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EFFECTS OF FARMLAND FRAGMENTATION ON CROP PRODUCTION OF THE SMALLHOLDER FARMERS: EVIDENCE FROM ARSI ZONE, SOUTH EAST ETHIOPIA

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AUTHORS' CONTRIBUTIONS

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ABSTRACT

Ethiopia has low crop production in the agriculture of smallholder sector where farmland fragmentation is one of the major factors behind this problem. This study aimed at assessing the effects of farmland fragmentation on crop production of smallholder farmers in Arsi zone of South East Ethiopia. Data were generated by using survey questionnaire, focus group discussion, and interviews. Farmland fragmentation was measured by Simpson index and both descriptive and inferential statistics were used for data analysis. Sample sizes of 314 households were selected by using systematic random sampling technique from sampling frames. Simpson index was applied to compute farmland fragmentation. Multiple linear regressions were also employed to test how well fragmentation was able to predict crop production per hectare with relative contribution of each variable in the model. Results indicated that the study area has 3.54 average numbers of plots, 0.55 fragmentation indexes, 0.45 ha mean plot size, and 28 quintals total mean crop production per hectare. The qualitative data results also revealed that land transaction via dividing smaller plots was the major factor for land fragmentation. Multiple regression models established that land fragmentation had negative relationships with crop production per plot. Thus, the study suggested that the local government should curb the need for scarce farmlands by initiating nonfarm livelihood strategies among the farming households.

Keywords: Arsi zone; crop production; Ethiopia; farmland fragmentation; smallholders.

1. INTRODUCTION

Since the appearance of mankind on the planet Earth, land based resources are essential capital for the fulfillment of human needs. In line with this concept, FAO [1] states that land is critical natural resources that contains many other natural resources that are needed for life systems as a whole. As a result of many complicated factors, land fragmentation is a major concern in many of sub-Saharan African counties leading to adverse effects on the farming practices as it leads to enhancement of production costs and farm inefficiencies [2,3].

In Ethiopia, land is ruled by the state ownership land policy. The current rural land policy of Ethiopia was instituted in the 1995 constitution [4]. According to Yigremew [5], the Federal Democratic Republic of

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Ethiopia (FDRE) proclamation canceled the earlier rural land restrictions such as lease of land, hiring of labor on private farm and individual land holding of more than 10 hectare (ha). Thus, in Ethiopia, rural land is state property and allowed to be accessed by government allocation, inheritance, gift, and land leasing but cannot be sold, exchanged or mortgaged (FDRE, Proc. No. 456/2005). In relation to this, the government claims that state ownership of land prevents concentration of land in the hands of small number of land owners by purchasing with little money through misery sales of poor peasants [6,7].

Conversely, scholars comment on expropriation and redistribution of land in Ethiopia even based on legal conditions such as unoccupied land, land with no heirs and improper management imposed extreme fragmentation [8,9]. Proponents of privatization advocate that tenure security and efficiency of land productivity cannot be attained by state ownership of land [10]. As a result, the current land policy still casts shadow over issues such as usufruct land right and farmland fragmentation. Nearly, in 2010s about 72.1% of farmers operate on smaller than or equal to 1.2 ha, 43% of rural populations are landless, 60 % of the households do not have sufficient farmland [11]. The average farmland size in Ethiopia is 0.71 ha with 3.3 plots per households [12].

The country has fragmented smallholder agriculture. In relation to this, Bodurtha et al. [13] affirmed that average farm size in Ethiopia is 0.96 ha per household although it shows variation among regions such as Oromia 1.15 ha, Amhara 1.09 ha and Tigray 0.49 ha. Bezu and Holden [14] indicated that the average farmland size in southern Ethiopia is 0.86 ha. Teshome [15] described that in northern Ethiopia farm size average holding is 1.02 ha although some land holders have 5 ha and others are landless. Report on farm land fragmentation pattern of African countries from 1930 to 2005 showed less than 2 parcels on average per household although few countries including Ethiopia had 3.3 average plots per holdings [16].

In Ethiopia, fragmentation was overlooked as a problem of agriculture of the country for it was mixed up with studies of land tenure and land resources. In light of that, Rahmato [8] as well as Bodurtha et al. [13] well addressed challenges of shortage of land and reforms in Ethiopia. Mengistu [17] discussed the challenges of smallholder farmers in food production. Similarly, Bimerew [18] realized that shortage of land results in low income, food shortage and social insecurity. More specifically, Paul and Gĩthĩnji [12] discussed challenges of agricultural community in their production partially in relation to farmland fragmentation. Nevertheless, these studies disregarded empirical measurement of fragmentation although they discussed fragmentation in one or the other way.

