Effects of Rural Habitat Distribution and Farm Size on Food Production Index Growth in Sub-Saharan African Region: A Case of East Africa Countries

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Abstract

In Burundi, Rwanda, Kenya, Tanzania, and Uganda, agriculture is still the backbone of the economy. A significant concern remains to adequately feed the galloping population mainly living dispersed in rural areas with fragmented agricultural lands. We used the comprehensive Feasible Generalized Least Square regression for estimation. Our analysis sought to seize the effects of the dispersion and agglomerated habitat, the agricultural land size per capita on the growth of the food production index. We also considered other essential control variables whose influence improved the results. Findings reveal that reducing the disseminated habitat by promoting the agglomerated ones stimulates the food production index growth through more efficient land use. An increase in the agglomerated population of 1% accelerates the development of the food production index of 0.961 %. Results also revealed that other variables such as the ratio of agricultural researchers per 100 000 farmers, the percentage of cultivated land irrigated, and agricultural land size per capita influence the dynamics of the food production index. We suggest that promoting the people to live in agglomerated areas could liberate the agricultural land size per capita. That enables to envisage viable farming models, facilitating agricultural mechanization, innovations policy, and allowing for agricultural automation, innovations policy high productivity.

Keywords

Dispersed-Population, High-Yields, Large-Farms, Merging-Land, Viability

1. Introduction

Food production index growth remains the primary determinant of food security and rural welfare in most East African developing countries. More than 90 % of this region's people depend on agriculture for their income and still mainly live in rural areas [1]. While agriculture is one of the East African countries' key sectors, it remains primarily subsistence agriculture [2].

Although East Africa 's agriculture is the pillar of people's livelihoods, agricultural land is scarce due to high demographic pressure and the dispersed habitat. An accelerated population growth rate explains the excessive fragmentation of land and the decrease in the size of farms households (less than 0.05 hectares of agricultural land area per household) [3, 4]. Yet, agricultural land availability can enormously increase agricultural productivity [5]. Under these conditions, we cannot claim better productions and rational use of cultivable land [6]. In other words, the small plot is an obstacle to the modernization of agriculture because "the small plot is no longer profitable from rational mechanized and motorized work" [2]. Hence, in conducting such a study, the following paper targets increasing knowledge of a successful paradigm for the best agrarian rural space management associated with food production levels.

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The specific objectives are to:

- Assess the relationship between the population distribution and better yields.
- Verify which land-use model able to supply the maximum attainable output
- Investigate the kind of habitat model capable of bringing scattered households together into one area and increasing the size of agricultural land per capita.

2. Literature Review

Despite some efforts to promote agriculture, this sector faces multiple and severe problems that hamper its development in East Africa countries. The industry's slow growth combined with the increasingly manifest inability of agriculture to meet the needs of rural families and the absence or scarcity of basic infrastructures [6, 7]. With the agricultural land scarcity, households cannot produce enough to meet their minimum food security requirements and generate a certain income level.

Farmers in East African countries produce to consume, not to sell [1]. Farmers currently do not produce enough food to satisfy the high demand [8]. Nevertheless, developing countries like Eastern Africa, with economies more than 50% dominated by the agricultural sector, have to prioritize the development of agricultural programs [9]. Agriculture contributed to 40%; 29,04%; 24,21%; 27%; and 28,74% of the Gross Domestic Product (GDP) for Burundi, Rwanda, Uganda, Kenya, and Tanzania, respectively [10].

East Africa countries are fundamentally rural nations: more than 90% of the population lives isolated in the countryside with fragmented families [2]. According to some economic theorists, developing a country without creating its rural environment and industry without developing agriculture [10]. East Africa is one of Sub-Saharan Africa's heavily populated agricultural regions with a dispersed population [11]. The isolated population distribution makes it challenging to access essential infrastructure [12]. It accentuates individualism and isolation, which probably explains the slow penetration of modern technologies into the rural world and the weakness of trade [13].

The distribution of habitat dictated by the population density may explain the habitat distribution at two angles [14]: a strong population density contributes to the constitution of the aggregation of the habitat. In contrast, the opposite explains the habitat dispersed [6]. The distributed character habitat implies a fragmentation of the habitat and reduces plots per capita[15].

