

**RELATIONSHIP BETWEEN LAND SIZE
AND PRODUCTIVITY: EMPIRICAL
EVIDENCE FROM PADDY FARMS IN
IRRIGATION SETTLEMENTS OF SRI
LANKA**

N.C. Wickramaarachchi

Jeevika Weerahewa

Sri Lanka Journal of
Economic Research
Volume 5(2) March 2018
SLJER.05.02.07:
pp.125 - 142
Sri Lanka Forum of
University Economists



Abstract

Irrigation settlements in Sri Lanka were characterized by equal sized allotments among settlers at the time of their establishment. Over time, informal land markets were created and land fragmentation and consolidation occurred simultaneously. This resulted in cultivation of a number of small plots by an individual farmer as well as that of large extents by one or more farmers. This paper assesses the effects of such sub-divisions and consolidations on paddy land productivity in irrigation settlements in Sri Lanka. Specific objectives were to examine the effects of land size on land productivity, labor productivity and use of machinery in paddy farming. Primary data gathered from 1,230 lowland plots covering 935 paddy farms from three irrigated settlements in Anuradhapura district were used for the analysis. Land and labour productivities of plots and farms were regressed against land size and other plot-specific and farm-specific characteristics respectively to test the nature of relationships between productivity and land size. Bivariate probit models were estimated to determine the effects on land size on the likelihood of machinery use in paddy farming. The results of the econometric estimation of the above models provided mixed results with respect to the inverse relationship between land size and productivity found in many developing countries. Though the relationship between plot size and land productivity was clearly positive, an inverse relationship between farm size and land productivity was noted as land size increased beyond a certain limit. The relationship between labor productivity and land size was also similar: labor productivity first increased with land size and then decreased. This observation was equally valid for both plots and farms. The results further indicated that mechanized farms were more productive and that the likelihood of mechanization increases with farm size. Measures to consolidate small land plots until they reach their maximum potential are recommended in order to enhance agricultural productivity in irrigated settlements in Sri Lanka.

Key Words- Land fragmentation, Paddy productivity, Farm size, Plot size, Irrigation Settlements, Sri Lanka

N.C. Wickramaarachchi

Department of Estate, Management and Valuation, Faculty of Management Studies and Commerce, University of Sri Jayawardenepura., +94112802004, nishani@sjp.ac.lk

Jeevika Weerahewa

Department of Agricultural Economics & Business Management
University of Peradeniya, Sri Lanka. jeevikaw@gmail.com

INTRODUCTION

The history of settling people by alienation of government lands in Sri Lanka goes back to the early decades of the 20th century. The process of settlement involved the provision of irrigation water to lands which are characterized by water shortages, transfer of cultivation rights of lands to landless people, and establishment of village centers. They are hence termed as irrigated settlements or colonization schemes. The government of Sri Lanka initially expected to achieve a number of objectives through this effort, such as the protection of the peasant farmer, alleviation of landlessness among the poorest of the poor, and increase in food production, particularly paddy. Backed by such objectives, heavy investments were made for the development of water reservoirs, construction of the irrigated networks, and establishment of schools and hospitals in the settlements. The settlers were assured of free water supply through a canal system managed by an administrative entity and were granted with two acres of highland. The extent of lowland granted varied over time: early settlers were granted five acres and the allocation reduced thereafter to three acres and later to two acres in subsequent allocations. These provisions were introduced through the Land Development Ordinance (LDO) No. 19 of 1935. The Ordinance restricted further subdivisions and all forms of transactions. Later, amendments were introduced stipulating a minimum legal size of 1.5 acres for a lowland plot. In addition, a farmer with a valid deed was given transfer rights subject to the sanction of the government administrative officer of the respective settlement area.

The present situation in settlements is much more complex than was anticipated by the LDO. Despite restrictions imposed by law, there have been informal sales of land, subdivisions and transformations. The initially equal land allocation was subdivided and distributed among second and third generation farmers. According to Wanigarathne (1995) and Chandrasiri (2009), a decrease in land sizes by 45 to 60 percent 30 years after the establishment of settlements can be observed and cultivating lowland extents of 0.25 acres is not uncommon. At the same time, there was a tendency among entrepreneurial farmers to acquire more land plots leading to an increase in the sizes of land plots and farms.

In order to assess the economic effects of informal fragmentation and consolidation in irrigation settlements, the relationship between the land size and the land productivity is to be established first. The outcome of such an investigation will help in identifying the efficiency of the current land use pattern and in designing an appropriate mechanism to address inefficiencies if any. Global literature on the relationship between land size and productivity suggests that it is context-specific. Some authors have found that small farms are more productive: i.e., that there is an inverse relationship; and some others found that increase in land size increases

agricultural productivity. The overall objective of this paper is to ascertain the relationship between land size and paddy productivity in irrigated settlements of Sri Lanka. The specific objectives are (i) to determine the effects of land size on land productivity of plots and farms, and (ii) to evaluate the extent to which land size determine the use of machinery.

