International Journal of Food and Agricultural Economics
ISSN 2147-8988, E-ISSN: 2149-3766
Vol. 6, No. 4, 2018, pp. 21-33

# THE EFFECT OF OXEN ON AGRICULTURAL PRODUCTIVITY AND FARM INCOME IN NICARAGUA

**Pablo A. Garcia-Fuentes**
Midwestern State University, Dillard College of Business Administration, Department of Economics, Finance, and General Business, 3410 Taft Blvd Wichita Falls, TX 76308-2099, USA, Email: pablo.fuentes@msutexas.edu

**Yoshi Fukasawa**†
Midwestern State University, Dillard College of Business Administration, USA

**Edgar A. Martinez Rodriguez**
Movimiento Comunal Nicaraguense-La Trinidad, Esteli, Nicaragua

**Conney Vargas**
Midwestern State University, Dillard College of Business Administration, USA

**Rodrigo Mireles**
Midwestern State University, Dillard College of Business Administration, USA

**Abstract**

*This study[1] uses survey data to assess the effect of oxen as draft animals on agricultural productivity and farm agricultural income in Nicaragua during the year 2017. The results suggest that farms that use oxen to plow the land have higher bean productivity than farms that use stick to plant crops. On average, using oxen increases farm's bean output by 7.75 100-pound bags, and hiring oxen increases farm's bean output by 8.5 100-pound bags. Also, using or hiring oxen increases total farm planted area. The main finding about the effect of oxen to plow the land through farm planted area on agricultural farm gross income suggests that using oxen to plow the land increases agricultural farm gross income by 18.13 percent, and that hiring oxen increases agricultural farm gross income by 25.55 percent.*
**Key words:** *Agricultural productivity, farm income, oxen, Nicaragua*
**JEL codes**: *O13, Q10, Q18*

## 1. Introduction

Nicaragua's economic growth rate during the last decade was 3.2 percent which was lower than the growth rate of the other Central American countries and is not enough to generate faster economic development and poverty reduction (Inter-American Development Bank [IDB], 2012). About 42.5 percent of the population of Nicaragua still lives below the national poverty line (World Bank [WB], 2012). Also, the percentage of poor people living in rural areas is 63 percent while that of urban areas is 27 percent (IDB, 2012).

Nicaragua's agricultural sector represents about 20 percent of its gross domestic product (GDP), employs 40 percent of the population, and creates 70 percent of total exports (IDB, 2012). This sector comprises two subsectors. One subsector represents the commercial farms

that sell their products in the export market, while the other sector represents small farmers who own about 80 percent of the country's farms, have limited access to capital, and produce about 90 percent of the country's output of corn, beans, and sorghum (IDB, 2008). However, average yields in Nicaragua are below the Latin America and the Caribbean regional averages (WB, 2012). In addition, it is argued that limited productive credit for new projects to farmers and small businesses in rural areas has been one of the constraints to economic development in Nicaragua (Agosin, Bolaños, & Delgado, 2008). Hence, increasing agricultural productivity can contribute to increasing farmers' income and decreasing poverty in rural areas. However, increasing agricultural productivity requires that small farmers have access to agricultural inputs such as oxen as draft animals.

Regarding the importance of draft animals in agriculture in developing countries, Kjaerby (1983) highlights that the use of oxen in agriculture allows for decreasing land preparation time and for increasing planted area and labor productivity. Sansoucy (1995) argues that draft animals make an important contribution to crop production and income. Lawrence and Pearson (2002) also argue that poor farmers would continue depending on draft animals, and that the lack of draft animals would limit the planted area, contribute to late planting, and contribute to crop failure. Further, Suarez, Rios, and Sotto (2005) suggest that draft animals are a more appropriate option for crop cultivation on small and medium size farms. More recently, Cajina and Moreno (2013) report that the highest corn yields in Nicaragua were achieved on farms that used tractors, and that tractors were used in 4.1 percent of the farms, while oxen were used in 29.7 percent of the farms and a stick (a spear like hand tool used to plant crops) was used in 66.2 percent of the farms.

The current paper uses survey data on farm activities for the year 2017 to assess the effect of oxen as draft animals on agricultural productivity and on agricultural farm income in Nicaragua. Specifically, it assesses the effect of oxen on farm's bean productivity, the effect of oxen on total farm planted area, the effect of total farm planted area on agricultural farm gross income, and the effect of oxen through farm planted area on agricultural farm gross income. The results show that farms that use oxen or hire oxen to plow the land have higher bean yields and higher agricultural gross income. A very important finding is that oxen have a positive and significant impact on agricultural farm gross income through farm planted area. The main finding about the effect of oxen to plow the land through farm planted area on agricultural farm gross income suggests that using oxen to plow the land increases agricultural farm gross income by 18.13 percent, and that hiring oxen increases agricultural farm gross income by 25.55 percent.

