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The Impacts and Causes of Land Fragmentation on Farm Productivity: Case Review of East African Countries

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Abstract

This report provides an overall assessment of land fragmentation problems in East Africa. Many parts of East Africa have become highly fragmented, putting development systems and activities in these areas at risk of complete collapse. Land fragmentation occurs when land gets converted for agriculture, industrialization, or urbanization, invaded by non-local plants, or enclosed for individual use and by subdividing farmlands into subsequent smaller units called parcels with varying average farm sizes. Fragmentation results from inappropriate agricultural development processes and ineffective land use planning that fails to recognize how farmland is used, and the importance of its interconnected areas. Insecurity of tenure and resource rights are key factors in making this possible. Land fragmentation is one of the key reasons why the ability of most resources in East Africa becomes scarcer, and those remaining become "privatized" by more powerful community members—keen to maintain their access to them. Such individualistic attitudes are new and disadvantage the poorest even further by affecting the traditional customary safety nets and agricultural outputs. Neither the government nor customary governance systems effectively protect resource access for the poorest. This review summary report identifies the key causes, measures, and implications, government interventions, and the common remedies to land fragmentation problems in the East African Countries of Kenya, Uganda, Rwanda, and Tanzania including neighboring Ethiopia, and the Sudan. The findings indicated from 2005 to 2015, the population kept increasing for all the named countries in East Africa with Rwanda and Uganda having a substantial increase in population density. The study review further explores the trend in the performance

of agriculture by average farm sizes within the intervals of five years by highlighting their strong linkages and found that the average farm size has declined drastically, especially for Kenya. This can only mean that small farms kept becoming smaller and smaller and that there were more small-scale farmers. The results further depicted that the major and commonly cultivated food crops among the East African countries include maize, sorghum, rice, cassava, sweet potatoes, bananas, Irish potatoes, beans, peas, etc., with maize yields (Mt/ha) in 2003 for Uganda being the highest (1.79 Mt/ha) and the lowest in Rwanda (0.77 Mt/ha) respectively. Therefore, from the review results, recommendations are being made as to how the negative impacts of land fragmentation on agricultural productivity can be reduced or mitigated. One way is by community sensitization and awareness about the importance of land consolidation and its proposition on farm productivity.

Keywords

Land Fragmentation, Land Consolidation, Farm Productivity, Industrialization, Impacts, Causes, Average Farm Size, Population, East Africa

1. Introduction

Globally, since the emergency of land reforms in the Mid-Nineteenth Century, land fragmentation has been a major concern among policymakers and economists. The renewed concern is a result of declining agricultural productivity, farm efficiency, and persistent food security problems, especially in developing countries [1]. The nature of land fragmentation is understood and defined differently within various economic contexts and as a result, several approaches and methods have been developed and used to analyze the phenomenon [2] [3] [4]. The lack of a single conventional approach has led to contradicting views and conclusions regarding whether land fragmentation should be considered a problem or not [5]. The varied multidisciplinary treatment and measurement of the phenomenon has resulted in what can be termed as a "contested causation" which has seen persistent scientific disagreement and debate.

Land fragmentation, also known as pulverization, parcellization, or scattering [6] [7], is commonly defined in the literature as the situation in which a single farm consists of numerous spatially separated parcels [8] [9] [10]. [11] defined the nature of land fragmentation in sub-Saharan Africa as a situation where a household operates more than one separate parcel of land. This definition, however, does not capture the nature of existing land fragmentation in the region today. [12] and [13] distinguished four dimensions under which land fragmentation can be defined: fragmentation in ownership; the number of land users (or size of use units); within a farm (or internal fragmentation); and fragmentation due to overlap or separation of ownership and use. It is characterized as a fun-

damental rural spatial problem concerned with farms that are poorly organized at locations across space [14] [15].

2. An Overview of Land Fragmentation Problem and Its Extent in East Africa

This report tends to provide the basics on analyses of land fragmentation in East African Countries as an observed phenomenon in many countries around the world, and how often land fragmentation is viewed as an obstacle to agricultural productivity and modernization regarding its aspects been documented in all parts of the world. Fragmentation is recognized as a major threat to agricultural productivity, wildlife conservation, and mobile pastoralism among the East African Countries [16]. This is primarily driven by land tenure and policy, increasing human population, expansion of settlements and agricultural farms, road networks, and urban development [17] [18] [19] (**Figure 1**). To understand and characterize the forces driving habitat fragmentation in the East Africa context, it is important to analyze the influence of biophysical factors (soils, slope, rainfall, rivers) and human-created features (roads, towns, parks, quarries). The literature proposes several explanations for the causes, measures, and implications (both positive and negative) of land fragmentation. These explanations are often divided into two main categories; demand-side and supply-side factors [5]. The supply-side factor treats fragmentation as an exogenous imposition on farmers, which harms agricultural production, while the demand-side factors assume that the farmers voluntarily choose beneficial levels of fragmentation. To understand the long-term effects of the land fragmentation problem in East Africa, we need to identify the root causes of land fragmentation in sub-Saharan Africa [5].

