Can Land Fragmentation Reduce the Exposure of Rural Households to Weather Variability ?

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Abstract

Climate change continuously affects African farmers that operate in rain-fed environments. The traditional way of coping with weather risk through credit and insurance markets is almost inexistent as these markets are imperfect in the African economies. Even though land fragmentation is often considered as a barrier to agricultural productivity, this study aims at exploiting whether land fragmentation, as an insurance alternative, is able to reduce farmers exposure to weather variability. In order to address this research question, I use the Living Standards Measurement Study-Integrated Surveys on Agriculture (LSMS-ISA) data on Uganda. After dealing with the endogeneity of land fragmentation, I find that higher land fragmentation decreases the loss of crop yield when households are experiencing rain deviations. Therefore, policy makers should be cautious with land consolidation programs.

JEL: Q12, Q15, Q54

Keywords: climate change, land fragmentation, rainfall, yield, insurance

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1 Introduction

Global warming is a crucial issue for the African continent and it is expected that this situation will get even worse in future. At the same time, Africa is the least responsible for GHG emissions, but would be the most affected by the consequences as its adaptive capacity is very low. The majority of the population is engaged in agriculture sector which is highly sensitive to weather variability. Climate change affects agricultural production and livelihoods and it increases the frequency and the severity of extreme events. A great part of the population in Africa experienced already a variety of stresses and shocks. The traditional way of coping with weather risk through credit and insurance markets is almost inexistent as these markets are imperfect in the African economies. Despite the lack of access to these markets, households employ different arrangements in order to cope with it. Among others, they choose sub-optimal low-risk/low-return portfolios, diversify the sources of income by working in the non-agricultural sector or by migrating.

Land fragmentation, defined as a farm that has spatially separated parcels of land, is an incidence observed in many countries especially in developing countries. About 80% of the land holdings in the world are fragmented. Land fragmentation is often considered as a barrier to agricultural productivity. There are empirical evidences that increases in land fragmentation leads to lower agricultural output and agricultural productivity [Wan and Cheng, 2001, Rahman and Rahman, 2009, Van Hung et al., 2007, Tan et al., 2010]. Another problem associated with land fragmentation is the distance between parcels. In particular, when parcels are dispersed, travel time and costs in moving labor and machines can increase. In this sense, it was shown by the literature that land fragmentation increases costs of production and cost of labor [Shuhao et al., 2008]. In addition, it is also shown that land fragmentation can hinder machinery use by farmers [Foster and Rosenzweig, 2011]. Another drawback of land fragmentation are fencing costs, small size and irregular shape of parcels, and conflicts among neighbors [Demetriou, 2013]. However, there is not a consensus on whether land fragmentation has a negative impact on agricultural outcomes. [Shuhao et al., 2008] find that the level of land fragmentation has no significant impact on yield and therefore rejects the hypothesis that fragmentation is inefficient in the case of Ghana and Rwanda.

Besides this land fragmentation can provide benefits to farmers. It can facilitate risk management thought seasonal and spatial diversification of crop production [Blarel et al., 1992, Bentley, 1987, Van Hung et al., 2007]. This would minimize the exposure of farmers to climatic variability and disasters as production risk is spatially spread. Blarel et al. [1992] proved empirically that land fragmentation reduces the variability of agricultural output per acre. Fragmentation also allows for adjustments of household labor across seasons as crop scheduling is feasible when parcels are scattered in different locations with different agro-ecological characteristics [Fenoaltea, 1976]. Furthermore, land fragmentation improves agro-biodiversity as crops are better matched with the operated soil types [Di Falco et al., 2010].

This paper aims at exploiting the ability of fragmented land holding of farmers to reduce their exposure to weather variability. More precisely, the objective is to study empirically whether households with higher degree of fragmented land incur smaller reducing in their agricultural income when they are subject to rainfall irregularities compared to households with more consolidated land. The contribution of the paper is twofold: it does a quantitative research on the incidence of fragmentation on agricultural income by taking into account the rainfall variability, which to the best of my knowledge, has not been addressed by the literature; and to contribute to the cost/benefit debate of land fragmentation in the case of Uganda.