The rest of the paper is organized as follows. Section two reviews the empirical findings on farm size and land productivity relationship. Section three presents empirical models and section four presents the study area and data. The context, results and discussion are shown in section five. Section six sets out the conclusion.

REVIEW OF LITERATURE

Productivity is defined as the ability of a unit of an input to produce a certain level of output. Agricultural productivity shows how efficient a farmer is in the use of a particular input given the range of alternative technologies available. Partial measures of productivity are obtained by dividing total physical product by the usage of a given input. Accordingly, land productivity is the yield per unit of land and labor productivity is the average output per unit of labor used. In examining the relationship between farm size and productivity, land productivity was considered as the relevant measure of productivity in most studies.

An inverse relationship between size of the operational land holding and land productivity holds in many regions. A negative relationship between farm size and land productivity was first noted in Russia by Chayanov (1926). According to Sen (1962) smaller farms in India are more productive as the operators of small farms apply more input, particularly labor, and hence the resulting output is larger. The total amount of family labor used goes up remarkably when the size falls. Berry and Cline (1979) observed a similar relationship in other developing countries. Deolalikar (1981) found that the inverse relationship between yields and farm size hold only for traditional agriculture. Analyzing data from fifteen developing countries² Cornia (1985) found that output per unit of farm land systematically declines as farm size rises. Labor is more abundant and cheaper for small farmers; therefore in principle a large excess of labor is available for small farms. Assuncao and Ghatak (2003) examined the relationship after controlling the heterogeneity of farmer skills and found that small farms are more productive. Thapa (2007) also finds that small farms in Nepal are more productive than large farms because of their intensive use of both labor and cash inputs than those of large farms. Ansoms *et al* (2008) who found a

² The fifteen countries are Barbados, Mexico, Peru, Ethiopia, Nigeria, Tanzania, Uganda, Syria, Sudan, Bangladesh, Burma, India, Nepal, Korea and Thailand.

strong inverse relationship between land size and productivity in Rwanda pointed out that the relationship should not be interpreted merely as a reflection of efficiency. It is positive because of extreme land scarcity which compels farmers to overexploit their lands in the absence of other income.

A few studies revealed positive relationships between land size and productivity. Obasi (2007) concludes that farm size is positively related to agricultural productivity in Nigeria. The impact is due to the low quality inputs used by small holders. Rahman and Rahman (2009) argue that the relationship of size-productivity is positive in technologically advanced regions, whereas the typical inverse relationship still exists in developing regions. Chen *et al* (2011) observes similar results to Obasi (2007) in Chinese agriculture and support the view of Rahman and Rahman (2009). Chen *et al* (2011) pointed out that the said inverse relationship is not inherent to China with the technological development and the technology transformation can produce a positive relationship between farm size and productivity. Therefore, there is no urgency to recommend a reduced size policy. Mixed results were obtained by Tamel (2011) in the United States agriculture; in some areas that the farm size and productivity is positive and in some others it is negative. Hence, it was concluded that the long-standing academic assertion that small farms are more productive than large farms was more of a locational phenomenon than a stylized fact.

Ali and Deininger (2015) highlighted the effects of land fragmentation on productivity gains apart from the effects of farm size. It has been argued that when fragmentation is present, farmers may spend additional resources to travel between plots, plough discontinuous fields, monitor labor in different areas and move farm equipment (Rahman and Rahman 2009; Kawasaki 2010). Paul and Githinji (2017) find an inverse relationship between farm size and yield, and a positive association between yield and land fragmentation in Ethiopia. Yagi (2012) combined plot and farm databases and examined the distances to respective field plots from potential holders in different farm size classes. The results clarify that field plots at a greater distance from a farm command less rent. Lu *et al.* (2018) using a plot-level dataset found that there are increasing returns to scale in agricultural production and that land fragmentation reduces yields. The authors suggest that moderate expansion of the plot can reduce average cost, implying that agriculture can achieve economies of scale within each plot and economies of scale should be developed by keeping farm size constant, reducing the number of plots, and expanding the size of each plot.

Mechanization is one of the key determinants of agriculture productivity. Farmers tend to mechanize farm operations when biological sources of energy, human or animal labour, become costly or are in inadequate supply. According to Ghosh (2010), the optimal use of modern agricultural machinery requires a comparatively large size of land in Bengal. However, average farm size shows that the majority of

farms in Bengal are below one hectare. In addition, Sims and Kienzle (2006) reveal that the machinery power will generally not be economically feasible for a smallholder farmer who does not cultivate at least five hectares.

EMPIRICAL APPROACH

Based on the above literature, this paper tests the hypothesis widely popularized as ‘inverse relationship between farm size and productivity’. The paper attempts to explain the relationship between farm size and productivity in Sri Lankan paddy farming, paying special attention to the potential role that fragmentation may play in relation to the productivity of land. Models were specified at plot-level and farm-level treating a farm as a collection of one or more plots operated by a single farmer.