The global population is projected to grow by nearly 2.3 billion people by the year 2050 with the fastest growth expected to come from the sub-Saharan African region [20]. The major challenge for global agriculture today is how to produce food that will meet the demands of the growing population. An increase in population density implies increased pressure on limited natural resources including land and water. Market demand for food and animal feed is expected to reach 3 billion tonnes, up from today's nearly 2.1 billion tonnes [20]. Coupled with food demand is the emerging interest in feedstock driven largely by the demand for biofuels [21]. The current food security debate has now shifted to Africa's food security paradox. Despite Africa's huge potential, owing to its vast natural resources and large areas of arable land and water resources, food security in the East African region remains elusive [22]. The region has consistently recorded low agricultural productivity and low technology adoption hindering sufficient food production. Currently, sub-Saharan Africa's yields reach about 25% of their potential, comparatively, yields in Central America, Central Asia, Eastern Europe, and the Russian Federation reach approximately 40% of their potential [23]. It is estimated that about 60% of the world's arable land is in Africa [24], however, given the present trends, the continent can only produce

13% of its food needs by 2050. The historical accounts of the increase in agricultural output in Africa are mainly attributed to the expansion of cultivated area rather than the intensification of cultivation with rising yields per hectare [25]. Africa with a huge potential to feed itself requires sustainable and efficient utilization of resources to increase agricultural productivity thus addressing persistent food security threats in the region. It is argued that there are only two possible options left to increase food production; either increase yield per hectare expand the amount of land to be cultivated (not fragment land) or both [26]. Expansion of agricultural land area is, however, not feasible technically since arable land is limited; the latter remains the only viable option.

Figure 1. Map showing the countries comprising the East African region including its cities and neighboring countries with a population over one million [27].

3. The Causes of Land Fragmentation in East Africa

To understand the long-term effects of land fragmentation problem in East Africa, we need to identify the root causes of land fragmentation in sub-Saharan Africa. There are several factors causing communities and individuals to subdivide farmland into smaller units. These include but are not limited to low credits, rising prices for agricultural commodities, high productivity of poor rural farmers [2], changes in government land policy, high government taxation of farm produce on larger farms, urbanization through unregulated housing construction on arable land [18] [19] [29] [30], high economic and population growth rates [4] [31], landscape protection [32] [33], transport infrastructures [34], climate change [35], inheritance/customary laws [36], high land market prices, increasing inputs (labor, fertilizers, pesticides, improved seeds, and seedling distribution, etc.), high labor productivity and cultural perspectives [19]. However, in this review case, four major factors have been identified for discussion as key causes that might immensely contribute to land fragmentation. These include land inheritance [14]; population growth [37]; land markets; and historical/cultural perspectives [5]; as their influences on the subdivision of land can be described in the proceeding paragraphs:

Land inheritance is the key driver and the culture behind the declining arable farm sizes in East Africa [38]. Most societies in sub-Saharan Africa are characterized by a culture of patrilineal succession and inheritance of properties including land which is successively shared among heirs or only the sons in the family [38] [39]. Inheritance laws facilitate or demand the subdivision of holdings into equal parts among the heirs when the tradition continues among the subsequent generations on the same piece of land. The trend in inheritance will ensure that, as the population increases, not only does the size of holdings fall, but they are increasingly fragmented into smaller plots, scattered over a wide area [1] [40] [41]. Following the tradition reinforced by laws, landholdings, and some land parcels are equally divided among sons when they decide to live separately. This will ultimately result in smaller unsustainable landholding units.

Population growth is considered one of the major factors triggering land fragmentation in East Africa [42]. The increasing population pressure and uncontrolled land titling lead to the growth of land markets encouraging land fragmentation. However, unlike the followers of the Malthusian theory, we will not confine our minds to this factor as several others are also playing equally important roles. Though not directly related to land fragmentation, Malthus's "Principle of Population" can be considered the first effort made to link the implications of a steadily growing population to land. Malthus thought that if uncontrolled, population growth would accelerate pressure on land resources, thereby undermining the livelihood of people [43] [44]. This proposition has been rejected by several scholars, who found population growth as a factor contributing to improving land management and increasing agricultural production [45] [46] [47]. Particularly the problem of land-parcel fragmentation emanating from a

steadily growing population has been reinforced further by the tradition of land inheritance prevailing in almost all countries. Land fragmentation has thus become an ongoing process, resulting in landholdings and land parcels getting smaller and smaller, and dispersed over successive generations [48].

Land markets are very limited in rural areas of East Africa partly because, as experienced in some of the European countries [10], they are impeded by a huge number of small holdings that do not want to sell landholdings, which are their main source of livelihoods. Because there are very limited non-farming employment and investment opportunities, smallholder households are more vulnerable to the risk of being landless if the small amount of capital available at their disposal from the sales of landholdings is spent on purchasing subsistence requirements while seeking land elsewhere. However, in some areas where small farmers are earning a substantial income from non-farming sources, they are willing to sell landholdings and migrate to urban areas [49] [50] [51]. Other notable causes that might further cause land fragmentation include:

The breakdown of common property regimes is another cause of land fragmentation, particularly in areas with tribal communities that practice shifting cultivation in communal land for a long period, especially among the mountainous communities, and following their customary systems, where everybody had a right to use a small parcel of land for subsistence purposes, but nobody could claim the land as private property. This practice goes beyond land succession because purchasing land can be quite expensive [52].

On the supply side, some proponents assumed that land fragmentation is an exogenous imposition on farmers where they (farmers) involuntarily accept to hold many plots of land, which are often dispersed, thus farmers cannot freely choose to scatter their land holdings unless otherwise compelled by some other forces as reviewed in the proceeding paragraphs:

Extreme land scarcity also leads to land fragmentation as farmers in quest for additional land tend to accept any available plot of land within a reasonable distance of their house. When population pressure on land is high and when there are no other off-farm activities upon which the population can earn a living, fragmentation results.

The nature of topography itself may force farmers to own scattered land holdings in a sense that geographical barriers such as waterways and wastelands limit the possibilities for land consolidation. Expansion of the farm under such circumstances requires acquisition of new separate pieces of land which when done, implies land fragmentation.