Certainly, in Ethiopia literature suffers from misconception of fragmentation with scarcity and/or shortage of farmland. Fragmentation refers to dispersion of parcels computed by function of size of land, number of parcels, distance between parcels and home of owners [19]. The scarcity and/or shortage of farmland are insufficiency of size or ratio of farmland to holders in a given geographical area [20]. In view of that, Gudina [21] in his study in South East Ethiopia and Alemu et al. [22] in North West Ethiopia have measured farmland fragmentation. Nevertheless, these studies again missed modeling the effect of fragmentation on crop production. Accordingly, this study strived to model effect of fragmentation on crop production. Besides, the agro-ecological zones and gender dimension were given attention assuming that agro-ecological zones and gender would affect fragmentation and crop production at household level which were missed in the aforementioned studies. This study therefore aimed at measuring fragmentation, testing effect of number of plots on crop production, and to suggest on the current land policy implications to effective land use in the study area.

2. REVIEW OF FARMLAND FRAGMENTATION

2.1 Theoretical Background of Farmland Fragmentation

As Bentley [23] points, land fragmentation is defined as the situation in which a single owner consists of numerous spatially separated plots. Bizimana [2] also notes that land fragmentation refers to operating on two or more geographically separated tracts of land parcels. The most commonly acknowledged theory of farmland fragmentation is Schultz's theory of land sizes and productivity inverse relationship. The theory advocates that fragmentation reduces sizes of plots where as it increases the land productivity for it would motivate farmers into improving their farming techniques (Schultz, 1964). As the result, numerous supporters have come up all over the world promoting the assumption. Likewise, Barbier [24], Austin et al. [25], Wickramaarachi and Weerahewa [26] and Reuben et al. [27] who examined fragmentation and productivity inverse relationship had initiated many developing countries revising their rural land tenure systems with the assumption of thinking smallholder farms would be efficient and capable of responding to higher production.

Conversely, others found that farmland fragmentation has drawbacks in agricultural economy. As a result, agricultural productivity and income are reduced among practitioners [28]. The extreme drawback of fragmentation is that it limits the desire of a farmer to modernize or rationalize farm holding not only by introducing various new agricultural techniques such as machinery and irrigation systems but also preventing the introduction of new crops, disease controls and pesticides [29,30]. Therefore, it increases economic costs since it hinders mechanization, causes inefficiencies in production and involves large costs to alleviate its effects. Thus, scholars with rich experiences from all over the world point out that farm fragmentation is a significant factor in agricultural productivity [31-33,27].

2.2 Land Policy and Farmland Fragmentation in Ethiopia

Ethiopia has legalized three land holding policies in modern ages. In feudal Ethiopia, until 1974, *rist* and *gult* tenure systems were practiced [8] and the military *Derg* regime (1975 to 1991) ruled with state owned land law. In the current government, land is the property of state and the public with usufruct rights and it has become a point of debate among scholars and stakeholders [9]. The government advocates that state ownership of land prevents concentration of land in the hands of few people that aggravates landlessness and also leading to massive migration. Opponents favoring private ownership largely base their arguments on the behavior of economic agents and familiar property rights that will increase tenure security, investment and land market [10,34]. Likewise, beyond these disagreements of scholars and stakeholders on land ownership, the unforeseen effect of the existing rural land tenure of the country is great in encouraging land fragmentation.

Currently, Ethiopia experiences awful farmland fragmentation [21]. Evidences indicate that in feudal Ethiopia tenants were 42% of the total farmers. However, in 2010, of the total farming households 72.1% are operating on smaller than or equal to 1.2 ha, 60% of the households do not have sufficient farmland and the average farm size in Ethiopia is 0.96 ha per holding [14, 11]. Farm land fragmentation in Ethiopia was exacerbated during the Derg socialist regime due to successive land redistributions [22]. Considerably, the existing government land reform since 1997 has largely preserved the *Derg* system of expropriation and redistribution to deal with rural development issues in fragmented plots [13]. Indeed, the government has put in law inheritance of parents rural farmland by proclamation number 456/2005 (FDRE, 2005). However, the practice of dividing the existing smaller farmlands into other narrower plots and parcels has increased fragmentation for years in the country.

2.3 Conceptual Framework

Kassie et al. [35] argue that agro-ecology shapes the performance of agriculture in Ethiopia. Besides, Gudina [21] in his study sorts out demographic and socioeconomic factors affect fragmentation. Indeed, Alemu et al. [22] revealed that demographic and socioeconomic factors affect fragmentation and crop production. Consequently, this study was structured on the cause and effect relationship framework of variables in the study as stated by Imenda [36]. The framework has interwoven factors explaining the relationships between the dependent and the independent variables of this study. The dependent variable is household future voluntary land consolidation that is deemed to be influenced by independent variables as shown in Fig. 1.