In order to test whether land fragmentation may reduce the damages of exposure to rainfall variability, I estimate the impact of the degree of land fragmentation on agricultural yield of household. Land fragmentation is measured by the number of parcels that the household owns and also by a Simpson Index calculated for these parcels. An important issue that arises is that land fragmentation can be affected by some unobserved factors that influence agricultural income (management ability, entrepreneurial spirit). Also, farmers can choose their level of land fragmentation in order to deal with production risk. This is the case when land markers exist and land can be traded or rented. In order to deal with this issue, I instrument the fragmentation in operated land with the fragmentation in inherited land as inherited land fragmentation is exogenously imposed on the household through the inheritance process [Foster and Rosenzweig, 2011]. I use data from the Living Standards Measurement Study-Integrated Surveys on Agriculture (LSMS-ISA) for the years 2005/2006, 2009/2010, 2010/2011 and 2011/2012 established by the World Bank. The data used to construct the rain deviation variable is the TS3.12 dataset from the Climatic Research Unit of the University of East Anglia.

After instrumenting for the level of fragmentation, I find that higher land fragmentation is decreasing the loss of crop yield when households are experiencing rain deviation. The preliminary results show that the higher this deviation, the higher the beneficial effect of land fragmentation. These results are confirmed by the different measures used for land fragmentation.

Because of the wide acceptance of the inefficiencies of land fragmentation, some countries like Kenya, Tanzania and Rwanda, have adopted land consolidation programs. However if land, labor and insurance markets are imperfect, land fragmentation offer to households a risk mitigating tool, possibility to spread labor over seasons and provide food security. If labor market is imperfect, labor supply is fixed by the household and there is an important need to temporally spread labor. Moreover, farmers fail to cultivate land due to land market imperfections and not rather than its small size or fragmentation. Therefore, addressing land, labor and insurance market imperfection can be more suitable for agricultural productivity than consolidation programs.

2 Background

The main causes of land fragmentation are inheritance, population growth and land markets. In Uganda, population growth together with the traditional inheritance protocols are supposed to be the most important driver of the increased land fragmentation [Nkonya et al., 2004]. For instance, when the head of a household dies, his land is sub-divided among his sons. This phenomenon of land sub-division continues with each passing generation on the customary freehold lands. According to the World Bank indicators, about 84% of the population of Uganda lives in rural areas. Ugandan farmers tend to consider fragmentation as beneficial as it allows to grow different crops on parcels with different characteristics. However, in February 2015, the president Yoweri Museveni has strongly recommended farmers to stop land fragmentation that have increased in late years due to inheritance practices.

Uganda lies across the equator. Its climate is humid with very hot periods during the year. It has two rainfall seasons, one from March to June and another form August to November. Uganda has experienced extreme weather episodes in the last years, especially in the north. More precisely, between 1991-2000, Uganda experienced seven droughts. Nevertheless, the climate is suitable for crop production and the rainfall intensities are expected to grow. But the rainfall distribution across seasons will become more and more irregular. As the agricultural production is subsistent and rain-fed, the exposure of Ugandan farmers to such weather conditions is great and verifying whether land fragmentation can allow for reducing the damages is crucial.

3 Empirical strategy

In order to test whether land fragmentation may reduce the damages of exposure to rainfall variability, I estimate the following reduced form equation:

$$log(\frac{Y_{ht}}{A_{ht}}) = \alpha_0 + \alpha_1 X_{ht} + \alpha_2 F_{ht} + \alpha_3 log(A_{ht}) + \alpha_4 RAIN_{dt} + \alpha_5 RAIN_{dt} * F_{ht} + \mu_h + \eta_t + \varepsilon_{ht} \quad (1)$$

where Y_{ht} represents the value of total agricultural output of household h in time t. The total agricultural output is evaluated at mean village prices for each crop that the given household produces The dependent variable is the ratio between the value of the agricultural production and the total land cultivated in acres. X_{ht} accounts for the household socio-economic characteristics such as the number of adults which is a proxy for the labor endowment, education, and age of the household head. A_{ht} represents the total cultivated land.

The degree of land fragmentation of the household is given by the variable F_{ht}. Land fragmentation is usually measured simply by the number of parcels that the household operates[1]. This variable induces the parcels that a household owns and rents. Among the owned parcels, households mainly inherit the different parcels and a lower part of them is purchased.

The Simpson Index (SI) is also used in several studies [Blarel et al., 1992]. The SI is defined as:

$$SI_{ht} = 1 - \sum_{i=1}^{n} a_{it}^2 / (\sum_{i=1}^{n} a_{it})^2 \quad (2)$$

where n is the number of parcels and a_{it} is the size of parcel i in time t. SI close to zero means that the land of the household is completely consolidated, there is only one parcel. The closest the value to one, the more fragmented the land of the household is.

[1]Parcels under fallow are also included in the number of parcels operated by the household

The value of the Simpson index is therefore determined by the number of parcels, the average size of the parcels size and the parcel size distribution.