The egalitarian objectives and state laws may limit possibilities for land consolidation. For example, in China during the 1970s and 1980s, community leaders carried out land redistribution /fragmentation based on equality. Arable land was divided into several plots for quality and each household was given a plot [53]. In this case, the land redistribution process led to land fragmentation, especially at the village level.

The supply-side causes of land fragmentation explain why a young farmer might begin with a fragmented holding undermining the economic incentives for land consolidation. Such persistence indicates that there are other causes of land fragmentation which have been criticized for many reasons: Firstly, even when land markets afford farmers opportunities for consolidation, fragmentation persists. This persistence implies that the choice of households to own many plots of land is not always an involuntary one as assumed by proponents of the supply-side causes of land fragmentation. Secondly, land fragmentation has developed in areas where there is no serious land scarcity, such as in Kenya, Zambia, and Gambia [54] [55] [56]. Parents continue to bestow their heirs with scattered holdings, a practice that would seemingly be halted if land fragmentation was largely detrimental [54] [57].

The argument that land inheritance is designed for equity reasons runs into difficulty when it is observed that sub-division and fragmentation levels are eventually checked after reaching certain levels since it becomes practically impossible to continue subdividing very tiny plots, as noted in Sri Lanka [57] and in Mexico [58]. The raised criticisms suggest that supply-side causes are not sufficient enough to explain the existence and persistence of land fragmentation. It is upon this that researchers have conceived demand-side causes of land fragmentation.

4. Industrialization versus Land Fragmentation (Influence of Industrialization on Land Use)

Over the years, industrialization has had a substantial influence on the subdivision of land into fragments i.e. into smaller plots/sizes in diverse contexts. Especially, in the Pearl River Delta Region of China, rapid industrialization led to the establishment of a land share-holding system, which facilitated industrial development but also caused land fragmentation, low efficiency, low productivity, and disorderliness in rural land use systems [59]. This subsequently led to many smaller plots of land fragments due to ambiguous property rights and inefficient land-use practices. In a typical Chinese industrial city of Shunde, it is observed that industrial land expansion initially experienced phases of slow expansion, rapid expansion, and reverted through slow expansion again, with significant fragmentation still evident with factors like decentralization and marketization played key roles in this process [60]. In East Africa, for instance, in the agricultural sector, small-scale operations due to land fragmentation have affected investment in agricultural mechanization, influencing policy formulation for sustainable development [13] [61]. It has also exacerbated the land fragmentation process in agriculture, hindering efficient farming practices, technology adoption, and sustainable rural development due to small, scattered parcels [13] [62]. These findings highlight the complex relationship between industrialization and land fragmentation, emphasizing the need for strategic planning to mitigate the negative consequences on land use efficiency and sustainability. A study by [63] stressed industrialization leads to land fragmentation, hindering efficient farming due to

small, irregular patches unsuitable for modern farm equipment, impacting food production and water quality. Promoting active land markets through industrialization has contributed to land fragmentation leading to smaller, uncompetitive farm sizes which hampers efficient land management and conservation, and increases transport costs in rural areas [64]. Furthermore, industrial expansion has led to fragmentary industrial areas in many towns and cities worldwide, influencing urban development by either renewing spaces or increasing urban split and discontinuity known as urban sprinkling [65] [66]. Elsewhere, in East Africa, industrialization has led to a partial separation of energy provision from land use, increasing total biomass extraction and consumption, and impacting land fragmentation by shifting energy sources [67]. The shift from communal to individual land ownership, with varying degrees of administrative and market-based reallocations impacted land distribution and redistribution over time. As a result, it influences and increases land fragmentation through industrialization and modernization [68]. In addition, industrialization and modernization have led to changes in land use classes, such as increased built-up areas and decreased cultivable land, contributing to increased land fragmentation. This can influence land fragmentation by altering economic factors that affect farmers' decisions on consolidating or fragmenting farmlands, impacting optimal land use and development policies in developing countries [69] [70].

5. Measurement Indices and Different Approaches to Land Fragmentation

The literature on land fragmentation shows a variety of indices and approaches used to measure and estimate the land fragmentation effects on farm productivity. Several indices used to measure land fragmentation are documented by [5]. Most measures of land fragmentation have considered land fragmentation as a spatial phenomenon and problem where the concern is the geographical scattering of farmlands in terms of dispersion of parcels per ownership and the shape of parcels and non-spatial factors such as the type of ownership and the existence of accessibility of a parcel to a road. This depends on many parameters. [71] cite the following six relevant factors:

Factors relevant in the measurement and estimation of land fragmentation effects as by [71]:

- 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 holding size, and an average parcel size. Some other authors developed more complicated descriptors.

In particular, [72] calculated a fragmentation index as the percentage of a holding's land that is not adjacent to the farmstead. In addition, [73] proposed a land fragmentation index that considered 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:

$$FI = \left(\sum_{i=1}^{n} ai^{2}\right) \Big/ A^{2} \tag{1}$$

Where, *FI* is the fragmentation index, n is the number of parcels belonging to a holding, *a* is the parcel size and *A* is the total holding size. An FI value of 1 indicates that a holding consists of only one parcel and values closer to zero, imply higher fragmentation. The Simmons index becomes the Simpson index if it is subtracted from 1 [74].

Furthermore, [75] computed fragmentation by measuring the distance which a farmer would have to travel to reach each of his parcels, returning 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, [76] developed a similar fragmentation index to Simmons, combining the number of parcels per holding and their size distribution into a K index as follows:

$$K = \frac{\sqrt{\sum_{i=1}^{n} ai}}{\sum_{i=1}^{n} \sqrt{\sum_{i=1}^{n} ai}} \tag{2}$$

Where, *n* is the number of parcels, *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. The index has three main properties namely:

- 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 [11]. Note that Januszewski and Simmons indices are the most popular.