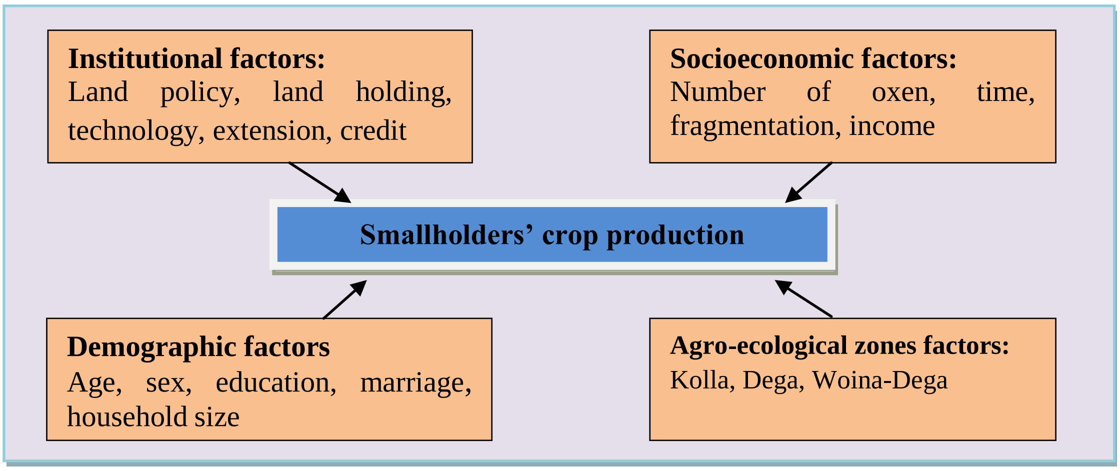

Fig. 1. The schematic diagram for crop production and predictor variables

Schematic diagram of variables showing the dependent variable (Blue) and the predictor variables categorized as institutional, demographic, socioeconomic and physical factors (Brown).

3. MATERIALS AND METHODS

3.1 Context of the Study Area

This study was carried out in Arsi zone of Oromia Region in South East Ethiopia which is located between $7^0$32'15"N and $8^0$32'45"N as well as $38^0$42' 30"E to $40^0$48'10"E (Fig. 2). Asella town is the capital center of the administrative zone situated at 166 Km from Addis Ababa. The zone has a total area of 20,982 km^2 that represents 7% of the total Oromia Region (Arsi-Bale Road Development Project, 2005). The Arsi zone altitude ranges between 600 meter above sea level (masl) in lowlands and above 4000 masl on higher peaks. The zone has agro-ecological zones of Kolla (tropical) 500-1500 masl, Woina-Dega (sub-tropical) 1500-2300 masl, Dega (temperate) 2300-3300 masl, and Wurich (alpine) above 3300 masl [37]. Accordingly, the zone experiences 12°C to 20°C annual range of temperature and bimodal rainfall from March to April and July to October [38].

According to CSA, the total population of Arsi zone in 2015 reached to 2,637,657 of which 1,323,424 were male and 1,314,233 were female [40]. The same data showed that 88.4% of the population is agriculturalists consisting of 0.3% pastoralists. The dominant livelihood in the zone is rain-fed subsistence farming. As Mesay and Tolesa [41] noted, Arsi is known for cool weather crops such as wheat (*Triticum aestivum*) and barley (*Hordeum vulgare*).

3.2 Sampling Techniques and Sample Size

Arsi zone was purposively selected as a study area based on researchers' prior knowledge of the problem of the study area. Currently, the study area is facing severe problem in farmland fragmentation and low crop production [21]. The study employed multistage sampling in selecting sample households. Initially, three districts namely Dodota, Hetosa and Tiyo were purposefully selected as study site. The reason for selecting these districts is related to the existence of more severe land fragmentation compared to other districts [42]. They also spatially occupy adjacent agro-ecological zones that represent much parts of Ethiopia with similar agro-ecological zones.

Subsequently, from each study district, two heterogeneous Rural Kebele Administrations (RKAs) (the lowest administrative units in the country) were randomly selected. Concurrently, sample size was computed in proportional size of each stratum as determined by using Kothari [43] formula as shown below.

$$n = \frac{Z^2 pqN}{e^2(N-1) + Z^2 pq}$$

where,

n= sample size,
Z= degree of confidence as value for selected alpha level,
p= precision of the population which is expected proportion of samples,
q= 1-p or variability value that is subtracted from precision of population,
N= population size and e= acceptable margin of error.