To assess the effects of plot size and farm size on land productivity, two production functions were estimated treating land-specific characteristics, conventional input usage, farmer-specific characteristics and location characteristics as vectors of independent variables and land productivity as the dependent variable. In order to capture a quadratic relationship between land productivity and land size, if any, square terms for land size were included. This allows a computation of optimal land size that results in maximum land productivity using the co-efficients of the two land size variables. Two separate functions were estimated, treating productivity of the plots and that of the farms as dependent variables. Plot-specific characteristics include sizes of plots, distance from home to plot, soil quality of the plot, and shape of the plot. Conventional inputs are mechanization, labor and seed variety. Farm-specific characteristics are age, education and number of plots operated. Locational characteristics are captured by the type of settlement scheme: i.e., whether it is Rajanganaya, Kagama-Katiyawa or Mahakandarawa.

The specifications to ascertain the relationship between land productivity and land size are given by equation (1) and (2) for plots and farms respectively.

$$\text{ProPlot} = \alpha_0 + \alpha_1 \text{PlotSize} + \alpha_2 \text{PlotSize}^2 + \alpha_3 \text{Distance} + \alpha_4 \text{Soil} + \alpha_5 \text{Shape} + \alpha_6 \text{Machinery} + \alpha_7 \text{Labour} + \alpha_8 \text{Seeds} + \alpha_9 \text{Age} + \alpha_{10} \text{Edu} + \alpha_{11} \text{NumPlot} + \alpha_{12} \text{DK} + \alpha_{13} \text{DM} + e_1 \quad (1)$$

Where, ProPlot is land productivity of the plot (output of the plot/plot size measured in kg per acre), PlotSize is land size of the plot (acres), Distance is distance from home to a plot (meters), Soil is soil quality (1= if fertile, 0= other), Shape is the shape of the plot (1= if regular, 0= other), Machinery is use of machinery (1 = if use, 0= other), Labour is labour usage (man days per acre), Seeds is variety of seed (1=if short grain, 0=other), Age is the age of the farmer (years), Edu is the level of education (level), NumPlot is number of plots, DK is dummy variable for Kagama-Katiyawa

and DM is the dummy variable for Mahakandarawa and e_1 is the random error term. The optimal plot size that gives the maximum land productivity is given by $\alpha_1/2\alpha_2$.

$$\text{ProFarm} = \beta_0 + \beta_1 \text{FarmSize} + \beta_2 \text{FarmSize}^2 + \beta_3 \text{Labour} + \beta_4 \text{AvgDistance} + \beta_5 \text{NumPlot} + \beta_6 \text{Age} + \beta_7 \text{Edu} + \beta_8 \text{DK} + \beta_9 \text{DM} + e_2 \quad (2)$$

Where, ProFarm is land productivity of the farm which consists of all the plots cultivated by a single farmer (total output of the farm/FarmSize measured in kg per acre), AvgDistance is average distance from home to the plots (meters) and e_2 is the random error term. The optimal plot size that gives the maximum land productivity is given by $\beta_1/2\beta_2$.

In order to ascertain the relationship between land size and labor productivity, two functions were specified for plots and farms, treating labor productivity as the dependent variable and plot- and farm-specific characteristics, and farmer-specific characteristics as vectors of independent variables. It was assumed that labour is a homogeneous input and it includes both family and hired labuor.

The specifications to ascertain the relationship between labour productivity and land size are given by equations (3) and (4) for plots and farms respectively.

$$\text{labourProPlot} = \alpha_0 + \alpha_1 \text{PlotSize} + \alpha_2 \text{PlotSize}^2 + \alpha_3 \text{NumPlot} + \alpha_4 \text{Distance} + \alpha_5 \text{Shape} + \alpha_6 \text{Soil} + \alpha_7 \text{Seeds} + \alpha_8 \text{Machinery} + \alpha_9 \text{Age} + \alpha_{10} \text{Edu} + \alpha_{11} \text{DK} + \alpha_{12} \text{DM} + e_3 \quad (3)$$

$$\text{labourProFarm} = \beta_0 + \beta_1 \text{FarmSize} + \beta_2 \text{FarmSize}^2 + \beta_3 \text{AvgDistance} + \beta_4 \text{NumPlot} + \beta_5 \text{Age} + \beta_6 \text{Edu} + \beta_7 \text{DK} + \beta_8 \text{DM} + e_4 \quad (4)$$

Where labourProPlot is labour productivity of the plot (output of the plot/labour), labourProFarm is labour productivity of the farm which consists of all the plots cultivated by a single farmer (total output of the farm/labor), e_3 and e_4 are random error terms. The optimal plot and farm sizes that give the maximum labour productivity will be given by $\alpha_1/2\alpha_2$ and $\beta_1/2\beta_2$ respectively.