Another fragmentation coefficient which is calculated by dividing the average distance to parcels by the mean parcel size was suggested by [77]. This study employed a mixture of measures of fragmentation including the size and the number of parcels, average distance to parcels, and Simpson index. The Simpson index is widely used because it is sensitive to both size and number of parcels. It is calculated arithmetically using the below formula:

$$SI = \frac{\sum_{i=1}^{j} \left(A_i\right)^{2}}{A^{2}} \tag{3}$$

Where, SI = the Simpson index; A_i = the area of the ith plot; $A = \Sigma A_i$ = total farm area.

The 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.

6. Results and Discussion

Major review findings of Average Farm Sizes (ha), major food crops cultivated and Population Density (Persons per sq·km^2) of total land area in East African Countries including its neighboring countries of Ethiopia and Sudan.

6.1. The Population Density Indicators for East African Countries: Persons per sq·km^2 of Land Area

Population density (people per sq·km of land area) in Tanzania in 2015 amounted to 60 people per sq·km, compared with 59 people per sq·km in 2014. It has increased by 14.9 p.p. from 2006 to 2015. The average annual growth rate of population density in Tanzania over that period was about 1.36%, with a maximum growth of 1.86% recorded in 2015 and a minimum growth of 1.35% recorded in 2006. The Population density in Tanzania from 2006 to 2015 had risen to 60 people per sq·km in 2015 as compared to 44 people per sq·km recorded in 2005 [78] (**Figure 2**).

In Ethiopia, the population density (people per sq·km of land area) in 2015 amounted to 99 people per sq·km, compared with 88 people per sq·km in 2010. While in Kenya, it increased from 71 in 2010 to 81 people per sq·km, in 2015. Rwanda's population density showed a high increase of 54 people per sq·km, from 417 in 2010 to 471 people per sq·km in 2015. The same trend in Uganda was noted in 2015 with 195 people per sq·km, compared with 165 people per sq·km in 2010, a rate of 30 people per sq·km within five years whereas, Sudan's population density elevated at a much lower rate (2.6 people per sq·km) of a total of 19.4 people per sq·km in 2010 to 22 people per sq·km in 2015 [78] (**Figure 2**).

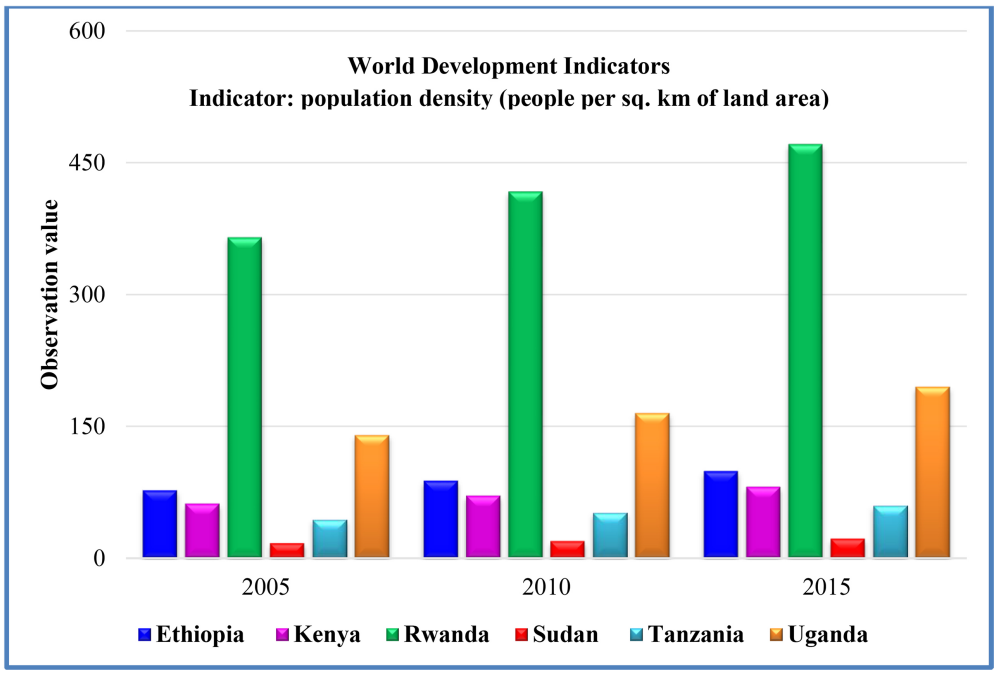

Figure 2. The average population density in East African Countries (persons/sq·km^2) of the total area.

From the above countries' population density information, it can, therefore, be concluded that from 2005 to 2015, the population kept increasing for all the named countries in East Africa with Rwanda and Uganda having a substantial increase in population density, including Ethiopia. However, Kenya, Tanzania, and Sudan's population density kept elevating at much lower rates. This means that high population growth rates in rural areas and urbanization driven by growth in other sectors of the economy can also contribute to the subdivision of landholdings to relatively smallholders' average farm sizes in East Africa [78] (**Figure 2**). From a breakaway country from Sudan, South Sudan has 12.23 million people as per 2016 census results.