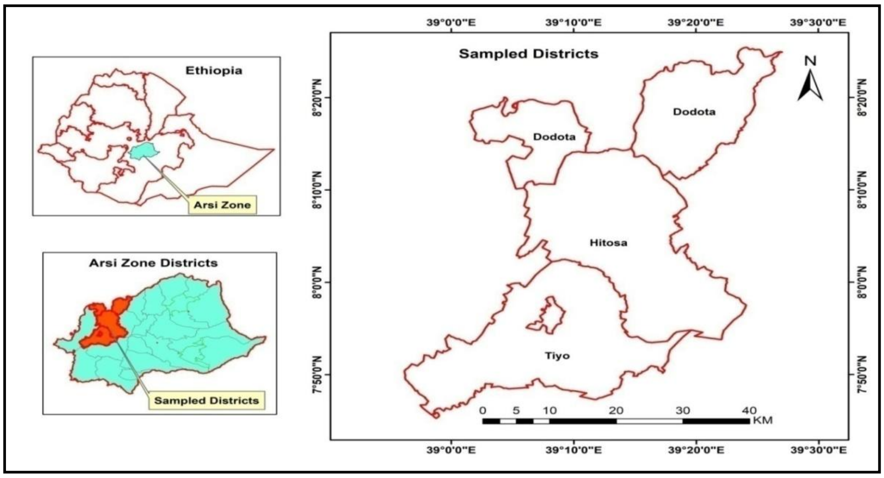

Fig. 2. Location map of the study area

Map of the study area showing location of Arsi zone (Blue) in Ethiopia (White) and sampled districts Dodota, Hitosa and Tiyo (White) in Arsi zone (Blue) as well as diverse colored (Left side map). (Source of the data/shape file: Oromia Urban Plan Institute, 2018) [39]

The constant value for Z at the significance level of 95% is (1.96), the proportion of the population is identified to be 75% that makes precision (0.75) and variability (0.25) according to the recent study made in the study area (Mengistu, 2014). The allowable error is 0.05 and the population consists of 5213 households in the study sites so that the computation shows:

$$n = \frac{1.96^2 x 0.75 x 0.25 x 5213}{0.05^2(5213-1)+1.96^2 x 0.75 x 0.25} = 273$$

Considering the advise by Naing et al. [44], 15% of the calculated sample size (273) was added and a total of 314 of which 241 male and 73 female were used in this study. Consequently, sampled households were selected by systematic random sampling techniques from sampling frames kept in the RKAs offices.

3.3 Data Collection and Analysis

According to Creswell, in concurrent mixed method research approach the researcher collects qualitative and quantitative data at the same time. This helps to carry out comprehensive analysis of the research problem as the qualitative describes the process and quantitative shows the outcome [45]. The data collection was carried out in May and June 2019 using data collection instruments, namely questionnaire, Focus Group Discussion (FGD), and Key Informant (KI) interviews.

3.3.1 Questionnaire survey

In this study, questionnaires composed of both closed and open ended questions were used. Major issues included in the questionnaire were household's demographic and socioeconomic characteristics, crop production, land tenure systems and land fragmentation. The questionnaire was pre-tested using pilot survey that supported correction of certain misconception in few questions. Subsequently, the questionnaire was addressed to sample farm households by 6 trained enumerators, all of them were Development Agents (DA)/Agricultural Extension Experts/.

3.3.2 Qualitative data

Qualitative data was secured from participants in FGD, KI and in-depth interviews. A total of 6 FGDs involving 36 participants (i.e. one FGD in each study Rural Kebele Administrations composed of six participants) were carried out. The participants were agriculture DA, two farmers, RKAs administrator, Kebele land administration expert, and women association leader. The Key informants were Zone administrator, Zonal senior agricultural extension expert, three district agricultural experts and three land administration experts. Indeed, six elderly farmers, one from each sample RKAs, were asked to narrate their life experiences. The KI interviews were interviewed to respond on how households get access to land, land fragmentation and crop production. The in-depth interview principally focused on exploring personal experiences in land fragmentation and crop production.

3.3.3 Data analysis techniques

Quantitative data were coded, edited, and entered into Statistical Package for Social Scientists (SPSS) software application version 20 for quantitative analysis. Qualitative data from FGD and interviews were analyzed using thematic analysis. Braun and Clarke (2006) substantiated that thematic analysis is a qualitative research method that can be widely used across a range of research questions for identifying, analyzing, organizing, describing, and reporting themes found within a data set. Besides, fragmentation was calculated by Simpson Index. In line with this, Demetriou et al. [19] stated that Simpson Index is compatible for measuring fragmentation. Accordingly, this index takes into account number of parcels belonging to holding, size of each parcel and total size of holding. Shuhao [46] defined that Simpson Index is a derivative of Simmons index subtracted from 1. Its index ranges between 0 and 1 where 0 implies no fragmentation for single plot and 1 shows highest fragmentation level.

$$\text{Simpson Index (SI)} = 1 - \frac{\sum_i^n (a2)}{\sum_i^n (A)2} \quad (1)$$

where,

n = number of parcel holding,
a= size of each parcel and
A= total farmland size.

