh S (2007). The economics of land fragmentation in the North of Vietnam. *Austr. J. Agric. Resour. Econ.* 5:195-211.
- Van Hung P, MacAulay TG, Marsh S (2006). The Economics of Land Fragmentation in the north of Vietnam, The University of Sydney.
- Wu Z, Liu M, Davis J (2005). Land consolidation and productivity in Chinese household crop production. *China Econ. Rev.* 16:28-49.