All of the above equations were estimated with corrections for heteroscedasticity using robust standard errors.

In above equations, the variable “Machinery” tests the extent to which mechanization helps in increasing productivity. In order to identify the factors affecting mechanization, two bivariate probit models were estimated at plot level and farm level treating decision to mechanize as the dependent variable and plot and farm specific characteristics, and farmer specific characteristics as vectors of independent variables. The specifications to ascertain the relationship between use of machinery and land size are given by equations (5) and (6) for plots and farms respectively.

$$\text{Machinery} = \alpha_0 + \alpha_1 \text{PlotSize} + \alpha_2 \text{NumPlot} + \alpha_3 \text{Distance} + \alpha_4 \text{Soil} + \alpha_5 \text{Age} + \alpha_6 \text{Edu} + \alpha_7 \text{DK} + \alpha_8 \text{DM} + e_5 \quad (5)$$

$$\text{Machinery} = \beta_0 + \beta_1 \text{FarmSize} + \beta_2 \text{NumPlot} + \beta_3 \text{AvgDistance} + \beta_4 \text{Age} + \beta_5 \text{Edu} + \beta_6 \text{DK} + \beta_7 \text{DM} + e_6 \quad (6)$$

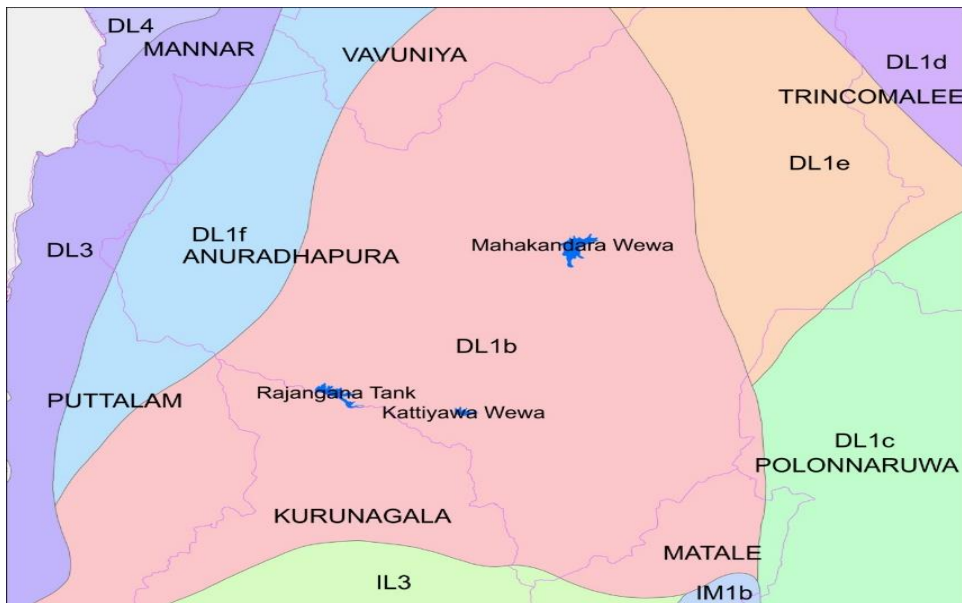
Machinery takes the value of either 1 or 0 in the equations (5) and (6) and e_5 and e_6 are random error terms.

The models that treat plots as the unit of analysis, i.e., (1), (3) and (5), empirically test the hypothesis of plot size and agricultural productivity. The models that treat farms as the unit of analysis, i.e., (2), (4), and (6), empirically test the extent to which fragmentation determines productivity. The inclusion of variables such as distance to plot and number of plots, enables capturing of entrepreneurial skills of the farm operators as farmers may spend additional resources to travel between plots, plough discontinuous fields, monitor labour in different areas and move farm equipment when multiple plots are cultivated.

STUDY AREA AND DATA

The data set gathered by Wickramaarchchi (2016) was used for the estimation of the above relationships. The detailed plot-level and farm-level data allows exploration of determinants of paddy productivity and the presence of a farm size-productivity and plot size-productivity relationship specified in equations (1) to (6).

Figure 1: Location of the three sites



This dataset exhibits plots of different sizes being simultaneously cropped by the same farm operator. The study population is the paddy farm operators in three irrigated settlements in Anuradhapura district in the dry zone of Sri Lanka: namely Mahaknadarawa, Kagama-Katiyawa and Rajanganaya. The three irrigated settlements were selected based on the initial allocation of lowland made at the establishment of the irrigation settlement, i.e., five, three and two acres in extent and all of them are in the DL1b agro-ecological zone (Figure 1). Random samples proportion to the size of the population had been drawn from each settlement treating head, middle and tail end farmers as strata. Data was gathered on plot level basis, during April to June in 2013 from 935 paddy farmers cultivating 1230 lowland plots and were aggregated to create the farm level dataset.

RESULTS AND DISCUSSION

Plot size and farm size

The general characteristics of farmers in the study area are given in Table 1.