Concurrently, multiple linear regressions were employed to test how well fragmentation was able to predict crop production per hectare together with the relative contribution of each variable in the model. In model assumptions, normality of data distribution was tested by Kolmogorov-Smirnov result. It relies on greater than 0.05 for no violation of normality of data distribution. Multicollinearity was tested by tolerance and variance inflation factors both being greater than 0.10 and less than 10 respectively.

Thus, model fitness was checked by model summary and the ANOVA result. In this model, a household's total production per hectare was the dependent

Table 1. Explanatory variables' descriptions and expected signs

Variable name	Variable description	Expected sign
X_1-Sex of HH head	1. Male 2. Female	+
X_2-Age of HH head	Continuous	+
X_3-Education of HH head	Grade level	-
X_4-Household size	Continuous	+
X_5-Fragmentation index	Continuous	-
X_6- Number of livestock	Continuous	+
X_7- Time to visit farmland	Continuous	+
X_8-Access to credit	1. Yes 2. No	+
X_9-Use of artificial fertilizer	1. Yes 2. No	+
X_{10}-Use of agricultural technologies	1. Yes 2. No	+

Source: compiled from the literatures

variable. The predictor variables were sex, age, education, household size, fragmentation, livestock number, time to reach farmland, credit access, use of artificial fertilizer and use of agricultural technologies as shown in Table 1. The model equation was estimated with ordinary least square (OLS) using robust standard errors as specifications were given as:

$$Y= \beta_0 + \beta_1X_1 + \beta_2X_2 + \ldots\ldots\ldots\ldots \beta_{10}X_{10} + \varepsilon \qquad (2)$$

where,

Y= crop production per hectare in quintals (constant),
ε = error term of the intercept and
$\beta_0, \beta_1 \ldots \beta_{10}$= regression coefficients.

4. RESULTS AND DISCUSSION

4.1 Demographic Characteristics of Households

The sex composition of respondents revealed that 76.8% are male-headed and 23.2% are female-headed households. The result shows that male-headed households have better crop production than female-headed households as presented in Table 2. The result is consistent with previous studies made in different parts of Ethiopia. Mengistu [17] reported that in Arsi zone rural households comprise 86% male-headed and 14% female-headed households. Mesele [47] also indicated that in Ethiopia rural households are composed of 75% male-headed and 25% female-headed households. The age of respondents ranged between 25 and 76 years with 44.7 years mean age. About 78% of the respondents' age is between 35-59 years and those above 60 years accounted only 9%. As it is presented in Table 2, the result shows that crop production is increasing to some extent with the increase of ages of the respondents. Urgessa [48] also finds that household head age is a positive determinant factor of agricultural production of rural households. Thus, the result establishes that age and crop production show positive relationships.

As explained in Table 2, education status classification was made based on the general education classifications of the country. Thus, out of sampled households 33.9% cannot read and write, 56.1% completed primary school and 10% attended secondary school. As it is presented in Table 2, the result explains that crop production is decreasing in quantity as the education status of the respondents is increasing. This implies that education status and crop production establish negative relationships as the less literate show more crop production in this study. Nonetheless, studies showed positive relationships of farmers' education and crop productions. Chowa et al. [49] in Malawi and Abrha [50] in Ethiopia find that knowledge and education enable farmers to adopt new technology, access inputs and properly market their agricultural products. Similarly, it can be observed in Table 2 that out of the total respondents 40.3% had 1-4 family members, 52% had 5-8 family members, 7.7% had 9-13 family members and average family size was 5.22. This result is congruent with Paul and Gĩthĩnji [12] finding in Ethiopia where the average family size is reported to be 5.27.

4.2 Land Holding of Households

Assessment of land holdings of households indicated that the average farm land holding is 1.59 ha with the standard deviation of 0.83 ha. In terms of number of plots of all respondents, 73.23% possessed 3-5 plots as illustrated in Table 3. The average number of plots was 3.54 and 79.4% of respondents experienced

Table 2. Demographic characteristics of sampled households

Demographic characteristics	Frequencies	Percentages	Total crops production in quintals
Sex			
Male	238	76.8	40.24
Female	72	23.2	30.78
Cumulative	310	100	38.04
Age			
25-34	40	12.9	24.53
35-59	241	77.7	39.17
60-64	11	3.6	63.62
65-76	18	5.8	50.39
Cumulative	310	100	38.04
Household size			
1-4	125	40.3	18.98
5-8	161	52.0	39.81
9-13	24	7.7	69.33
Cumulative	310	100	38.04
Education			
Cannot read and write	105	33.9	44.5
Primary school (1-8)	174	56.1	35.48
Secondary school (9-12)	31	10.0	30.54
Cumulative	310	100.0	38.04

Source: compiled from field data, 2019

Table 3. Land holdings of sample respondents

Households' land holding and number of plots	Frequencies	Percentages	Total crops in quintals
Total land size			
0.02-1.00 ha	78	25.16	27.41
1.01-2.00 ha	149	48.06	37.30
2.01-3.00 ha	57	18.38	44.06
3.01-4.00 ha	23	7.43	53.2
4.01-4.50 ha	3	0.97	130.32
Cumulative	310	100	38.04
Number of plots			
1-2 plots	65	20.96	24.96
3-5 plots	227	73.23	38.48
6-8 plots	18	5.81	80.83
Cumulative	310	100	38.04

Source: compiled from field data, 2019

changing number of plots over their farmlands in the last ten years. Consequently, results showed that 41% indicated decreasing, 38% increasing and 21% stated no change of number of plots as shown in Table 3.