This index does not take into account the total size of the land holdings of the farmer, the different characteristics of the parcels and the distance to the parcels. Therefore, the variable A_{ht} controls for these additional aspects of agricultural land. A_{ht} indicates the total land holdings of the farmer, the weighted average of land quality, the number of parcels with different slope and the number of parcels with different texture.

I include a variable $RAIN_{dt}$ that represents the annual deviation in rainfall at time t in the district d where the household lives, from the long run mean, divided by the long run standard deviation. $RAIN_{dt}$ accounts for the rainfall variability that households are facing. For sake of simplicity in interpretation, this variable is expressed in absolute terms. In addition, according to figure, there was more positive (and extreme) rainfall deviation in the different districts of Uganda than negative. The interaction term between the rainfall deviation and the degree of fragmentation accounts for a possible difference that might exist concerning the impact of rainfall variability on income between households that have different levels of land fragmentation. I expect that when households face the same rainfall deviation, more fragmented land holdings should lower the incidence on the income than more consolidated land holdings. Finally, mu_h and eta_t stand for household and time fixed effects.

A concern when estimating equation (1) is that land fragmentation is affected by some unobserved factors that influence agricultural income (management ability, entrepreneurial spirit). Also, farmers can choose their level of land fragmentation in order to deal with production risk. This is the case when land markers exist and land can be traded or rented. However in the case of Uganda, as land markets are incomplete we can assume that trading land is not entirely feasible. Still the degree of land fragmentation of the household can be, at least, partially chosen. In order to deal with this endogeneity issue, I instrument the fragmentation in operated land with the fragmentation in inherited land as inherited land fragmentation is exogenously imposed on the household through the inheritance process. [Foster and Rosenzweig, 2011]. Therefore the first stage estimation equation is as following:

$$F_{ht} = \beta_0 + \beta_1 X_{ht} + \beta_2 Ninherited_{it} + \beta_3 A_{ht} + \beta_4 RAIN_{dt} + \mu_h + \eta_t + \varepsilon_{ht} \qquad (3)$$

where *Ninherited* is the number of parcels inherited by the household i in time t. It should be noticed that the interaction variable, $RAIN_{dt} * F_{ht}$, in equation (1) is also endogenous and it is instrumented with the interaction term between rain deviation and number of inherited parcels. The other first stage equation is therefore given as:

$$RAIN_{dt}*F_{ht} = \gamma_0+\gamma_1 X_{ht}+\gamma_2 RAIN_{dt}*Ninherited_{it}+\gamma_3 A_{ht}+\gamma_4 RAIN_{dt}+\mu_h+\eta_t+\varepsilon_{ht} \quad (4)$$

4 Data and Descriptive statistics

In this study, I use data from the Living Standards Measurement Study-Integrated Surveys on Agriculture (LSMS-ISA) for the years 2005/2006, 2009/2010, 2010/2011 and 2011/2012 established by the Bill and Melinda Gates Foundation and implemented by the Living Standards Measurement Study (LSMS) within the Development Research Group at the World Bank. The Uganda National Panel Survey (UNPS) sample includes economic and social information on about 3 200 households (with about 2 000 households that are engaged in cultivation of crops). These households were previously interviewed in the 2005/2006 Uganda National Household Survey (UNHS). The sample also includes households that were randomly selected after 2005/2006. This sample is representative at the national, urban/rural and main regional levels (North, East, West and Central regions).

Table 1 presents definitions and the summary statistics of the dependent and explanatory variables used in the estimations. The main variable(s) of interest are the number of owned parcels and the Simpson index. The average number of parcels owned by households in the sample is 2.3 with the maximum being at 18. Considering the number of parcels with different texture and different slope, the average number of different parcels is 1.29 and 1.36 respectively. By definition, the Simpson index is between zero and one and the sample average is 0.35. The evolution of land acquisition of the households is given in Table 2. We observe that over the years the share of inherited land has increased and the share of inherited parcels stands for the half of the total parcel holdings of a given household.