Conversely, East Africa countries are characterized by low rates of urbanization (i.e., the most population living isolated in the countryside with less than one hectare of farmland per family), dispersed habitats, exclusively manual agricultural, and self-subsistence farming [16]. Economic growth mainly depends on the agricultural sector [17]. However, as this latter depends on agricultural lands' availability, it is still a priority for policy-makers.

This calls for urgency to reconcile the logic of the agricultural space development by restructuring the disseminated rural habitat and the growth of agricultural production that arises in rural areas. Due to the demographic pressure, it is necessary to find a better way to optimize the land use and the dispersal habitat by adopting a new agricultural systems model in rural areas of East Africa countries. This may hold the attention of many researchers.

3. Materials and Methods

3.1. Materials

We used the Eviews 9 software to study the stationarity of the series and the various tests and estimates. We employed annual, and panel databases collected from the [18] for 5 East African countries (Burundi, Kenya, Rwanda, Tanzania, and Uganda) and cover 26 years, from 1990 to 2015. The 26 years were chosen to observe the dynamics in the food production index achieved through the rural habitat distribution (population density) and the farm size. Variables used are described as follows: (1) FPI: Food Production Index: the indices indicate the relative level of the overall volume; (2) PD: Population Density is people per square kilometers; (3) ALSPC: Agricultural Land Size per Capita (in hectares); (4) PUP: Percent of Urban Population which refers to the proportion of the population living agglomerated in urban areas. It is, therefore, a group of dwellings constituting a village or a city independently of the administrative limits; (5) EA: Employment in Agriculture, percentage of the total employment; (6) RARF: Ratio of Agricultural Researchers per 100 000 farmers; (7) PU: Pesticides Used (kg/ha); (8) ARS: Agriculture Research Spending; (9) PCLI: Percentage of Cultivated Land Irrigated; (10): PTS: the Size of the Total Population.

3.2. Methodology

The comprehensive Feasible Generalized Least Square (FGLS) regression has been used for estimation. Our analysis sought to seize the effects of PD, ALSPC, and PUP (taken as interest variables) on the growth of the food production index (FPI: dependent variable). We also considered other essential control variables whose influence improves the results, such as EA, PU, RARF, ARS, PTS, and PCLI.

The integral panel composition methodology was analyzed individually from 1990 to 2015. Therefore, we have adopted the transcendent logarithmic form for the following reasons:

- The linear, logarithmic form makes it possible to identify elasticities immediately, that is to say, the degree of sensitivity of the explained variable to a variation on an explanatory variable;
- The transformation of the variables into a logarithm allows the series to be stationary, and consequently, the estimations of the equations with the modified variables give good results;
- The series' transformation into a logarithm makes it possible to ensure the estimated models' linearity. It is also the basis of reducing the quantities of figures of the variables to be used.

The data in this understudy is a long panel and the random interference term ε_{it} . Specifically, GroupWise heteroscedasticity, autocorrelation within a panel, and contemporaneous correlation may have heteroscedasticity and autocorrelation. For such problems, some tests are then required.

The model takes the below formula:

$$ylFPI_{i,t} = \beta_0 + \beta_1 lPD_{i,t} + \beta_2 lALSPC_{\ i,t} + \beta_3 lPUP_{i,t} + \beta_4 lARS_{i,t} + \beta_5 lRARF_{i,t} + \beta_6 lEA_{i,t} + \beta_7 lPU_{i,t} + \beta_8 lPCLI_{i,t} + \beta_9 lPTS_{i,t} + \varepsilon_{it}$$

Where ylFPI is the logarithm of the Food Production Index; lPD is the logarithm of Population Density; lPUP is the logarithm of the Percentage of Urban Population; lARS is the logarithm of the Agriculture Research Spending; lRARF is the logarithm of the Ratio of Agricultural Researchers per 100000 farmers; lEA is the logarithm of the Employment in Agriculture; lPU is the logarithm of the total of the Pesticides Used; lPCLI is the logarithm of the Percentage of Cultivated Land Irrigated; lPTS is the logarithm of the Size of the Total Population; with $\varepsilon_{i,t} \sim error\ term$

4. Results

4.1. Descriptive Statistics

The values of the standard deviations (Table 1) show that the distributions of the variables considered do not deviate from the mean, except the PD variable. This one is closer to the mean. Besides, among all the variables, FPI, ALSPC, EA, and PTS variables are relatively stable and normally distributed (Prob. Jarque-Bera> 5%).