6.2. Average Farm Sizes (in Hectares) of Total Land Area in East African Countries

In Kenya, the average farm size fell from 2.3 ha between 1980 and 1999 to 1.9 ha between 2000 and 2010, and in Rwanda, the size fell from 1.2 ha in 1984 to 0.7 ha in 2000 [79]. It shows that average farm size decreased in most low-developed countries while global estimation is that average farm sizes decreased in Africa and Asia from 1950 to 2010 (**Table 1**). In Tanzania, like most of the African developing countries, the agriculture sector alone contributes towards 28 percent of the GDP and 73 percent of the population lives in the rural areas, there are about 3.7 million smallholdings (those smaller than the middle-size farm threshold of 2.2 hectares with a small sized average farm of 0.9 hectares), which make up for 80 percent of total farms (**Table 1**). In Ethiopia, for example, the average farm size declined from 1.43 hectares in the 1980s to 1.03 in the 2000 s (**Table 1**). In Africa, smallholder farms can be relatively larger, but only marginally. In East Africa, Kenya's smallholders' farm average size is 0.47 hectares meaning farms are severely fragmented into very small sizes the trend that followed Sudan (0.4 ha) and in Ethiopia and Tanzania, the average farm sizes shifted moderately with 0.9 hectares respectively as from between 2011 to 2015 as compared to Uganda with average farm sizes of 0.8 ha and Rwanda with 0.6 ha (**Table 1**). During these years, both countries experienced rural population growth, but no increase in agricultural land. The smallholder household families live in farms which in many countries are significantly smaller than 2 hectares. Average small farm sizes hide significant productivity differences across countries. These differences arise due to soil quality, technology, and productive assets, such as irrigation, high inheritance ratio among offspring, and population growth rates in rural areas; urbanization driven by growth in other sectors of the economy can also determine average farm size. Across the world, in both developed and developing countries, farm sizes evolve but tracing their evolution through time is difficult therefore, agricultural censuses are infrequent and definitions of who can be considered a farmer differ from one country to another. Despite these difficulties, in many countries of the developing world, the average farm size has declined. This can only mean that small farms become smaller and that there are more small farmers.

6.3. Comparison of Maize Yields (Mt/ha), one of the Commonly Cultivated Food Crops among the East African Countries

Like any other African region, East African developing countries largely depend on agriculture to sustain the livelihoods of their population, although contributions from other non-agricultural sectors are exceptional. The major food crops cultivated in East African countries in the average farm sizes (farm fragments) that decreased between 2000 to 2010 (Table 1) include maize, sorghum, rice, cassava, sweet potatoes, bananas, Irish potatoes, etc. However, categorically among the five East African countries of Rwanda, Burundi, Kenya, Tanzania, and Uganda, the following maize yields (Mt/ha) were obtained in 2003 (Figure 3). The result depicted that yields for Uganda were highest (1.79 Mt/ha). This was followed by yields for Tanzania (1.54 Mt/ha) and Kenya (1.53 Mt/ha). However, Rwanda had the lowest maize yield harvested (0.77 Mt/ha) in 2003 (Figure 3).

Table 1. Average farm sizes (in hectares) of total land area in East African countries.

	Average Farm sizes (Hectares)			Average Population Density (persons/km²) of total area		
Country	1980 - 1999	2000 - 2010	2011- *to date*	2005	2010	2015
Uganda	2.5	1.6	0.8 - 1.6	140	165	195
Kenya	2.3 - 2.5	1.9	0.47	62	71	81
Tanzania	1.5	1.3	0.9	44	52	60
Ethiopia	1.43	1.03	0.9	77	88	99
Rwanda	1.2	0.7	0.6	365	417	471
Sudan	2.5	1.7	0.4 - 1.7	17	19.4	22

Note: World Bank national accounts data, and OECD National Accounts data files@2017 The World Bank Group or http://www.worldbank.org/.

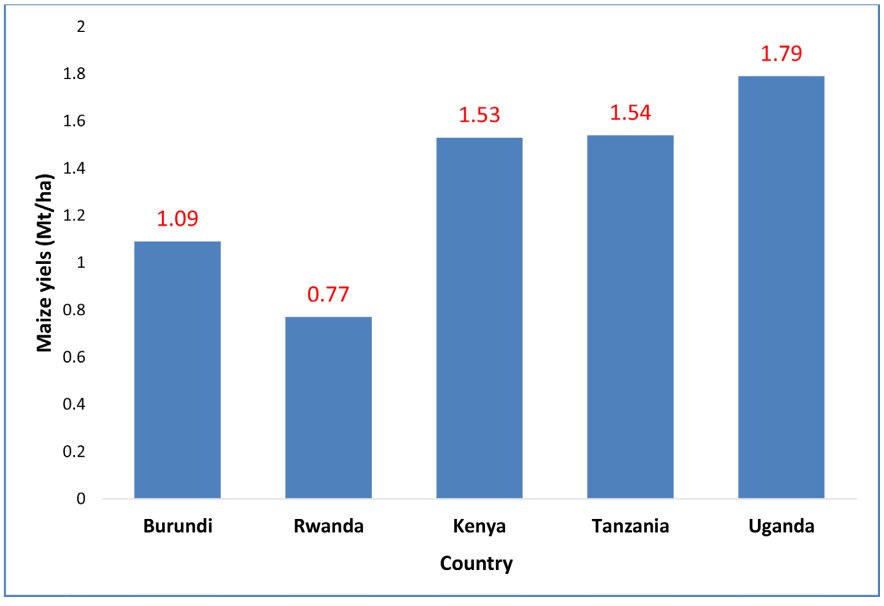

Figure 3. Comparison of Maize yield (Mt/ha) among the East African countries in 2003 [55] [80].