Household heads have on average 46 years, are mostly male (about 70 per cent) and have on average attended only primary school. Only two per cent of the households did

Table 1: Definition and descriptive statistics

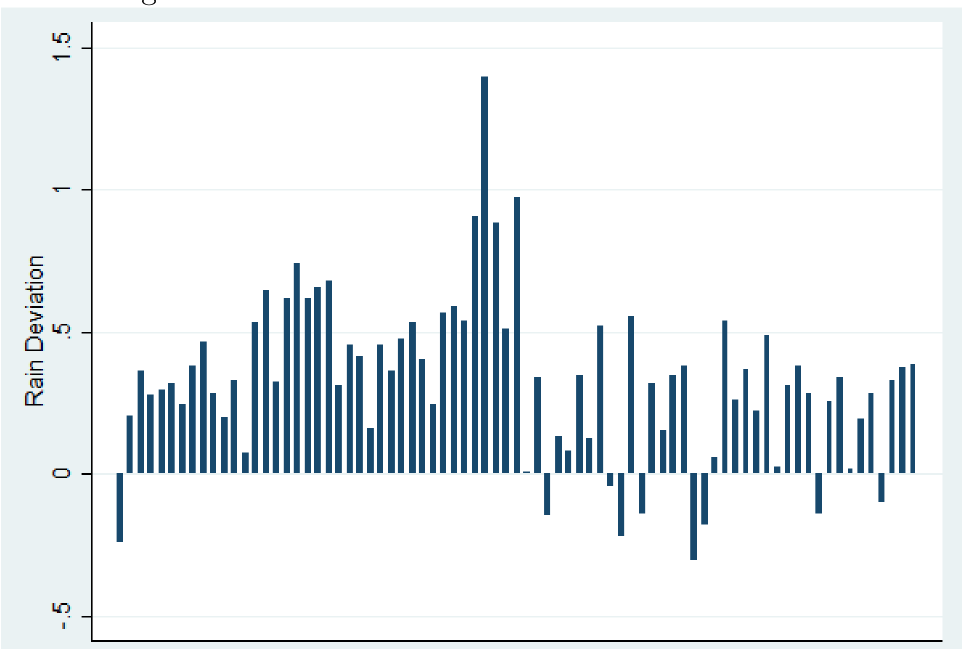
Variable	Definition	Mean	Standard dev.	Min	Max
agprod	total agricultural production in value	2.54e+07	2.54e+08	0	1.80e+10
yield	agprod/cultivated land in log	6.206	2.464	0	15.607
Land fragmentation					
n	number of parcels	2.28	1.38	1	18
n type	number of parcels with different soil texture	1.29	0.51	1	4
n topography	number of parcels with different slope	1.36	0.57	1	5
Simpson index	calculated as described by equation (3)	0.35	0.27	0	1
Household characteristics					
sex	the gender of the HH head; equals 1 if the HH head is male 0 if it is female	0.712	0.453	0	1
age	the age of the HH head	46.384	15.313	13	100
education	the highest school level achieved by the hh head 0-no education, 1-primary, 2-secondary	1.026	.659	0	2
adults	HH members above 16 years	2.960	1.686	0	24
Land characteristics					
cultivated land	cultivated land in acres	4.614	37.355	0 3000	
soil quality index	weighted index of soil quality with: level 1 being good quality and level 3 being poor quality	1.704	0.703	0	3
Weather characteristics					
rain dev	rain deviation in t in district d from the long run mean divided by the long run standard deviation in absolute terms	0.668	0.614	0.005	2.628

Table 2: Land acquisition

Parcels	2005/2006	2009/2010	2010/2011	2011/2012
Inherited	40%	47%	50%	53%
Purchased	25%	26%	25%	23%
Rented	27%	26%	23%	22%
Other	8%	1%	2%	2%

not receive any education. The average number of adult members of the households is around 3. The average size of the cultivated land is 4.6 acres and the soil quality is mostly fair.

Figure 1: Rain deviation 2005-2012 in the 80 Districts



The data used to construct the rain deviation variable is the TS3.12 dataset from the Climatic Research Unit of the University of East Anglia. It is a monthly average data on precipitations and temperature from high-resolution grids, 0,5 x 0,5 degrees, that covers more than one century (1901-2010). The temperature and precipitation anomalies are constructed as deviation in time t in the district d from long run annual mean divided by the long run annual standard deviation of the given district. From the descriptive statistics in Table (1), we can see that the average rain deviation in the 80 Districts included in the sample is 0.7 with the minimum being 0 and the maximum rain deviation being 2.6. Figure 1 gives the average deviation for the different districts in Uganda for the whole survey period. We observe that mainly there were positive rain deviations from 2005 to 2012.

5 Results

In this section the results from the estimation of equation (1) are presented. In Table 4, I use the number of parcels n as a measure for land fragmentation and in Table 5 this is measured with the Simpson index described before. In both tables a Ordinary Least Squares (OLS), Panel fixed effects (FE) and Panel Instrumental Variable (IV) estimations are included. Columns (2), (4) and (6) in each table include the soil quality index that is constructed for the last three rounds, as the data from the first round on land quality is missing.