Table 1
Descriptive analysis

	FPI	ALSPC	ARS	EA	PCLI	PD	PTS	PU	PUP	RARF
Mean	4.520887	-0.716530	4.081292	4.247348	-0.502901	5.013638	22986753	-2.576751	0.972513	1.451757
Median	4.577279	-0.667322	3.980992	4.255749	-0.482562	5.497168	24844480	-2.525729	1.033603	1.193922
Maximum	4.974663	0.133350	6.022721	4.530447	0.799757	6.133398	47878336	0.207014	1.239472	2.501436
Minimum	4.158883	-1.608948	1.824549	3.786006	-1.792760	3.332205	5438957.	-4.605170	0.607469	0.587787
Std. Dev.	**0.201424**	**0.498494**	**1.269192**	**0.245176**	**1.023265**	**0.981858**	**12761165**	**1.594590**	**0.161772**	**0.566918**
Skewness	-0.250871	-0.176417	-0.144159	-0.446808	-0.130049	-0.579390	0.018077	-0.134105	-0.654147	0.428689
Kurtosis	2.132523	2.044593	1.549816	2.169727	1.471240	1.544526	1.796427	1.578511	2.302738	1.677908
Jarque-Bera	3.347538	3.457645	7.287201	4.959678	8.015863	11.53726	4.832980	6.975222	7.326032	8.276745
Probability	**0.187539**	**0.177493**	**0.026158**	**0.083757**	**0.018171**	**0.003124**	**0.089234**	**0.030574**	**0.025655**	**0.015949**
Sum	361.6710	-57.32239	326.5033	339.7878	-40.23208	401.0911	1.84E+09	-206.1401	77.80107	116.1405
Sum Sq. Dev.	3.205155	19.63118	127.2570	4.748776	82.71868	76.15963	1.29E+16	200.8745	2.067436	25.39033
Observations	80	80	80	80	80	80	80	80	80	80

Source: Author (software output).

From 1990 to 2015, the variables under analysis displayed disparities trends observed at a different level. All variables (dependent and independent) evolve from top to bottom. Regarding the food production index, we detect an exponential development for Tanzania and Kenya (figure1).

From 1990 to 2015, East Africa country recorded a slow rate of urbanization population. Tanzania and Kenya own a high rate of agglomerated population with a high level of agricultural size per capita (figure 3/C). Regions with a high rate of dispersed and rural habitats have small agricultural land area per capita. Nevertheless, countries with a high agglomerated population hold large land areas (figure 1& figure 3 A/C). Further, the agricultural land size per capita variable has decreased in response to the growth of the total population size (figure 1 & figure 3).

During the last 26 years under observation, the population of the East Africa region has almost doubled (figure3/D). This demographic explosion did not follow the growth of the agricultural land area, whereas, 90% of that population still depends on the agriculture sector. This has led to considerable fragmentation of farm size per capita, which is currently less than one hectare (figure3/A). Besides, the food production index growth does not follow at the same rate as the increase in population (figure3/B & figure3/D).

By exploring the relationship between variables (figure 2), theoretically, until now, in East African countries, we note that agglomerated habitat (PUP) correlates positively with the growth of the size of agricultural land per capita (ALSPC).

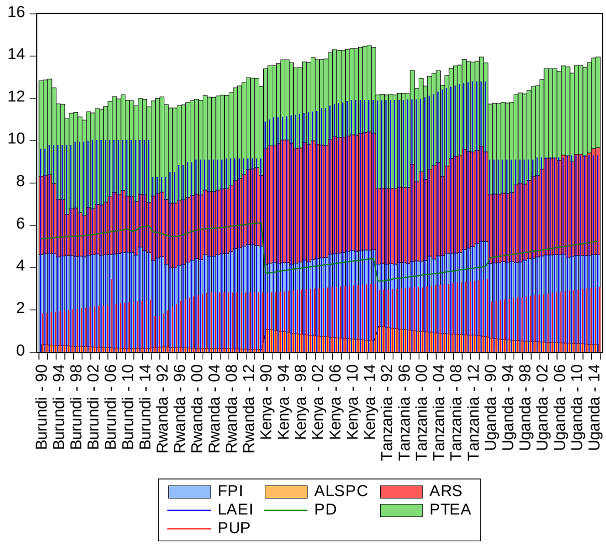

Figure 1: Variables evolution. Source: Author (software output).