As indicated in Table 3, results revealed that respondents' total farmland sizes ranged between 0.02 ha and 4.5 ha. Of all respondents 8.4% held 3-4.5 ha, 25.16% held less than 1 ha and 48% held 1-2 ha. The result matches with Mengistu's [17] findings in Oromia region where 8% of farmers are land less, 58% hold below 1 ha, 24% have between 1 and 2 ha, and 10% own 2 ha and above. The result also established that total crop production increased with the increase of total farm land sizes of the respondents (see Table 3).

The number of plots of the surveyed households ranged between 1 and 8. Noticeably, the result revealed that 21% possessed 1-2 plots, 73% possessed 3-5 plots, 6% possessed 6-8 plots and the average plot number was 3.54. Thus, the result is comparable to Gudina [21] findings where in Arsi highlands of Ethiopia among the smallholder farmers 18 % hold 1-2 plots, 69% have 3-4 plots and 13% own 5 and above plots. The plots varied in size, the smallest being 0.02 ha, the largest 1.25 ha and average parcel size 0.45 ha. Similar trends are also reported by Lowder [51] where in Central and Eastern Europe, the mean parcel sizes are recorded as 0.3 and 0.5 ha respectively. Key informants argued that rural land gift and inheritance were the major cause of farmland fragmentation. The same respondents verified that heirs/beneficiary of land gift abuse the land they get from parents/other family members by illegal subdividing and illicit land sales.

4.3 Farmland Fragmentation of Households

Computation on fragmentation of farmland owned by sample households measured in Simpson Index indicated that the smallest index is 0.00, the largest index is 0.98 and the average index is 0.55. In line with this, Austin et al. [25] suggested that fragmentation indices could be shown in summary table to understand the status of the calculated fragmentation indices. Thus, fragmentation indices of the households are depicted in Table 4.

As described in Table 4, 40% of the respondents practiced more than 0.60 fragmentation index which is regarded as excessive fragmentation. Pearson correlation was employed to test relationships between fragmentation and crop production per hectare. Thus, Pearson correlation between the two variables was negative and significant [$r = -0.156$, $n = 310$, $p = 0.006$]. Besides, an independent samples t-test was used to test statistical differences on fragmentation by sex of the respondents. The result explained that there was no difference in scores on fragmentation between the respondents by sex at $p < 0.05$ for male (M = 0.56, SD = 0.22 and female [M = 0.54, SD = 0.19; $t(308) = 0.537$, $p = 0.591$].

In addition, One-way ANOVA was employed to test differences in farmland fragmentation between agro-ecological zones. Thus, agro-ecological zones were grouped to three categories (Group1: Kolla; Group2: Dega; Group3: Woina Dega) as presented in Table 5.

The Post-hoc comparisons using Tukey test indicated that mean scores for Kolla (*M* = 0.53, *SD* = 0.17), Dega (*M* = 0.67, *SD* = 0.23) and Woina Dega (*M* = 0.45, *SD* = 0.17) were significantly different from each other at $p < 0.01$ [$F(2,307) = 38.017$, $P = 0.000$]. The land fragmentation in the Dega area is greater than that in the Kolla agro-ecological zone by a mean difference of 0.14580 and significant at $P < 0.01$. This means that compared to the Dega agro-ecological zone Kolla agro-ecological zone shows less fragmentation index by a mean difference of 0.14580 and this is significant at $P < 0.01$. Similarly, land fragmentation of Dega is greater than that of Woina Dega by a mean difference of 0.23078 and significant at $P < 0.01$. The study implies that Dega agro-ecological zone has the highest fragmentation rate.