Table 1: Socio-economic Characteristics of the Farmers

Variable	Units	Mean	Standard Deviation
Age	Years	49	11.55
Household Size	Number	4	1.23
Family labor	Number	2	0.57
Experience in farming	Years	25	10.66

Source: Wickramaarachchi (2016)

Table 2: Average Productivities between the two Land Extent Categories.

Land size	Number of Plots	Average Productivity (kg/acre)
Below 1.5 acres	569	1733.84
Equal to and above 1.5 acres	661	1921.27

Source: Wickramaarachchi (2016)

Table 2 presents average productivities between the two land extent categories. The average plot size is 1.5 acres. Approximately half of the plots are between one acre and two acres in extent and one fifth of the plots are below one acre. The independent

sample t-test results indicate that the average productivities in smaller lands are significantly lower than the rest. The average size of a farm was found to be 1.9 acres. Four categories of farms were identified according to the number of plots in a farm.

Table 3 presents the number of farms in each category, the average size of the farm, and the average productivities. Table 3 indicates that the average productivity in farms with a single plot is significantly higher than farms with multiple plots.

Table 3: Number of Plots Operated, Average Size and Average Productivity of the Farm

No. of Plots in a Farm	Number of Farms	Average size of the Farm (acres)	Average Productivity of the Farm (kg/acre)
1	222	2.0	1950.87
2	65	1.7	1705.30
3	17	2.7	1697.02
4	2	3.6	1662.50
Total	306	1.6	1882.70

Source: Wickramaarachchi (2016)

Results of the Econometric Estimations

Relationship between land productivity and land size

Table 4 shows the results of the estimation of equation (1). The results clearly indicate that size of plot has a positive and significant effect on productivity of plots and an increase in land size by one acre will increase land productivity by 75 kg per acre. The co-efficient of the square of the plot size is not statistically significant. The results show that plots which are located further away from home are less productive and plots with fertile soil are more productive.

The results indicate that the shape of the plot positively and significantly influences land productivity; implying regular shaped plots are more productive. The variety of seeds, mechanization and labor use have statistically significant effects on productivity. Short grain seeds produce a higher yield, mechanized lands are more productive, and increase in labour use increases productivity of plots. With respect to farmer characteristics, age and education level are statistically significant and have a positive effect on productivity. This implies that the older generation is more productive than the younger generation. Better performance is observed in educated farmers.

Table 4: Descriptive Statistics and the Estimated Coefficient Values - Equation (1)

Variable		Measure	Mean value	Std dev	Coefficient	P value
Plot specific characteristics	Constant				1438.9120	0.000
	Size of plot	Acres	1.49	0.85	75.3832 (22.4611)	0.001 ***
	Size of plot ²	Acres ²	2.96	3.41	-5.9362 (4.6205)	0.199
	Distance from home	Meters	1485.23	932.52	-0.0578 (0.0066)	0.000 ***
	Soil Quality	Dummy (1= if fertile; 0= other)			72.4767 (30.9355)	0.019 **
	Shape of the plot	Dummy (1= if regular; 0= other)			27.1023 (16.7144)	0.105
	Mechanization	Dummy (1= if adopted; 0 = other)			52.1017 (12.1694)	0.000 ***
Conventional Inputs	Labor	Persons days/acre	24.97	7.55	4.3157 (1.0132)	0.000 ***
	Variety of Seeds	Dummy (1=if short grain; 0=other)			160.4187 (13.1364)	0.000 ***
Farmer characteristics	Age	Years	49.11	11.55	2.3972 (0.5306)	0.000 ***
	Education	Level	4.59	2.94	8.3206 (2.3544)	0.000 ***
	Number of plots operated	Number	1.60	0.82	-56.6673 (6.2631)	0.000 ***
Settlement	Dk=dummy for Kagama-Katiyawa				-6.8468 (16.7222)	0.682
	Dm= dummy for Mahakanadarawa				-8.4021 (10.7127)	0.433

R squared = 0.55; No. of observations = 1230; Mean of land productivity = 1834.56 kg/acre

*, ** and *** represent significance at 10%, 5% and 1%, (Robust std errors in parenthesis)

Unit of analysis = plot; Dependent variable: Land productivity of plots

The results of the estimation further indicate that the number of plots is statistically significant and has a negative impact on productivity. This implies that when farmers operate more than a single plot, they become inefficient in managing the scattered

plots. This result suggests that farmers with a single large plot are more productive compared to farmers with multiple plots. There are no statistical differences in land productivity levels among the three irrigation settlements. Table 5 shows the results of estimation of equation (2). The coefficient of total extent of farm is positive and statistically significant and the co-efficient of the square term is negative and statistically significant suggesting a quadratic relationship between land size and land productivity at the farm level. Farm productivity increases until 4.21 acres and it declines thereafter.