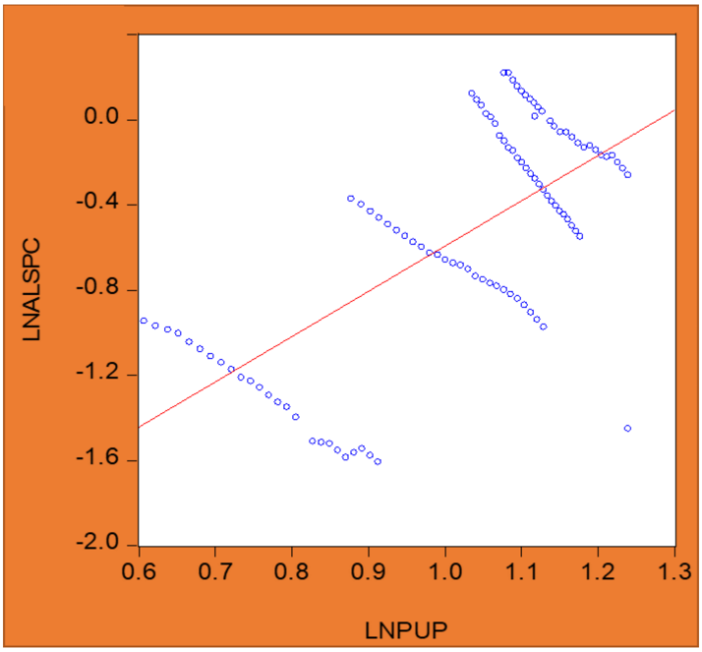

Figure 2: Relation between the food production index and the Percentage of the Urban Population. Source: Author (software output).

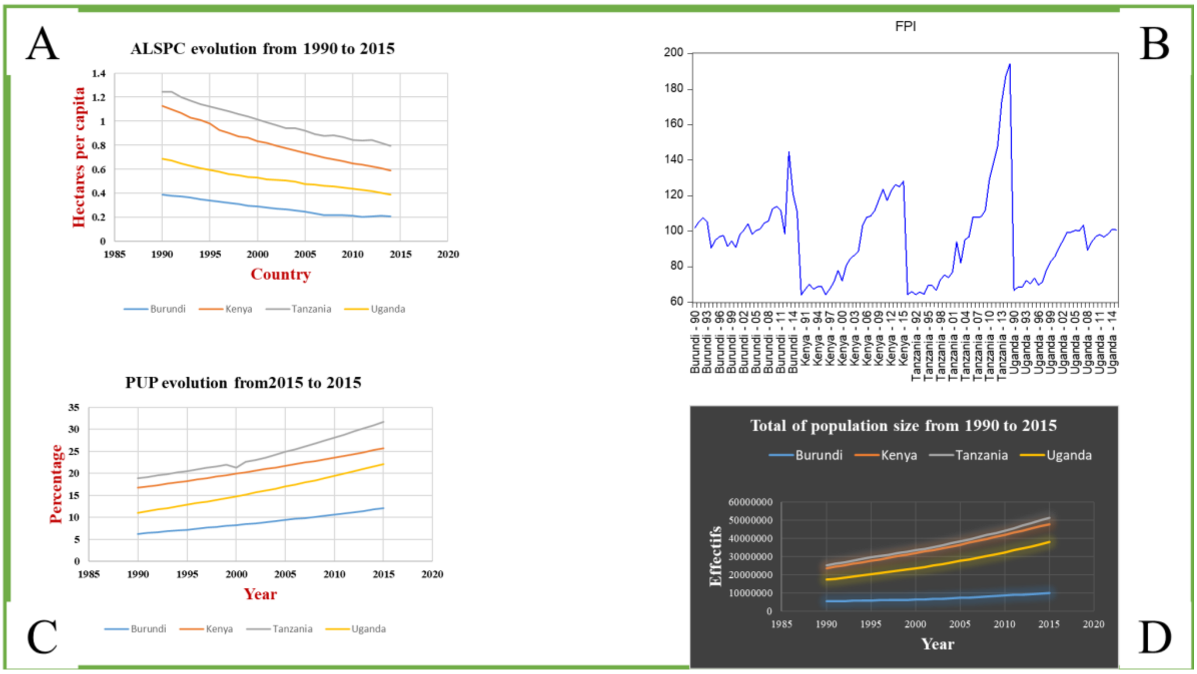

Figure 3: Auto-assessment and relationships between interest variables. Source. Author (software output).