4.4 Crop Production of Households

The average crop production per hectare per household was 28.5 quintals with the standard deviation of 24.33. Of total respondents, 35.4% produced 1-20 quintals, 55.2% produced 21-50

Table 4. Summary table for farmland fragmentation of sampled households

Fragmentation index	Frequency	Percentage
0.00-0.20	21	6.8
0.21-0.40	52	16.7
0.41-0.60	112	36.2
0.61-0.80	76	25.0
0.81-1.00	49	15.3
Mean/Cumulative	310	100

Source: compiled from field data, 2019

Table 5. Multiple comparisons between agro-ecological zones by fragmentation indices

(I) Agro-ecological zone households	(J) Agro-ecological zone households	Mean Diff. (I-J)	Std. error	Sig.	95% Confidence Interval	
					Lower	Upper
Kolla	Dega	-.14580*	.02639	.000***	-.2080	-.0837
	Woina-Dega	.08497*	.02626	.004***	.0231	.1468
Dega	Kolla	.14580*	.02639	.000***	.0837	.2080
	Woina-Dega	.23078*	.02676	.000***	.1678	.2938
Woina-Dega	Kolla	-.08497*	.02626	.004***	-.1468	-.0231
	Dega	-.23078*	.02676	.000***	-.2938	-.1678

Source: compiled from field data, 2019
*Note: ***= Significant at 1%*

quintals, 7.4% produced more than 50 quintals and 2% did not produce any crop during the study year (2019/20). The Pearson correlation between total number of plots and crop production per hectare was negative and significant [r = - 0.15, n = 310, p = 0.018]. This implies that larger number of plots gives higher total crop production but smaller crop production per hectare. The result is consistent with many studies made in different parts of the world such as Manjunatha et al. [52] in India, Teshome [15] in Ethiopia as well as Ali and Deininger [53] in Rwanda where increasing number of plots was reported to have negative effect on crop production per plots.

Results from FGD confirmed that scattered plots had advantages for enabling farmers to cultivate various crops over the dissimilar farm plots. Conversely, the same discussants mentioned that dispersed farm plots demanded traveling between scattered plots and hindered using machineries on smaller plots. Complementally, Key Informants addressed that the smallholder farmers in their local areas face shortage of farmlands and fragmentation has reduced their crop production and farm productivity. Accordingly, similar informants appended that there were no prohibitions on bisecting of farmlands beyond the minimum farm plot size limit (0.5 ha) which was fixed by land law of the Oromia Region state (Proclamation number No.103, 2007) [54].

Likewise, results showed that about 52% of the respondents feel that crop production is constrained by scarcity of farmland, 30% claimed climate variability and lack of modern agricultural technologies was stated by 17%. Regarding causes of land fragmentation and increasing of number of plots, more than half of the respondents (51%) stated high population pressure, 25% reported land leasing, 14% claimed land inheritance and 10% indicated sharecropping.

One in-depth interviewee talking on the problems related with the farmland fragmentation and low crop production in the study area reflected his own experience and feeling in the following way:

> *…''From security point of view, on producing different crops for the family, I prefer to operate on scattered plots in dissimilar fields. Nonetheless, working on scattered plots is a tiresome duty that needs walking up and down between plots and results in lower crop yields for smaller plots require higher production inputs. Thus, weighing the cost and benefit I have experienced, I suggest the government initiates land reallocation or land consolidation based on agreements of farm households…''(Farmer household narrator, June 2019).*

4.5 Household Crop Production per Plot

Multiple linear regressions were employed to identify determinants of household crop production per plots of land. In this regression model, a household's total crop production per hectare was taken as a proxy to a household's crop production per plots of land and hence the dependent variable of the model. Thus, a total of 10 variables were selected for modeling and the regression was estimated with Ordinary Least Squares as shown in Table 6. Out of the total predictors, five were significant at 1% probability level. Normality of data distribution was tested using Kolmogorov- Smirnov and Shapiro-Wilk tests. The results were 0.145 and 0.947 respectively and are greater than 0.05 suggesting that there was no violation of normality of data distribution. Multicollinearity was also checked using VIF and no problem of multicollinearity was reported. Besides, R^2 value is equal to 0.359 which indicates that all independent variables together explained about 35.9% of the total variations in the dependent variable. The ANOVA result showed that there was linear relationship between the dependent and independent variables at $P < 0.01$ ($F (10, 299) = 7.902$, $P =000$) and hence, the model is fitted.

The regression model established that the reduced regression equation for significant predictors in the model was developed to be as crop production per ha $= 1.548x_3 - 36.532x_5 -+2.220x_6 - 7.872x_8 + 9.997x_{9} + \varepsilon$. As a consequence, education status as a variable captures the influence of literacy on household total crop production per hectare. It was established that better literate households produced more total crop production per hectare compared to the less educated households. Thus, education of heads of households was positively and strongly correlated with crop production per hectare at $p<0.01$. Accordingly, a unit increase in education status increases household total crop production per hectare by a factor of 1.548. The implication behind is that literacy directly results in improving household total crop production per plot of land on fragmented farming. The result is consistent with the studies made in different parts of Ethiopia. Accordingly, Mengistu [17] found in South east Ethiopia that education plays great role in improving household crop production. Abrha [50] also found in Northern Ethiopia that education plays great role in improving household crop production by enhancing skill of farmers for managing their farming.