Table 3: First stage estimation: Inherited land as instrumental variable

	n	Simpson index
Instruments		
n inherited	0.581***	0.0881***
	(0.0293)	(0.00495)
rain deviation	-0.128***	-0.0310***
	(0.0274)	(0.00580)
sex	0.134	0.0209
	(0.0940)	(0.0220)
age	-0.00254	0.000276
	(0.00322)	(0.000854)
adults	0.00947	0.00377
	(0.0135)	(0.00298)
cultivated land (log)	0.298***	0.0382***
	(0.0334)	(0.00682)
primary education	0.0168	0.0123
	(0.0592)	(0.0150)
secondary education	-0.0281	0.0173
	(0.0976)	(0.0217)
	(1)	(2)
Constant	1.405***	0.172***
	(0.182)	(0.0444)
Validity Tests		
F-statistic	27.56	25.6
Stock and Yogo 10% IV size	7.03	7.03
Observations	8,342	8,342
R-squared	0.265	0.162
Number of HHID	2,718	2,718

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Before discussing the further results, I will comment the results for the first stage estimation and the validity of the instruments. Table 3 gives the first stage results of land fragmentation measures and suggests that the number of inherited parcels has a positive and significant impact on number of owned parcels and the Simpson index constructed on the land holdings. If the land markets in Uganda were perfect, the coefficient of the inherited fragmentation would have the value 0 as households can freely decide about the level of fragmentation they want to operate. The closest this coefficient to 1 is, the more the household land fragmentation is determined by its inheritance.

Concerning the validity of the instrument used, the Sargan statistic is 0 which indicates that the equation (3) is exactly identified. The F-statistic is higher than 20 in both estimations and higher than the Stock and Yogo 10 per cent IV size which indicates that the instruments are valid[2].

The measure of fragmentation changes between Tables 4 and 5, but the results are analogous which makes the empirical analysis consistent. Also, taking into account the panel dimension of the data set and treating the endogeneity of the variable(s) of interest improves the statistical significance and increases the magnitude of the coefficients. Therefore, I focus on column (5) in each Table when interpreting the results. In order to quantity the results, we have to take into consideration that the estimation equation is in a semi-log form. According to Table 4, one parcel more reduces the agricultural yield by 30 percent if there is no rain deviation that the farmer is facing. As expected, higher fragmentation leads therefore to lower yield per acre. If we suppose that rain deviation is equal respectively to 0.5 and 1, then the agricultural yield decreases by 3 percent in the first case and increases by 21 percent in the second case when the number of parcels is increasing by one unit. Regarding the impact of rain deviation, if we consider for example that the number of parcels of a farmer equals two, one rain deviation more will decrease the yield by 25 percent. If the household has the average number of parcels, 2.35, then this decrease of the yield is reduced at the level to 6.7 percent.

In the same vein, if there is no rain deviation, an increase of the Simpson index by 0.1 units decreases the agricultural yield by 16 percent. When there is one rain deviation, then the increase of the index of 0.1 conducts to even an increase of the yield by 8.7 percent which offsets the impact of the previous case. If the Simpson index is equal to 0.3, 0.35 (average) or 0.5, then on rain deviation reduces the yield by 16 percent, 13

[2]When regressing inherited land fragmentation on the different household characteristics such as sex, age and education, no single covariate has a significant impact. We can consider this as another validity check the instrument is exogenous to household characteristics and satisfies the exclusion restrictions

percent and increases by 26 percent in the last case. This confirms our *ex ante* hypothesis that land fragmentation can be beneficial for those households that are exposed to higher weather irregularities. The results of this paper demonstrated that the higher the rainfall deviation is, the higher the beneficial effect of more fragmented land owning.

From the estimated model, we can predict the yield for each level of rain deviation by considering the degree of land fragmentation. This is given if Figure 2. For households that have one parcel and do not face rain deviation, the predicted yield is the highest. On the contrary, household that operate 5 parcels have the lowest level of predicted yields when there is no rain deviation. If rain deviation increases, the yield of the most consolidated land (n=1) decreases and the yield of the most fragmented land (n=5) increases. Land fragmentation can be therefore perceived as detrimental for household that are not exposed to rainfall variability. But, benefits form land fragmentation can be present if uninsured households face higher rainfall irregularity.