4.2. Correlation and Causality between Dependent and Interest Variables

Remember that a variable *X* variable is said to cause *Y* if *Y's* future values can be better predicted using both *X* and Y than it can by using the past values alone.

According to the results from table 2, there are unidirectional causalities between dependent and interest variables:

- Population density (PD) causes both the agricultural land size per capita (ALSPC) and the percent urban population (PUP).
- The population density does not cause directly on the growth of the food production index in East Africa. The population density indirectly explains the dynamics of the East African region's food production index (FPI) through the percentage of the urban population. Figure 4 summarizes the causal links found between variables.

Table 2

Results of Block Exogeneity Wald Tests

K	Dmax	Dependent variables	Explanatory or causal variables/Probability			
			LFPI	ALSPC	LPD	LPUP
		LFPI	-	5.14 (0.07)	5.51 (0.06)	0.13* (0.03)
		ALSPC	137 (0.50)	-	14.46* (0.00)	2.72 (0.25)
4	1	LPD	4.11 (0.12)	1.12 (0.57)	-	4.38 (0.11)
		LPUP	4.38 0.11)	3.57 (0.17)	7.13* (0.02)	-

*Source. Author (software output); (.): Probabilities (p-value); *: significant at 5%; and values = statistics of x2; k: optimal lag of the level VAR (SIC); d_{max}: maximum order of integration of variables.*

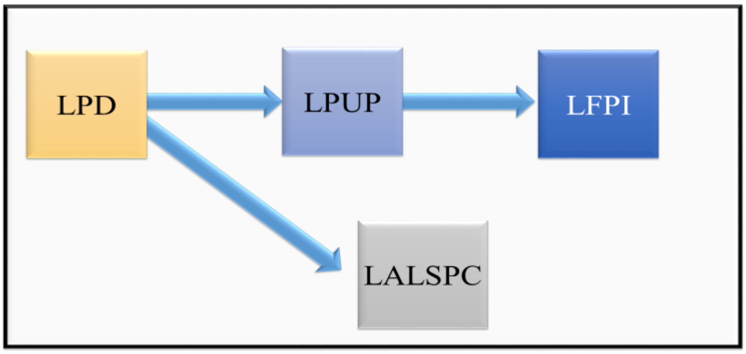

Figure 4: Causality between dependent and interest variables. Source. Author (software output).

4.3. Feasible Generalized Least Square (FGLS) Regression

The data in this study is a long panel. The random interference term ε_{it} may have heteroscedasticity and autocorrelation. For such problems, we need to test first:

(1) Groupwise heteroscedasticity : the p-value that both ordinary least squares (OLS) and the FGLS strongly reject the original hypothesis of homovariance, that is, there is heteroscedasticity between groups. Probability > Chi2 (113.76) = 0.0000;

(2) Autocorrelation within the panel: According to the results of the Wald test, the p-value is 0.0818, there is intragroup autocorrelation;

(3) Contemporaneous correlation: results of this test show that the p-value of Breusch Pagan LM statistic is 0.0011, which strongly rejects the original assumption of "no contemporaneous correlation", that is, it is considered that there is a contemporaneous correlation.

Above (1), (2), and (3) effects exist, so the FGLS method should be used for estimation.