The rest of the paper is organized as follows. The second section provides a description of the rural household and the farm. The next section reviews the relevant literature, followed by a description of the methodology and data. The following section presents a discussion of the results. The last section presents the conclusions.

## 2. Household and Farm Characteristics

This section gives a description of the rural households of the municipality of La Trinidad, Esteli, Nicaragua based on the descriptive statistics of the relevant variables (see appendix 1). The sample includes 102 households from a population of about 4,313 households and it represents 51 of the 56 villages in the municipality. In our sample, nine percent of the households are beneficiary of the Zero Hunger Program, while five percent are beneficiary of the Agro-Food Support Program. Of the total households, 88 percent are male headed households, and 98 percent of the farmers are farm owners. The average annual household gross income is $1,172, of which, on average, 71 percent comes from the sales of beans, corn, and sorghum.

Regarding the characteristics of the farm, the average farm size is 11.41 manzana[2] (Mz) or 19.8 acres, while the farm average planted area is 3.93 Mz. Ninety five percent of the farms use native seeds, while 98 percent of them use fertilizers. The annual average bean planted area is 4.43 Mz, that of corn is 1.27 Mz, and that of sorghum is 0.30 Mz. The annual average farm yield for beans is 36.91 100-pound bags, for corn is 23.25 100-pound bags, and for sorghum is 3.37 100-pound bags. The average farm sale price of a 100-pound bag of beans is $34.01, that of corn is $9.84, and that of sorghum is $11.45.

About the use of draft animals, 86 percent of the farms use oxen to plow the land and no farm uses tractors. Fifteen percent of the farms own oxen, while 84 percent of the farms hire oxen and pay for them with money. The average time for planting one Mz of land using oxen is 17.7 hours, while using a stick requires 43.4 hours. In addition, because of the lack of oxen, all farmers state that they plant late, while 99 percent of the farmers state that they miss the optimum planting window. Further, the farmers argue that having oxen would allow them to increase the planted area by 2.43 Mz on average.

The average price of an adult ox is $893.13, and 99 percent of the farmers state that they do not own oxen due to lack of money to pay for them. In addition, access to credit is limited, five percent of the farmers have access to credit, and one percent of them only is able to get a loan to buy a couple of oxen. All farmers state that there is no program that finances oxen and consider that it is important to have a program that could finance oxen to farmers. Further, given a scale from 1 to 10 (10 being the most important), the farmers state that, on average, the importance of using oxen for plowing the land, increasing agricultural productivity, planting during the optimum planting window, increasing the cultivated area, and increasing household income is at least 9.6.

## 3. Literature Review

Economic development in developing countries is associated with improving poor people's living standards. Ward, Sutherland, and Sutherland (1980) argued that development in the world would depend on helping poor people in rural areas to increase their incomes and their participation in the national and international economies. They highlighted the importance of promoting the use of draft animals in agriculture as a development strategy rather than increasing mechanization because of increasing fuel costs. Kjaerby (1983) describes the problems and contradictions of using oxen in agriculture in Tanzania and shows that despite the failure of the use of tractors to increase agricultural productivity, there has been very little effort and funding allocated to promoting the use of oxen in agriculture. The study highlights that the use of oxen in agriculture allows for decreasing land preparation time and for increasing planted area and labor productivity. It also states that farmers borrow ox teams and plows, and that hiring ox teams is very expensive but it is very common. However, it is argued that the lack of financial means prevent poor farmers from getting access to ox teams and ox-plows. Thus, the lack of credit to poor farmers may be an important constraint to increasing agricultural productivity.

In 1992, there were about 479 million hectares cultivated in developing countries excluding China, of which 32 percent were cultivated with tractors, 52 percent with draft animals, and 26 percent with hand tools (Gifford, 1992). Sansoucy (1995) argues that draft animals make an important contribution to crop production and income and that it is important to promote a more efficient use of draft animals in agriculture. However, Asamenew, the Bangladesh Bureau of Statistics, and Gryseels (as cited in Sansoucy, Jabbar, Ehui, & Fitzhugh, 1995) argue that small farmers in developing countries neither have draft animals nor have an appropriate number of them. Thus, the lack of draft animals may contribute to lowering agricultural productivity.

Lawrence and Pearson (2002) focus on the role of draft animal power on small farms in Nepal and Indonesia and argue that poor farmers would continue depending on draft animals, and that the lack of draft animals would limit the planted area, contribute to late planting, and increase crop failure. They also state that it is almost impossible to use tractors for farming in the hills of Nepal and that draft animals contribute to poverty reduction on small scaled mix farms. In addition, the lack of oxen has also lead to sharecropping between households that do not own oxen and those that do, so the former has paid the latter up to 50 percent of their harvest for the borrowing of oxen (Ashley & Sandford, 2008). Further, Starkey (2010) reports that the use of oxen increased from 350,000 to 2 million during the past 50 years in the French speaking part of West Africa and that 7 million oxen are used to plow land in Ethiopia and neighbor areas. Thus, draft animals are an important power source in developing countries' agricultural systems.