6.4. The Consequences (Impacts) of Land Fragmentation on Agricultural and Land Productivity

Land fragmentation is a phenomenon that is discussed by many scholars to harm agricultural productivity and its modernization in several ways with polarized shreds of evidence. These consequences include: farming on different small landholdings can increase transport costs especially when the plots are located far from the home, and far from each other, difficulty in management and supervisory services, and work in far scattered plots [81], small and scattered 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 [82]. For instance, in Bulgaria, fragmentation was found to reduce farm profitability but boost the richness of species [83]. As land fragmentation increases, land plots become more dispersed in space, leading to lower efficiency in the use of fertilizers, pesticides, agricultural machinery, and labor input. For instance, in Rwanda, the average shrinking farm sizes are in turn causing encroachment and degradation of natural ecosystems and forests. The nature of policies on land property rights has also tended to encourage land fragmentation, which represents a key obstacle to agricultural development because it impedes agricultural mechanization, causes inefficiencies in production, and incurs higher costs to alleviate its operation [13].

On the other hand, there are positive implications of land fragmentation on agricultural productivity and modernization that come with reducing risks of total crop failure on the variety of soil and growing conditions, it has a positive effect on food sustainability and food quality thus supporting food security at household levels, it enhances production risks by increasing product diversity. Land fragmentation also minimizes risks from natural disasters such as heavy storms, drought, floods, insect infestations, etc. Many different types of plots allow farmers access to land of different qualities regarding soil, slope, micro-climatic variations, and environmental conditions [13]. Farming the same crops in several plots may also spread out the risk as fields with high yields in a consolidated plot one year may degrade the soil and may generate much lower yields in the following year. In addition, a parcel with several plots facilitates crop rotation and the ability to leave some land fallows [7]. Furthermore, spatially separated small plots of farmland lower the risk of entire crops being affected by disease in the same growing season [84].

6.4.1. Disadvantages of Land Fragmentation

There is a viewpoint that sees land fragmentation as the source of ineffective agriculture. According to this viewpoint, land fragmentation is said to harm productivity in several ways because continuous subdivision of farms would lead to small-sized land holdings that may be hard to economically operate [83] [85] [86] such as:

- 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 traveling in-between the plots and home to plots.
- Management, supervision, and securing of small, scattered plots can also be more difficult, time-consuming, and costly for farmers [87].
- Small and scattered plots of wasteland area require more land for fencing, border construction, and paths and roads.
- Land fragmentation might also increase the risk of disputes between neighbors and heirs [88].
- Small, fragmented land holdings might also cause difficulties in growing certain high-profit crops that require larger plot areas, so if the farmers only possess small and fragmented plots they may be forced to grow only less profitable crops [82].
- Other noticeable disadvantages associated with land fragmentation include the hindering of economies of scale and farm mechanization and affecting access to irrigation networks [89].
- Small and scattered plots may hamper the use of machinery and other large-scale agricultural practices.
- Small land holdings might also discourage the development of infrastructure like transportation, communication, irrigation, and drainage facilities [34] [88].
- Finally it is noticed that banks are sometimes unwilling to take small, scattered landholdings as collateral, which prevents farmers from obtaining credit or loans to make investments (ibid).

6.4.2. Advantages of Land Fragmentation

The counter viewpoint sees land fragmentation as a positive situation under which farmers can cultivate many environmental zones, minimize production risk, and optimize the schedule for cropping activities [7] [90] [91]. The following entails the positive implications of land fragmentation on agricultural productivity:

- One benefit 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 options to cultivate.
- Many different plots allow farmers access to land of different qualities associated with soil, slope, micro-climatic variations, and environment.
- Consolidated fields with high yields one year may the following year be degraded and may generate much lower yields, thus farming of the same crop on several different plots also spreads out the risk.
- In addition, a holding with several plots facilitates crop rotation and the ability to leave some land fallow (ibid) to regain sufficient fertility grades.
- Another benefit of land fragmentation is the use of multiple ecozones. 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 helps farmers avoid household labor bottlenecks. This is especially important when the growing season of the crop is short and easily creates seasons of peak labor demand (ibid).

- Farmers may also prefer fragmented land holdings when there are diseconomies of scale concerning the size of the parcels. This phenomenon might be a result of labor market failure that is, the lack of off-farm job opportunities, that can also result in a large number of unproductive family members working on the farm due to their low opportunity cost. The resulting high ratio of labor to land makes the productivity per acre of land high [92].

6.5. Government Policy Measures and Legal Frameworks on Land Fragmentation

A comprehensive review of the earlier debate on land fragmentation has been contained in [87]. In this context, policymakers took an extreme view in favor of land consolidation by considering preventive legislation to reverse the land fragmentation trend, while economists adopted a balanced viewpoint arguing that land fragmentation can be adaptive under certain circumstances but may become non-adaptive with changes in technology and factor costs [87]. This view implies that the issue of land fragmentation takes a spatial-temporal dimension requiring a context-specific evaluation while considering existing local socioeconomic and environmental conditions before any policy decision is made. In the wake of dwindling land holdings and intensification, especially in developing countries, there is a renewed interest in attempting to understand and resolve the controversy surrounding the impacts of land fragmentation on agricultural production [81] [93] [94].

One of the least discussed drivers of land use change is government policy and related laws and regulations. Policy is viewed as a means of promoting desired future conditions, yet there is resistance to acknowledge that it is thus inevitably a driver of land use changes and as such possible negative, as well as positive, results. These policies and laws have had a significant impact on patterns of land use change in East Africa [95]. Contemporary land uses in East Africa reflect the influence of colonial policy and laws, some extending back to the late 19th century. Of particular importance are the land policies since the colonial period that have shaped the land tenure systems with wide implications on the utilization of the land. These, coupled with the agricultural, wildlife and forest conservation, resettlement, and more recently the structural adjustment policies have all worked together to bring about significant changes in land use within the East African region.