Table 3
Cross-sectional time-series FGLS regression

FPI	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
EA	-.232	.236	-0.99	.325	-.694	.23	
RAFRF	.014	.009	1.68	.093	-.002	.031	*
PU	-.06	.058	-1.05	.296	-.173	.053	
ARS	0	0	0.07	.941	-.001	.001	
PCLI	.099	.055	1.82	.069	-.008	.206	*
PD	.961	.268	3.58	0	.435	1.487	***
PUP	-.061	.047	-1.30	.193	-.153	.031	
ALSPC	-.636	.318	-2.00	.045	-1.258	-.013	**
Indivi : base 1	0	.	.	.	.	.	
2	1.387	.503	2.76	.006	.401	2.374	***
3	2.058	.597	3.45	.001	.888	3.228	***
4	.695	.217	3.20	.001	.27	1.121	***
t	-.014	.007	-1.89	.058	-.028	0	*
Constant	.693	1.94	0.36	.721	-3.108	4.495	
Mean dependent var		4.532	SD dependent var			0.243	
Number of obs		104	Chi-square			203.202	

**** p<.01, ** p<.05, * p<.1*

Source: Author (software output)

A high agglomerated population (high density) influences positively and significantly the food production index (table 3). An increase in agglomerated population (PD) 1% accelerates the food production index (FPI) growth of 0.961 %. Results from table 3 reveal that RARF, PCLI, and ALSPC variables also influence the dynamic of FPI.

5. Conclusion and Discussion

From 1990 to 2015, the agricultural land size per capita variable has not progressed in response to the increasing population and the disseminated habitat associated with acute scarcity of agricultural land. Countries (Tanzania and Kenya) with a high percentage of urban population (agglomerated habitat) display a high level of food production and high agricultural land per capita size. This implies that increasing the number of people living in agglomerated areas will liberate and expand the scope of agricultural land per capita. Besides, countries with a high rate of the dispersed rural population (Burundi, Rwanda, and Kenya) display a small agricultural land per capita and a low level of the food production index.

The population density variable is assimilated to a given region's dispersion and agglomerated habitat, which correlates with the availability and size of agriculture land per capita [19].

Densely populated areas provoke an agglomerated habitat. Rising the agglomerated habitat could increase the size of agricultural land per capita and the food production index.

Therefore, we can deduce that urbanization contributes to liberating and increasing the agricultural land size per capita, gradually fragmented by the dispersed rural population. A problem remains: how to improve the food production level to feed the galloping population adequately? This population mainly lives scattered in rural areas with fragmented agricultural lands. In East Africa, mitigating the current dispersed character of the habitat distribution deserves particular attention to alleviate food security issues and the increasing population [16]. Therefore, different viewpoints have been developed by various researchers.

Many scholars hold a relationship between farm structure, thus size, and its productivity. They emphasize that the isolated population negatively correlates with land use, whereas agricultural land availability increases agricultural productivity enormously [11]. The demographic pressure and the dispersed habitat cause the farmland to decline. This hampers its appropriate and sustainable use [6]. Researchers assert that the land area's size influences the farming system's efficiency and the best yields [20]. Large farms are more beneficial than small farms in terms of financial profitability, productivity, and agricultural technological development, such as facilitating agricultural mechanization and innovations policy [21, 22]. A firm can maximize its output efficiently using the inputs and technology at its disposal [23]. The increase in the size of farms can be brought about by the land consolidation policy of households, reducing production costs (investments), and positively influencing agricultural productivity growth [22, 24]. Large farms facilitate farm research and development and the establishment and use of agricultural infrastructure. Land consolidation makes it possible to mix small isolated plots, making it easy to achieve agricultural investments [25, 26]. The success of the farmland consolidation policy requires solving the disseminated rural habitat. These issues remain concerns in East Africa's rural areas [27]. This will contribute to making more viable agricultural land use. In the past, some nations were essentially agricultural societies, living atomized and dispersed in rural areas, and are now experiencing tremendous socioeconomic transformations. This has been achieved thanks to the increasing rate of urbanization and the establishment of new rural economy units: the village programs and agricultural cooperatives.

The impact of grouping villages has been perceived as the best to accelerate developmental work in interior villages [28]. The latter are considered as models guaranteeing the self-organization of a collective way of life [29]. Many scientists have already shown the multiple advantages of grouping populations into villages to increase the size of the area and agricultural productivity. The villages unite the people living dispersed in a given territory, allowing the grouped populations to enlarge their cultivation plots and live with them near them [30]. Reconstituting villages enables efficient and sustainable land use [31]. The reinstalling of rural villages increases the agricultural size and income of rural population. In short, this policy makes it possible for agricultural collectivization programs and other economic activities [32]. If the rural people live in villages, it would be possible to preserve and recover residential, and agricultural land. Once the rural populations embrace villages, it becomes easy to set up some public infrastructures such as irrigation systems, bridges, roads, schools, and hospitals to improve living conditions and household income inhabiting these villages.