Table 5: Descriptive Statistics and the Estimated Coefficient Values –Equation (2)

Variable		Measure	Mean Value	Std Dev	Coefficient	P value
Farm specific characteristics	Constant				1546.3110 (50.9526)	0.000
	Total extent	Acres	1.97	1.00	234.2768 (23.6792)	0.000***
	Total extent ²	Acres ²	4.89	5.37	-27.8059 (4.1990)	0.000***
	Average Distance to plots from home	Meters	1921.05	1653.05	-0.0559 (0.0054)	0.000***
	Number of plots	Number	1.31	0.61	-96.5636 (14.9029)	0.000***
Conventional Inputs Farmer Characteristics	Labor	Persons days/acre	24.48	9.59	2.3357 (0.9308)	0.012**
	Age	Years	50.67	11.79	3.2998 (0.5801)	0.000***
	Education	Level	4.61	2.95	5.3711 (2.1067)	0.011**
Settlement	Dk=dummy for Kagama-Katiyawa				24.6843 (15.2974)	0.107
	Dm= dummy for Mahakanadarawa				35.4775 (12.5281)	0.005***

R squared = 0.52; Number of observations = 935; Mean of land productivity = 1905.37 kg/acre
*, ** and *** represent significance at 10%, 5% and 1%, (Robust std errors in parenthesis)

Unit of analysis = Farm; Dependent Variable =Land productivity of farms

The results of the estimation of equation (2) also indicate that the number of plots has a statistically significant and negative effect on farm productivity. This implies that farmers are less efficient at managing farms with multiple plots. The farms in Rajanganaya found to be less productive than those in Kagama-Katiyawa and Mahakanadarawa. The results also reveal that the average distance from home to plot has a statistically significant and negative effect on productivity. The co-efficients of demographic characteristics of the farmers indicate that the education level of the

farmer has a positive effect on farm productivity implying that educated farmers are more efficient at managing a farm. The age of a farmer has a positive effect on farm productivity suggesting that the older generation is more efficient in managing the farm than that of the younger generation.

Relationship between labour productivity and land size

Table 6: Descriptive Statistics and the Estimated Coefficient Values - Equation (3)

Variable		Units	Mean Value	Std Deviation	Coefficient	P value
Constant					30.9521 (3.4129)	0.000
Plot specific characteristics	Size of plot	Acres	1.49	0.84	31.4716 (1.4635)	0.000** *
	Size of plot ²	Acres ²	2.96	3.42	-1.7425 (0.3593)	0.000** *
	Distance from home	Meters	1485.2 3	932.52	-0.0014 (0.0005)	0.008** *
	Soil Quality	Dummy (1= if fertile, 0= other)	0.87	0.45	2.9267 (1.2910)	0.024**
	Shape of the plot	Dummy (1= if regular 0= other)			-0.5199 (1.3363)	0.697
Conventional Inputs	Mechanization	Dummy (1= if use, 0 = other)			6.3326 (1.0119)	0.000** *
	Variety of Seeds	Dummy(1 =if short grain, 0=other)			5.8321 (1.0177)	0.000** *
Farmer Characteristics	Age	Years	49.11	11.55	0.0417 (0.0412)	0.311
	Education	Level	4.59	2.94	0.5168 (0.1912)	0.007** *
	Number of plots operate	Number	1.60	0.82	--1.9927 (0.5174)	0.000** *
Settlement	Dk=dummy for Kagama-Katiyawa				-5.2543 (1.3917)	0.000** *
	Dm= dummy for Mahakanadarawa				2.9914 (0.9505)	0.002** *

R squared = 0.7543; No of observations = 1230; Mean labour productivity = 80.87 kg/labour
*, ** and *** represent significance at 10%, 5% and 1%, (Robust std errors in parenthesis)

Unit of analysis = plot; Dependent Variable = Labor Productivity of plots

Table 6 above shows the results of estimation of equation (3). They indicate that labour productivity and plot size has a quadratic relationship. An increase in land size will increase labour productivity till the plot reaches 9.03 acres and further increases in plot size will decrease labour productivity. Distance from home to plot is statistically significant and has a negative effect on labour productivity. The number of plots operated by a farmer is statistically significant and has a negative effect on labour productivity indicating that farmers become less efficient when the number of plots operated increases. Soil fertility of the plot has a positive and significant effect on labour productivity. Mechanized plots are more productive. Short grain varieties produce comparatively higher yields. Older farmers are more experienced and highly productive than the young generation. Educated farmers are more productive than non-educated or less-educated farmers. Kagama-Katiyawa (Mahakandarawa) plots were found to be less (more) productive than those in Rajanganaya.