Cuba's agricultural system is an interesting case about the use of draft animals. Funes-Monzote (2007) reports that Cuba' agriculture faced the strongest crisis in the early 1990s due to the lost support from the former Soviet Union, but this created an alternative agricultural model. The number of agricultural tractors increased from 7,000 in 1960 to 70,000 in 1990 due to the modernization of agriculture, but it decreased to 40,000 in 1995; the number of oxen decreased from 500,000 in 1960 to 163,000 in 1990, but increased to 376,000 in 1995; and the number of draft horses decreased from 800,000 in 1960 to 235,000 in 1990, but increased to 300,000 in 1995 (Rios, 1999). The decrease in the number of agricultural tractors was mainly due to the rupture of the former Soviet Union that supplied agricultural equipment, parts and fuel to Cuba. Consequently, the Cuban government transformed the large government farms into small scale farms, recognized that draft animals were more appropriate than tractors, and promoted the introduction of 200,000 oxen and more productive agricultural implements (Rios, 1999). Further, a study on the differences between the use of tractors and draft animals in Cuba showed that draft animals are a more appropriate option for crop cultivation on small and medium size farms (Suarez et al., 2005).

More recently, Cajina and Moreno (2013) focus on corn production in Nicaragua over the period 2001-2013. Based on data for the 2012-2013 crop season, they report that the farms that used tractors achieved the highest corn yields, that 4.1 percent of the farms used tractors, that 29.7 percent of the farms used oxen, and that 66.2 percent of the farms used a stick (a hand tool). However, they argue that their estimations may suffer from omitted variable bias. For example, they did not control for the optimum planting window which could affect corn yields. Some research finds that delaying planting beyond the optimum planting window decreases corn yield in the United States (Coulter, 2012; Farnham, 2001; Nafziger, 2008), which can be about a 25 percent decrease (Myers & Wiebold, 2013). Thus, lack of oxen may contribute to planting late, missing the optimum planting window, and lowering yields.

## 4. Methodology and Data

### 4.1 Methodology

The equations below show the relationships between farm's bean productivity and oxen, total farm planted area and oxen, agricultural farm gross income[3] and total farm planted area, and agricultural farm gross income and oxen through farm planted area. Equation (1) shows that oxen affect farm's bean productivity. That is,

$$Y = f(Ab, L, Fs, Ox) \tag{1}$$

where $Y$ is farm's bean output, $Ab$ is bean planted area in Mz in the farm, $L$ is total labor used to cultivate one Mz of beans, $Fs$ is farm size in Mz, and $Ox$ is a dummy variable that

takes the value of 1 if the farmer uses oxen to plow the land and zero if the farmer uses a stick to plant the crops.

Equation (2) shows that oxen affect farm planted area. That is,

$$Af = f(Fs, Ox) \tag{2}$$

where $Af$ is total farm planted area in Mz and the other variables are defined above.

Equation (3) shows that farm planted area affects agricultural farm gross income. That is

$$Ia = f(Af, LnPb, LnPc, LnPs) \tag{3}$$

where *Ia* is agricultural farm gross income, *Af* is total farm planted area, *LnPb* is farm sale price of beans, *LnPc* is farm sale price of corn, and *LnPs* is farm sale price of sorghum.

Equations (2) and (3) show that oxen affect agricultural farm gross income through total farm planted area. Therefore, we also estimate Equations (2) and (3) simultaneously to assess the effect of oxen through farm planted area on farm gross agricultural income.

### 4.2 Data

This research uses survey data. In March 2017, we administered the survey to 94 farmers who attended a workshop at the Movimiento Comunal Nicaraguense-La Trinidad (MCN-LT) in La Trinidad, Esteli, Nicaragua. The 94 farmers represented 34 villages of the municipality of La Trinidad. The survey collected data on farm activities for the year 2016. However, in order to collect more data, during November and December 2017, we administered a follow-up survey to 103 farmers from 51 of the 56 villages of the municipality of La Trinidad. The follow-up survey collected data on farm activities for the year 2017. Because of better data, we use the data from the follow-up survey. The survey includes 74 questions that gather data on the households and farms. The sample of 103 farmers represents 4,313 rural households. These farmers are affiliated with the MCN-LT which is a non-profit organization that aims to contribute to improving the wellbeing of people. Monetary figures in Nicaragua's currency were converted to nominal dollars using the average of the 2017 November and December daily exchange rate of the Nicaraguan Cordoba against the U.S. dollar[4]. In addition, descriptive statistics for the relevant variables are in Appendix 1.