The grouping of rural populations in villages reflects a fundamental transformation of rural forms into a purely collective approach [32]. Villagization policies have already shown their positive effects in many African countries as well as in Asian countries. In Tanzania and South Korea the grouping in villages of the populations (Ujamaa and Saemaul, respectively) dispersed in rural areas has allowed people to reduce agricultural imports due to independent production. The agrarian reform operated by Tanzania and South Korea through the village policy concluded as a production village made it possible to abolish private property through community collectivization [32].

Since the second half of the twentieth century, through collective efforts, China has modernized its agriculture through science and technology. The households' resettling into collectivities make the best success in farming [33-37]. This country initiated a village creation policy just after the Tanzania independence period. It was a question of reinstalling dispersed farms to live and work together. This collective life has allowed the acquisition of large farms exploitable sustainably [9, 26]. Reconstruction villages in favor of rural areas makes it possible to increase arable land, agricultural land, infrastructure, and public services. In doing so, Rwanda has set up a land model to bring together populations in villages (Umudugudu). This enabled that country to maximize its soils production and occupation [38]. In Ethiopia, the program to reinstall and the group dispersed households by gathering them in the positive effects on improving the livelihoods of these households. The village lifestyle allowed families to increase the size of their land properties and abandon traditional agricultural practical modes [27, 39]. The village policy's success has grown the rural population dispersed and abolished small individual farms; turning them into collective farms and accelerating the rapid urbanization process [32, 40]. To enable agricultural producers' groups to promote commercial agriculture and not that of practical remembers, decision-makers in sub-Saharan African countries invest in agricultural R & D to develop appropriate technologies [12].

Thus, promoting innovative research for agricultural development and extension is helpful by improving agricultural practices and high-yielding varieties. This requires to initiation of the farming producer to support services programs. As a result, the latter must be mobilized to join and group themselves in associations or cooperatives, proper channels of technological relays.

The agriculture sector is vital for a large segment of the East African countries' population. This sector is a significant opportunity to drive East Africa's economic growth [7]. The Eastern Africa region can alleviate the current food security problem and the low-income level of East African farmers through increasing agricultural productivity [1]. Increased agricultural productivity in sub-Saharan Africa could positively impact food security [41]. Indeed, the Sub-Sahara Africa region owns agricultural potentialities that improve and stimulate its economic sector growth [41]. Thus, Eastern African countries can rethink ways to revitalize their agricultural production factors to find sustainable solutions linked to genuine major challenges such as hunger, malnutrition, rural poverty, and the rural exodus [12].

There is a closer correlation between the habitat distribution and the increase in the urban population rate paired with agricultural area per capita dynamics. The increase in the proportion of people living in urban areas contributes to the rise in the urbanization rate by facilitating the release of rural land. This will consequently incite land enlargement through land consolidation and agricultural land size per capita availability. Accordingly, once the East African countries own large agricultural areas, they can envisage viable farming models allowing high productivity of cultivated land.

Within East African countries, agriculture is the pillar of the economy and people's livelihoods, although the land is scarce due to high demographic pressure. Simultaneously, agricultural inputs are not easily accessible due to high costs and low incomes; technological innovation is limited, and mechanization is almost non-existent. Thus, the policy-makers need to rethink how to model the optimal and efficient agricultural land use required to increase farm productivity and secure sustainable livelihoods. Knowing that more than 90% of the East African population are farmers living dispersed in rural areas with an income below the world poverty threshold, we assume that, like strategy, decision-makers can regroup households into villages that will allow for land consolidation. This could help liberate and expand farms. Hence, the cultivated land could be exploited economically and with better productivity.

The grouping of rural populations into villages will allow the change in the farming systems and the implementation of an optimal agricultural production and productivity model. Additionally, it facilitates intensive agriculture (using inputs and equipment such as tillers, mechanical threshers, and harvesters) and crop specialization, stimulating agricultural production maximization. This production system can promote agricultural mechanization mode to raise productivity and increase agricultural incomes. The success of this mechanization requires an increase in the size of cultivable areas.

Reducing the disseminated habitat by promoting the agglomerated ones stimulates the food production index growth through a more efficient land use resulting from grouping the rural population into villages through the land consolidation policy.

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