Table 7: Descriptive Statistics and the Estimated Coefficient Values –Equation (4)

Variable		Measure	Mean Value	Std Deviation	coefficient	P Value
Farm Specific Characteristics	Constant				51.2667 (3.9752)	0.000***
	Total extent	Acres	1.97	1.00	43.8115 (2.1282)	0.000***
	Total extent ²	Acres	4.89	5.38	-3.9515 (0.4028)	0.000***
	Average Distance to plots from home	Meters	1921.05	1653.05	-0.0024 (0.0006)	0.000***
	Number of plots	Number	1.31	0.62	-20.9424 (1.9442)	0.000***
Farmer Characteristics	Age	Years	50.67	11.7	-0.0100 (0.0631)	0.873
	Education	Level	4.61	2.94	0.2841 (0.2846)	0.318
Settlement	Dk=dummy for Kagama-Katiyawa				-5.1231 (1.9502)	0.009**
	Dm= dummy for Mahakanadarawa				5.9033 (1.3179)	0.000***

R squared = 0.6346; No. of observations = 935; Mean labour productivity = 87.35 kg/labour
*, ** and *** represent significance at 10%, 5% and 1%, (Robust std errors in parenthesis)

Unit of analysis = Farm; Dependent Variable = Labor Productivity of farms

Table 7 above shows the results of estimation of equation (4) specified at the farm level are similar to those of the plot-level analysis. The results indicate that the relationship between the farm size and labour productivity is quadratic. The increase of the farm size beyond 5.54 acres would decrease labour productivity. Farms in Rajanganaya are found to be less (more) labour productive than those in Mahakandarawa (Kagama-Katiyawa). Distance from home to plot and number of plots in a farm negatively affect labour productivity suggesting that farmers with more plots are less efficient. Age and education have no statistically significant effects on labour productivity.

Relationship between mechanization and land size

Table 8 and 9 below show the results of the estimation of equations (5) and (6) respectively.

Table: 08 Descriptive Statistics and the Estimated Coefficient Values-- Equation 05

Variable		Units	Mean Value	Std Deviation	Coefficient	P Value
Plot Specific Characteristics	Constant				-0.7082 (0.2851)	0.013
	Size of plot	Acres	1.49	0.85	0.4057 (0.0635)	0.000** *
	Distance from home	Meters	1485.23	932.52	-0.0003 (0.0000)	0.000** *
	Soil Quality	Dummy (1= if fertile, 0= other)	0.87	0.44	0.3307 (0.1738)	0.057*
Farmer Characteristics	Age	Years	49.11	11.55	0.0164 (0.0039)	0.000** *
	Education	Level	4.59	2.93	-0.0389 (0.0209)	0.063*
Settlement	Number of plots operate d	Number	1.60	0.82	-0.2249 (0.0541)	0.000** *
	Dk=dummy for Kagama-Katiyawa				-1.0480 (0.1395)	0.000** *
	Dm= dummy for Mahakanadarawa				0.7063 (0.0966)	0.000** *

Log likelihood = -634.48; Wald Chi 2(8) = 297.73***; Pseudo R² = 0.2446; Number of observations = 1230;

***-significant at 1% (Figures in parenthesis represent standard errors)

Unit of Analysis = Plot; Dependent variable = whether the plot is mechanized or not

Table 09: Descriptive Statistics and the Estimated Coefficient Values – Equation (06)

Variable		Measure	Mean Value	Std Deviation	Coefficient	P Value
Constant					-0.5209 (0.2591)	0.044**
Farm Specific Characteristics	Total extent	Acres	1.97	1.00	0.4055 (0.0598)	0.000***
	Average Distance to plots from home	Meters	1921.05	1653.05	-0.0002 (0.0000)	0.000***
	Number of plots	Number	1.31	0.61	-0.2132 (0.1163)	0.067*
Farmer Characteristics	Age	Years	50.67	11.79	0.0167 (0.0045)	0.000***
	Education	Level	4.61	2.94	0.0388 (0.0216)	0.072*
Settlement	Dk=dummy for Kagama-Katiyawa				-1.0531 (0.1393)	0.000***
	Dm= dummy for Mahakanadarawa				0.6268 (0.1181)	0.000***

Log likelihood = -474.3094; Wald Chi 2(7) = 207.26***; Pseudo R² = 0.2247; Number of observations = 935;

*significant at 10% **significant at 5% ***significant at 1%

(Figures in parenthesis represent standard errors)

Unit of Analysis = Farm; Dependent variable = whether mechanized or not

They indicate that relationship between mechanization and land size is positive and statistically significant as measured by plot size and farm size respectively. Distance from home and number of plots clearly have negative and significant effects on probability to mechanize. There is a higher tendency to mechanize fertile plots and by older farmers. The effect of education of the two models provide some ambiguous results. Compared to Rajanganaya, probability of adoption of machinery, in both plots and farms, is lower (higher) in Kagama-Katiyawa (Mahakandarawa).