Colonial policies and legal frameworks used to enforce them led to the alienation of land for European settlements and large-scale farming and ranches in the East African region. This directly affected the distribution of lands between na-

tive peoples and colonial settlers in Kenya, Tanganyika, and Uganda. The legislation included the British Land Act No.3 of 1993 in the then Tanganyika, the treaties between the Masai and British in 1911 and 1912, and other land laws in Kenya [96], as well as Agreements between the British protectorate government, and the Kingdoms of Buganda, Toro and Ankole in Uganda that included the Buganda Agreement which was later supported by the Busuulu and Envunjo law of 1927 and the Toro landlord and Tenant law of 1937 [97].

The post-independence period witnessed several law reforms while new ones were enacted. Post-independence laws, whose enactment and implementation had a significant influence on land use change, include the 1968 Land Adjudication Act in Kenya, the 1962 amendments to the Local Authority Ordinance of 1953, the Wildlife Conservation Act No. 12 of 1974, the Village Act of 1975, the 1983 Labour Deployment Act, and the Land Act No. 6 0f 1999 in Tanzania, among others [96] [98].

In Kenya, the privatization and individualization of land rights resulting from the implementation of the 1968 Land Adjudication Act transformed agricultural systems as economic and social systems changed from ones based on communal management of resources to private management, and from primarily pastoralism to cultivation with some animal raising [96]. In Embu and both sides of Mt Kilimanjaro, entire landscapes changed from those dominated by bush and woodland to those almost completely covered by agriculture [99].

In agriculture, post-independence governmental programs in both Kenya and Tanzania promoted export crops through the establishment of parastatals, such as the National Food Corporation (NAFCO) in Tanzania and Nyayo Tea Plantation in Kenya as well as coffee cooperative parastatals in Kenya and Tanzania. These often incorporated existing producers and also led to the establishment and expansion of additional estates and plantations [100].

In Uganda, the post-independence laws including the Land Reform Decree of 1975, legally transferred all land to the state, and most of the land was accessed for export production and commercial agriculture [101]. However, many of the estates that had been sustainably managed with due conservation measures remained in ruin because of the expulsion of the Asians from Uganda. Other legislation with significant impact on land in Uganda include the 1995 Constitution and the 1998 Land Act, which are likely to stimulate further changes in land use in the future. Both of them attempt to streamline and free the land markets in Uganda [101].

In brief, there are two other policy considerations. First, the government should facilitate the establishment of micro, small, and medium-sized enterprises that create jobs and promote economic growth. For a long time, interest rates have been very high discouraging borrowing and investing in labor-intensive activities where imports that are used as inputs in industries have become very expensive. Thus a combination of high interest rates in part to keep money out of circulation and control inflation and expensive imports due to excessive devalu-

ation of currency have worked against diversifying and transforming East Africa's economy from agriculture to manufacturing thus keeping surplus labor trapped in the rural economy on small, uneconomic pieces of land. This policy needs to be modified to address massive unemployment and under-employment which market forces and laissez-faire capitalism have been unable to address.

Secondly, the education of girls and the empowerment of women will in the end help them to manage their reproductive behavior, have fewer children, and reduce pressure on the land. In France, land fragmentation was addressed through inter alia birth control. In East Africa, particularly Uganda policymakers need to refocus development priorities in the wake of a shift from neo-liberal economics to public and private partnership. This will require modification in institutions and staffing at policy and expert levels as was done in 1987 at the start of the structural adjustment program [101]. There is an urgent need to have economists at the top government level as policymakers or experts/advisers with a neo-Keynesian bias.

6.6. Common Remedies to Land Fragmentation Problems in East Africa

Land fragmentation is a big problem. If not well addressed, it is the source of poverty and low development in many nations. To solve or mitigate problems of land fragmentation, governments, and their relevant stakeholders must formulate proper land policies on tenure systems, regulate land laws, and the decisions on investments, and take into consideration these various land-related factors in designing, planning, and implementing policies and programmes. Worldwide, the most used land management strategies to deal with land fragmentation issues are land consolidation, land banking, voluntary land exchanges among landowners, and cooperative/societies farming.

Land consolidation: According to [80], there are four approaches to land consolidation involved namely: simplified land consolidation, individual land consolidation, voluntary land exchange, and comprehensive land consolidation [80]. Simplified land consolidation involves re-allocation of holdings, exchange of farmlands, and providing additional land from land banks including only some basic infrastructure [30]. Re-allocation is done by pooling and redistribution during a land consolidation process where many parcels from a defined number of land holdings are combined, and from the same area of land, the holdings emerge but in a new physical and legally recognizable shapes. Land consolidation is normally carried out for all of the holdings within a very specific geographically definable area. The size and extent of land consolidation vary from minor readjustment of boundaries between two adjacent holdings to the complete rearrangement of hundreds of holdings with planning and investment in a new rural or urban infrastructure [3] [30]. At a fundamental level, the land consolidation and land readjustment process is intended to restructure outdated or unsatisfactory land ownership patterns. Farmers with smaller landholdings should

be encouraged to mechanize their landholdings through the combination of their parcels. Governments should initiate land consolidation programs to curb land fragmentation issues. However, the success of any land consolidation program, therefore, rests on how well farmers' needs, capabilities, and aspirations are reconciled and integrated into it. A program will be able to achieve success only when appropriate incentives, institutional flexibility, and necessary infrastructure are in place and the end users are genuinely involved in designing it [30] [102]. Hence, land consolidation may also prove a valid and feasible solution for land fragmentation in East Africa.