When considering the other covariates from Tables 3 and 4, having a household head that is older increases the yield. This result should be linked to the experience of the household improves agricultural efficiency. In addition, a household head with primary or secondary education has higher increase in the agricultural yield compared to household heads with no education. This impact is even higher in the case when the head is having secondary education compared to the primary education. Concerning the production factors, labor and land, increase in the number of adults has positive impact on the agricultural yield. However, there is a negative relationship between the size of the cultivated land and the yield. This variable takes into account the total cultivated land by the household without considering the fragmentation. If we consider that the higher the size of the total land is correlated positively to the number of parcels owned, then the negative influence is intuitive. It should be noticed that the higher the soil quality index, that refers to a worse soil quality, reduces the agricultural yield as expected.

Table 4: Panel Tobit estimation on the fertilizer use and intensity

	OLS	OLS	Panel FE	Panel FE	IV Panel FE	IV Panel FE
Yield (log)	(1)	(2)	(3)	(4)	(5)	(6)
n	-0.0287	-0.0887**	-0.254***	-0.451***	-0.251***	-0.768***
	(0.0276)	(0.0367)	(0.0311)	(0.0484)	(0.0815)	(0.109)
rain deviation	-0.244***	-0.612***	-0.553***	-0.706***	-1.109***	-1.737***
	(0.0856)	(0.102)	(0.0894)	(0.110)	(0.188)	(0.227)
n*rain deviation	0.169***	0.206***	0.181***	0.238***	0.444***	0.697***
	(0.0340)	(0.0399)	(0.0366)	(0.0433)	(0.0867)	(0.0997)
sex	0.160**	0.228***	-0.904***	-1.006***	-0.890***	-0.986***
	(0.0625)	(0.0760)	(0.168)	(0.267)	(0.170)	(0.278)
age	0.00934***	0.00687***	0.0749***	0.0220*	0.0755***	0.0199
	(0.00190)	(0.00235)	(0.00945)	(0.0121)	(0.00847)	(0.0123)
adults	0.0962***	0.0640***	0.0962***	-0.0649*	0.0886***	-0.0706*
	(0.0170)	(0.0205)	(0.0264)	(0.0386)	(0.0274)	(0.0418)
cultivated land (log)	-0.780***	-0.783***	-0.950***	-0.959***	-1.023***	-0.967***
	(0.0398)	(0.0502)	(0.0603)	(0.0833)	(0.0690)	(0.0947)
primary education	0.957***	0.982***	0.672***	0.669***	0.667***	0.633***
	(0.0732)	(0.0900)	(0.130)	(0.182)	(0.136)	(0.195)
secondary education	1.178***	1.178***	1.281***	1.594***	1.258***	1.496***
	(0.0873)	(0.107)	(0.187)	(0.250)	(0.196)	(0.270)
land quality index		-0.561***		-0.933***		-0.897***
		(0.0479)		(0.0508)		(0.0551)
Constant	5.530***	7.370***	4.299***	9.702***		
	(0.137)	(0.191)	(0.417)	(0.602)		
Observations	8,342	6,251	8,342	6,251	8,342	6,251
R-squared	0.071	0.090	0.080	0.139	0.070	0.115
Number of HHID			2,718	2,477	2,718	2,477

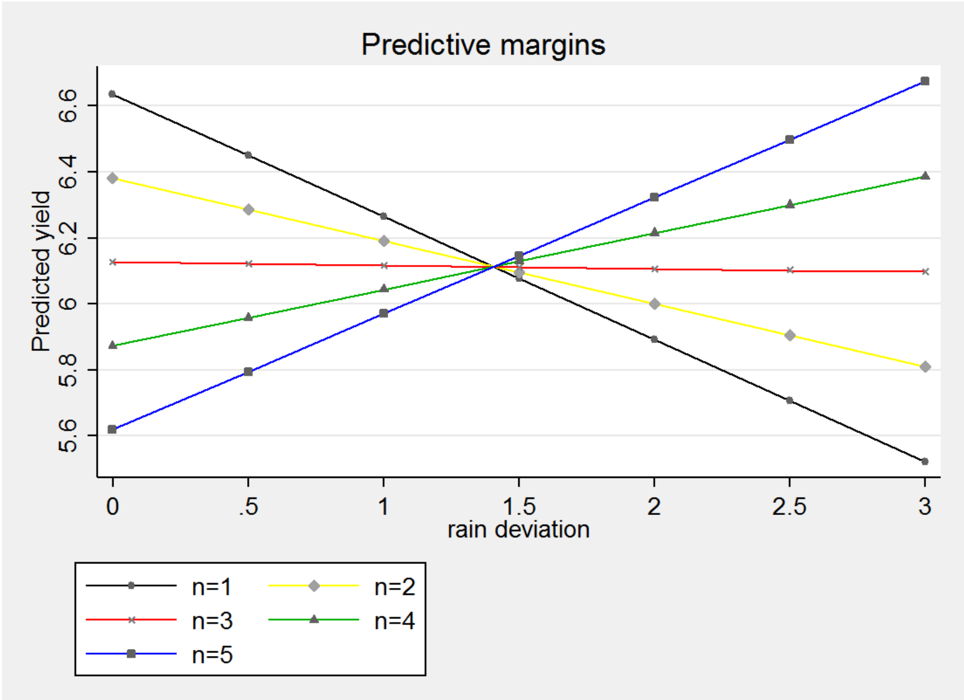
Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 5: Panel Tobit estimation on the fertilizer use and intensity