SUMMARY AND CONCLUSIONS

The results of the estimations clearly reveal that there exists a quadratic relationship between land productivity and farm size. When farm size increases, land productivity of farms increase up until 4.21 acres and any further increases in farm size decrease land productivity. The results also indicate that the number of plots in a farm and distance to plot are influential predictors of loss of productivity. This could be due to inherent inefficiencies associated with managing scattered plots. Plots at greater distances from farmers' homes are less productive and increase both travel time and

costs of inputs. Estimations of models to ascertain the relationship between labour productivity and land size show that plot size and farm size have a quadratic relationship with labour productivity. Labour productivity increases until plots and farms reach 9.03 acres and 5.54 acres respectively. Having more and distant plots are less labour productive when other factors affecting productivity are held at constant levels. The estimations in the relationship between the mechanization and land size in both plot- and farm-level indicate that the probability of using machineries is higher in larger plots. The above results suggest that it is advisable to consolidate agricultural lands until they reach their maximum potential. Measures to discourage further subdivisions of lowland plots are recommended to enhance productivity in paddy cultivations in irrigation settlements of Sri Lanka.

REFERENCES

- Ali, D.A., & K. Deininger. (2015). Is there a farm-size productivity relationship in African agriculture? Evidence from Rwanda. *Land Economics* 91 (2), 317–43.
- Ansoms, A. Verdoodt, A. & Ranst, E. (2008). The inverse relationship between farm size and productivity in rural Rwanda, Discussion paper, Institute of Development Policy and Management, University of Antwerp
- Assuncao, J. & Ghatak, M. (2003). Can unobserved heterogeneity in farmer ability explain the inverse relationship between farm size and productivity, *Economics Letters*, 80,189-194.
- Berry, A. & Cline, W. (1979). *Agrarian structure and productivity in developing countries*, Baltimore; Johns Hopkins University press, Maryland
- Chandrasiri, J. (2009). Informal land transactions in settlement schemes in Sri Lanka and their impact on Production. Hector Kobbekaduwa Agrarian Research & Training Institute of Sri Lanka
- Chayanov, A. V. (1926). *The theory of peasant cooperatives*. Columbus, OH: Ohio State University Press.
- Chen, Z. Huffman, W. & Rozelle, S. (2011). Inverse relationship between Productivity and farm size: The case of China, *Contemporary Economic Policy*, 29, 580-592.
- Cornia, G.A. (1985). Farm size, land yields and the agricultural production function: An analysis for fifteen developing countries, *Journal of World Development*, 13, (4), 513-534.

- Deolalokar, A. B. (1981). The inverse relationship between productivity and farm size: A test using regional data from India, *American Journal of Agricultural Economics*, 275-79.
- Ghosh B K (2010), Determinants of Farm Mechanization in Modern agriculture: A Case study of Burdwan districts of West Begal, *International Journal of Agricultural Research* 5 (12), 1107-1115.
- Kawasaki, K. (2010). The costs and benefits of land fragmentation of rice farms in Japan. *Australian Journal of Agricultural and Resource Economics* 54(4),509–26.
- Lu, H., H. Xie, Y. He, Z. Wu, & Zhang, X. (2018). Assessing the impacts of land fragmentation and plot size on yields and costs: A translog production model and cost function approach. *Agricultural Systems*. 81-88.
- Obasi, P.C. (2007). Farm size-productivity relationship among arable crops in Imo State, Nigeria, *International Journal of Agriculture and Rural Development*, 9(1), 97-105.
- Paul, M. & Githinji, M. (2017). Small farms, smaller plots: land size, fragmentation, and productivity in Ethiopia, *The Journal of Peasant Studies*, DOI:10.1080/03066150.2016.1278365
- Rahman, S. & Rahman, M. (2009). Impact of land fragmentation and resource ownership on productivity and efficiency: The case of rice producers in Bangladesh, *Land Use Policy*, 26, 95-103.
- Sen, A.K (1962). ‘An aspect of Indian agriculture’, *Economic Weekly*, 14, 243-246.
- Sims, B.G & Kienzle, J. (2006). Farm power and mechanization for small farms, *Agricultural and food engineering technical report* FAO, UN
- Tamel, T. (2011). New facts for old debated: Farm size and productivity in US agriculture, MPRA paper, No. 31920.
- Thapa, S. (2007). ‘The relationship between farm size and productivity; empirical evidence from the Nepalese Mid hills’, MPRA paper, No. 7638.
- Wanigaratne, R.D. (1995). Informal tenure conditions in irrigated settlements in Sri Lanka: A review of empirical research evidence, *Land Tenure Center*, University of Wisconsin, Madison.
- Wickramaarachchi, N.C. (2016). Effects of Land Fragmentation and Tenure Security on Paddy Productivity: An Empirical Investigation in North Central Province of Sri Lanka. PhD thesis submitted to University of Colombo, Sri Lanka.

Yagi, H. (2012). Farm size and Distance-to-Field in Scattered Rice Field Areas with Integration of Plot and Farm Data. Selected Poster prepared for presentation at the International Association of Agricultural Economists (IAAE) Triennial Conference, Foz do Iguaçu, Brazil, 18-24 August, 2012