Voluntary land exchange: This means exchanging parcels of land between the landowners, which would result in the grouping of the adjacent land parcels of a landowner [3] [30]. This approach is less expensive and less time-consuming in tackling land fragmentation as compared to the land consolidation approach, although it does not offer a broader impact than that of land consolidation [30] [80].

Land banking: This is alternatively, an approach where agricultural land is obtained from landowners who accept to sell it as per the normal market conditions and redistribute it, during the land consolidation project phase to ensure better results [30] [103]. Where there is interest, private entrepreneurs should be encouraged to be involved in land marketing through the provision of loans, provided it is necessary.

Cooperative farming or cooperative societies: This is a land management approach in which several farmers pool their land resources together and cultivate jointly, more effectively, and distribute benefits economically [30]. It is considered to be an effective instrument through which small and fragmented landholdings could be consolidated into economically operational units. [104] considered such farming as capable of transforming the agrarian economy and overcoming obstructions to efficiency, improved productivity, and efficient utilization of labor [19]. Cooperative farming also plays an important role in contributing to better market access, improving rural employment, and increasing household incomes [105] [106].

Other notable common remedies to Land Fragmentation problems include the following:

Legal restrictions by the provision of laws for controlling land fragmentation: It is noted that without strong legal backup, landholdings would over time revert to their pre-consolidation state even if a consolidation program is effectively enforced. Any parcel of land less than one unit of the standard area set by the state government is considered a fragment that cannot be transferred to anybody. According to this legal provision, owners willing to sell a plot of land must get a fair price appraised by the government agency. Following this, firstly, the plot must be offered to the owners of contiguous plots for sale. If they do not agree to purchase the land at the stipulated price, the government should purchase the land and then sell it to the owners of contiguous plots [107]. Such legal provision

has also been made in Nepal to prevent land fragmentation [108]. Farmers willing to sell any plot of land must first offer it to the owners of the contiguous plots of land. If this law is violated, the contiguous plot owners can claim their rights in court.

Land taxes must be imposed as a policy on land purchases: This is levied in areas where there are no immediate buyers, but farmers are willing to sell land and migrate elsewhere, as in the case of some villages in Nepal [108] [109]. Governments may decide to plant trees in such lands if they are in inaccessible areas such as watershed areas, valleys, and wetlands thereby providing benefits to the society as a whole. Alternatively, governments may sell or lease out lands to interested parties and individuals on the condition that they will not subdivide landholdings.

In view of the sub-division of paternal land mainly associated with the traditional inheritance systems of our communities, which also still treasure large families as being one of the major causes of land fragmentation, one may argue for discouraging such practice through the imposition of high inheritance tax on the land property in question. Such a measure is likely to aggravate the economic conditions of the majority of rural people in East Africa because they possess very small landholdings [110].

There is a need for a proper land tenure system to promote leasehold markets through the provision of new laws facilitating the leasehold system and removal of existing legal barriers if any. Land lease systems facilitate the structural consolidation of small landholdings [111]. However, the existing tenancy laws and rules may constrain the development of such systems, as there is a constant fear of ownership claims of landholdings by leaseholders particularly when landholdings are leased for a long time. Landowners would usually avoid such risks by shortening the lease period, which reduces the economic viability of landholdings and investment incentives [10] [111].

7. Conclusions and Recommendations

The issue of land fragmentation remains a key empirical question in the East African region with the need for more comprehensive datasets to evaluate it exhaustively. Despite a gradual increase in population density, there are dwindling farmland sizes among the countries, indicating that small farms become smaller and that more small farmers exist. Continuous decrease in farm size is likely to negatively impact farm-level efficiency, especially food production. Therefore, understanding land fragmentation within a specific context and using a consistent approach will serve as a guide and solution to the key policy decisions in agriculture. Following conventional practice, some scholars like [107] and [112] have advocated curative measures of land fragmentation such as land consolidation and legal restriction on free transfer and alienation of landholdings. Such measures, as we know from experience, would bear little fruit, as they do not address the structural causes of land fragmentation such as population growth,

laws of inheritance, and scarce non-farming employment opportunities. As long as such structural forces are active, whatever achievements are made through measures suggested by [107] and others, will not last long because the ever-increasing population continues to depend on land as a major source of livelihood. So, any endeavor aimed at promoting land consolidation should adopt a strategy comprising preventive measures such as population growth control and promotion of non-farming employment and investment opportunities, cooperative/societal farming, and curative measures that encompass several flexible options for land consolidation [113].

The review on the effects of land fragmentation on agricultural productivity in East African Countries showed that land fragmentation has been discussed by several studies. However, most of these studies have not investigated the factors that sustain fragmentation despite its negative manifestations on production and the socio-economic well-being of the farming households. Therefore, this study review suggested that more research has to be conducted in the area of cultural land inheritance systems in East African societies to establish the reason for its persistence even when it is uneconomical to subdivide land further. By doing so, the following were then drawn and suggested: Firstly, the review is worth recommending that cultural practices of land inheritance be reviewed and family planning should be enhanced to have manageable families and households to reduce pressure on land by heirs. Secondly, communal land use practices should be considered to avoid wastage of land due to separate homesteads. Thirdly, it can also be recommended that a policy on land prohibiting subdivision of land beyond economic units be put in place. Finally, the review recommended that an in-depth study be carried out to determine more comprehensively the factors that affect agricultural production and to determine why people are so attached to ancestral land even where they have the ability to buy or own land elsewhere.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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