	OLS	OLS	Panel FE	Panel FE	IV Panel FE	IV Panel FE
Yield (log)	(1)	(2)	(3)	(4)	(5)	(6)
simpson index	0.105	-0.238	-0.917***	-1.694***	-1.506***	-4.744***
	(0.142)	(0.189)	(0.176)	(0.263)	(0.537)	(0.697)
rain deviation	-0.0167	-0.349***	-0.362***	-0.447***	-0.945***	-1.568***
	(0.0681)	(0.0822)	(0.0679)	(0.0841)	(0.154)	(0.193)
simpson*rain deviation	0.407***	0.537***	0.635***	0.824***	2.343***	3.932***
	(0.156)	(0.183)	(0.153)	(0.182)	(0.435)	(0.512)
sex	0.162***	0.232***	-0.916***	-1.016***	-0.880***	-0.936***
	(0.0625)	(0.0761)	(0.168)	(0.271)	(0.172)	(0.291)
age	0.00944***	0.00679***	0.0757***	0.0236*	0.0749***	0.0198
	(0.00190)	(0.00236)	(0.00946)	(0.0122)	(0.00851)	(0.0124)
adults	0.0976***	0.0652***	0.0925***	-0.0657*	0.0813***	-0.0816*
	(0.0170)	(0.0206)	(0.0263)	(0.0387)	(0.0276)	(0.0426)
cultivated land (log)	-0.768***	-0.767***	-1.001***	-1.025***	-1.030***	-1.006***
	(0.0392)	(0.0497)	(0.0591)	(0.0829)	(0.0634)	(0.0911)
primary education	0.956***	0.986***	0.674***	0.687***	0.658***	0.630***
	(0.0733)	(0.0901)	(0.130)	(0.183)	(0.137)	(0.202)
secondary education	1.179***	1.183***	1.292***	1.652***	1.246***	1.545***
	(0.0874)	(0.107)	(0.187)	(0.251)	(0.197)	(0.274)
land quality index		-0.567***		-0.933***		-0.874***
		(0.0480)		(0.0505)		(0.0565)
Constant	5.408***	7.239***	4.076***	9.247***		
	(0.133)	(0.185)	(0.417)	(0.600)		
Observations	8,342	6,251	8,342	6,251	8,342	6,251
R-squared	0.069	0.088	0.076	0.131	0.059	0.079
Number of HHID			2,718	2,477	2,718	2,477

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Figure 2: Predicted yield for each level of rain deviation and number of parcels



As a robustness check, instead of only taking into account the number of parcels, Table 5 includes the number of parcels with different soil type and soil topography which gives a more detailed aspect of risk diversification of a land holding. The results are consistent with what was previously found. A higher number of parcels with different soil type, the lower is the exposure of a given household to a rain deviation. However this is not verified for the number of parcels with different topography. The other covariates have similar impacts as in the previous estimations. The average size of the cultivated land is 4.6 acres and the soil quality is mostly fair.

Another robustness check is to include the average distance to the parcels in order to account for the time cost. The information on distance is only given for the three last survey years. The results are given in Table 6. The average distance is calculated as the average of the time that it takes for a farmer to arrive to the different parcels. As expected, the higher this average distance, the lower the agricultural yield. The previous results and conclusions do not change when we control for the distance.