Table 6. Multiple linear regression of mean total crop production per hectare

Variables considered in the study	Unstandardized coefficients		Standardized coefficients		Sig.	Collinearity	
	B	Std. error	Beta	T		Tolerance	VIF
Constant	57.113	15.207		3.756	.000		
Sex of HH head	-2.146	3.247	-.037	-.661	.509	.830	1.204
Age of HH head	.218	.178	.091	1.225	.222	.477	2.097
Education of HH head	1.548	.504	.222	3.073	.002***	.505	1.979
Household size	-.720	.677	-.064	-1.064	.288	.734	1.363
Farmland fragmentation	-36.532	7.131	-.318	-5.123	.000***	.687	1.455
Number of livestock	2.220	.501	.282	4.435	.000***	.652	1.533
Time to visit farmland	.039	.112	.019	.350	.727	.856	1.168
Access to credit	-7.872	2.715	-.160	-2.900	.004***	.868	1.152
Applying fertilizers	9.997	3.697	.142	2.704	.007***	.956	1.046
Applying Agri. technologies	-5.989	4.997	-.065	-1.199	.232	.910	1.099

Source: compiled from field data, 2019
*Note: *** Significant at 1%*

Likewise, the number of livestock owned by a household was positively and strongly correlated with household total crop production per hectare at $p < 0.01$. A unit increase in the number of livestock increases household total crop production per hectare by a factor of 2.220. This implies that extra number of livestock gives an opportunity to improve crop production in various ways. The studies made in Ethiopia addressed that smallholder farmers mostly depend on oxen for plowing and it influenced household crop production per plots (Baye, 2017) [21].

Besides, application of artificial fertilizer by a household on fragmented plots was positively and strongly correlated with household total crop production per hectare at $p < 0.01$. A unit increase in using artificial fertilizer on farm plots increases household total crop production per hectare by a factor of 9.997. The studies made in Ethiopia indicated that smallholder farmers mostly depend on application of artificial fertilizer on their farms to increase crop production per plots [50, 48].

Conversely, households with less credit access produced higher total crop yield per hectare compared to households with higher credit access. Thus, a household's credit access was negatively and strongly correlated with its total crop production per hectare at $p < 0.01$. Accordingly, a unit increase in household credit access decreases households total crop production per hectare by a factor of 7.872. Here what should be realized is that credit access does not directly result in impeding and/or improving household total crop production per hectare. However, households with more credit access were engaged in non-farm alternative livelihood strategies.

Farmland fragmentation was negatively and strongly correlated with household total crop production per hectare at $p < 0.01$. A unit increase in fragmentation decreases a household's total crop production per hectare by a factor of 36.532. This attributes to declining of inputs and time farmers have to use on fragmented plots as the number of plots increases. The same result was reported by Kakwagh et al. [55] in Nigeria where extra number of plots is creating difficulty to improve crop production per plot. Kiplimo and Ngeno [33] in Kenya found that increasing number of plots increases production costs per plot as fragmentation hinders mechanization. Similarly, Manjunatha et al. [52] in India, Ali and Deininger [53] in Rwanda, Wickramaarachchi and Weerahewa [26] in Sir Lanka as well as Alemu et al. [22] in Ethiopia found that fragmentation negatively affect crop production per plots on smallholder farmers. Contrary, Unal [56] in Turkey reported on positive correlation of fragmentation and crop yield. Paul and Gĩthĩnji [12] in Ethiopia also realized that an additional plot is significantly increasing the crop yield of farmers. The contrasting incidents warrant the need for more extensive research to establish credible empirical evidences in the context of any country where farm land fragmentation is evident.

5. CONCLUSION

The series of discussions in this study have shown that most small holder farmers are operating on fragmented farmland and shortage of farm land is rampant. It is also learnt that in the study area, farmland fragmentation has shown great effect on smallholders' crop production. Rural land gift and inheritance were identified as the major causes for bisecting household farmlands. To make the matter worse, these land rights are abused due to illegal selling of part of the land and absence of strong government institutions to stop the illegal practice. The study further exhibited that farmland fragmentation is attributed to scarcity of land by households. The inverse relationship between farmland fragmentation and crop production evidenced in this study poses a great challenge to land administrators to craft interventions that could compensate the crop loss.

To mitigate the low crop production per plot resulting from continuous farmland fragmentation, it is suggested that the local governments should initiate non-farm livelihood strategies among farming households. The local land administration institutions should sensitize farm households to consider farmland consolidation on voluntary basis and gradually proceed to systematic land consolidation. They should also enforce farm households to observe the minimum farm plot size stipulated in the rural land law. Furthermore, efforts should be made to stop illegal sale of land secured through gift, inheritance and government allocations to curb further land fragmentation. In sum, the federal government should review the current land policy in light of actions that could enhance escaping further land fragmentation and moving towards measures that could motivate farmers to appreciate the values of land consolidation.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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