Table 6: Panel Tobit estimation on the fertilizer use and intensity

Yield (log)	OLS (1)	OLS (2)	Panel FE (3)	Panel FE (4)
n soil type	-0.408***	-0.404***	-0.773***	-0.762***
	(0.109)	(0.108)	(0.116)	(0.116)
n topography	0.323***	0.351***	-0.180	-0.154
	(0.103)	(0.101)	(0.126)	(0.126)
rain deviation	-0.808***	-0.501***	-1.306***	-0.737***
	(0.147)	(0.147)	(0.146)	(0.157)
n soil type*rain deviation	0.517***	0.461***	0.639***	0.530***
	(0.117)	(0.115)	(0.128)	(0.129)
n topography* rain deviation	-0.163	-0.198*	-0.0117	-0.0704
	(0.106)	(0.105)	(0.121)	(0.124)
sex	0.223***	0.235***	-0.925***	-1.024***
	(0.0769)	(0.0760)	(0.268)	(0.269)
age	0.00608**	0.00680***	0.0171	0.0207*
	(0.00237)	(0.00235)	(0.0115)	(0.0123)
adults	0.0610***	0.0641***	-0.0488	-0.0621
	(0.0208)	(0.0205)	(0.0406)	(0.0387)
cultivated land	-0.758***	-0.761***	-1.044***	-1.025***
	(0.0500)	(0.0494)	(0.0906)	(0.0839)
primary education	1.010***	0.990***	0.747***	0.665***
	(0.0910)	(0.0901)	(0.181)	(0.182)
secondary education	1.238***	1.177***	1.707***	1.617***
	(0.108)	(0.107)	(0.256)	(0.254)
quality index		-0.564***		-0.949***
		(0.0481)		(0.0510)
Constant	6.452***	7.198***	8.751***	10.03***
	(0.219)	(0.225)	(0.612)	(0.634)
Observations	6,251	6,251	6,251	6,251
R-squared	0.070	0.090	0.072	0.133
Number of HHID	2,477	2,477	2,477	2,477

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 7: Panel Tobit estimation on the fertilizer use and intensity

Yield (log)	IV Panel FE (1)	IV Panel FE (2)	IV Panel FE (3)	IV Panel FE (4)
n	-0.441***	-0.760***		
	(0.049)	(0.110)		
Simpson			-1.412***	-4.703***
			(0.247)	(0.703)
rain deviation	-0.710***	-1.726***	-0.518***	-1.559***
	(0.110)	(0.226)	(0.107)	(0.193)
land frag.*rain deviation	0.242***	0.694***	0.169***	3.916***
	(0.043)	(0.099)	(0.042)	(0.511)
distance	-0.118*	-0.136*	-0.126*	-0.104
	(0.068)	(0.073)	(0.069)	(0.078)
sex	-1.014***	-0.994***	-1.043***	-0.942***
	(0.266)	(0.278)	(0.270)	(0.291)
age	0.022*	0.020	0.024**	0.020
	(0.012)	(0.012)	(0.012)	(0.012)
adults	-0.064*	-0.069*	-0.062	-0.081*
	(0.039)	(0.042)	(0.039)	(0.043)
cultivated land land	-0.955***	-0.958***	-1.045***	-1.000***
	(0.083)	(0.094)	(0.082)	(0.090)
primary education	0.671***	0.634***	0.695***	0.631***
	(0.182)	(0.195)	(0.183)	(0.202)
secondary education	1.591***	1.493***	1.659***	1.542***
	(0.250)	(0.270)	(0.252)	(0.274)
land quality index	-0.930***	-0.895***	-0.933***	-0.871***
	(0.051)	(0.055)	(0.051)	(0.057)
Constant	9.868***		9.339***	
	(0.608)		(0.604)	
Observations	6,250	6,250	6,250	6,250
R-squared	0.139	0.116	0.131	0.080
Number of HHID	2,477	2,477	2,477	2,477

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

6 Conclusion

The aim of this study is to explore the role of land fragmentaion when agricultural household face weather irregularities in Uganda. After instrumenting for the level of fragmentation, I find that higher land fragmentation is decreasing the loss of crop yield when households are experiencing rain deviation. The results show that the higher this deviation is, the higher is the beneficial effect of land fragmentation. This result is confirmed all the measures used for land fragmentation. I also find that labor endowment and education are crucial for the agricultural efficiency.

One important factor that has to be included in this study is the distance from the parcels operated by the household to the living place. This aspect should improve the measure of the spatial diversification potential of land fragmentation. Another improvement of the study is to construct a seasonal rain deviation in order to capture a more precise effect of weather on agricultural yield.

The preliminary results in this paper indicate that developing countries have to be cautious with the policy of land consolidation. If insurance markets are missing, then land fragmentation can be an alternative for farmers operating in rain-fed environments. Therefore, instead of focusing on land consolidation programs, the imperative of policy makers should be focused on improving other imperfect or missing markets that influence agricultural productivity.

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