## 5. Results

This section presents the results of assessing the effect of oxen on farm's bean productivity, the effect of oxen on total farm planted area, the effect of total farm planted area on agricultural farm gross income, and the effect of oxen through total farm planted area on agricultural farm gross income.

### 5.1 Effect of Oxen on Farm's Bean Productivity

Table 1 shows OLS robust to heteroskedasticity estimations of the effect of oxen on farm's bean productivity. Model 1 assesses the effect of using oxen to plow the land against using stick to plant crops. Ox is a dummy variable that takes the value of 1 if a farm uses oxen to plow the land and zero if it uses a stick to plant crops. The estimate on Ox is positive and significant and suggests that, on average, using oxen increases farm's bean output by 7.75 100-pound bags. In addition, bean planted area and total hours of labor to cultivate one Mz of beans

have positive and significant effects on farm's bean yield. Thus, Model 1's results suggest that farms that use oxen are more productive than those that use stick to plant crops. In our sample, 86 percent of the farmers use oxen to plow the land. Model 2 assesses the effect of hiring oxen to plow the land on farm's bean productivity. Hire Ox is a dummy variable that takes the value of 1 for a farm that hires oxen if it does not own oxen and zero if the farm does not hire oxen. The estimate on Hire Ox is positive and significant and suggests that, on average, hiring oxen increases farm's bean output by 8.5 100-pound bags. In addition, bean planted area, total hours of labor to cultivate one Mz of beans, and farm size have positive and significant effects on farm's bean productivity. Thus, Model 2's results suggest that farms that hire oxen to plow the land are more productive than farms that do not. In our sample, 84 percent of the farmers hire oxen to plow the land. Furthermore, the farmers in our sample do not use tractors to plow the land, and they consider that the level of importance of using oxen to plow the land and to increase productivity is at least 96 percent (see appendix 1).

**Table 1. Effect of Oxen on Farm's Bean Productivity**

| Dependent Variable: 100-pound bags of beans per farm | | |
|---|---|---|
| Variable | Model 1 | Model 2 |
| Constant | -4.0090<br>(0.63) | -4.0550<br>(0.69) |
| Bean planted area | 4.8296***<br>(65.13) | 4.6616***<br>(59.56) |
| Labor | 0.0513**<br>(5.24) | 0.0499**<br>(5.03) |
| Farm size | 0.1881<br>(2.26) | 0.2324*<br>(3.48) |
| Ox | 7.7458**<br>(4.91) | |
| Hire Ox | | 8.5007**<br>(6.52) |
| R-squared | 0.3299 | 0.3368 |
| Observations | 98 | 98 |

**Note:** OLS robust to heteroskedasticity estimations. Model 1 estimates the effect of oxen or stick on farm's bean productivity. Model 2 estimates the effect of hiring oxen on farm's bean productivity. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively. The numbers in parentheses are chi-squared values.

The results of Table (1) give support to Cajina and Moreno's (2013) study that describes the first-season[5] corn production in Nicaragua for the period 2001-2013 and reports that farms that use oxen are more productive than those that use stick to plant corn. Their study reports that corn yield was 35.9 100-pound bags for farms that used tractors, 21.4 100-pound bags for farms that used oxen, and 15.8 100-pound bags for farms that mostly used stick. In addition, the results on the effect of hiring oxen to plow the land on agricultural bean productivity give support to Kjaerby's (1983) study that argued that farmers borrowed ox teams and plows, but that hiring ox teams was very expensive and very common. Further, Sansoucy (1995) argues that draft animals make an important contribution to crop production and income, and that it is important to promote a more efficient use of draft animals in agriculture.

### 5.2 Effect of Oxen on Total Farm Planted Area

The results of OLS robust to heteroskedasticity estimations of the effect of oxen on total farm planted area are shown in Table (2). Model 1 assesses the effect of using oxen to plow the land on total farm planted area. The estimate on Ox (defined above) is positive and significant at the 1 percent level and suggests that, on average, using oxen to plow the land increases total farm planted area by 0.93 Mz. Thus, farms that use oxen to plow the land have more planted area than those that use stick to plant crops. Farm size has a positive and significant effect on total farm planted area. Model 2 assesses the effect of hiring oxen to plow the land on total farm planted area. The estimate on Hire Ox (defined above) is positive and highly significant and suggests that, on average, hiring oxen to plow the land increases total farm planted area by 0.94 Mz. Thus, farms that hire oxen to plow the land have more planted area than those that do not. Farm size has a positive and significant effect on total farm planted area. This results are in line with Kjaerby's (1983) study that highlights that using oxen in agriculture allows for decreasing land preparation time and for increasing planted area and labor productivity. The farmers in our sample consider that the level of importance of using oxen to increase cultivated area is about 99 percent (see appendix 1).

**Table 2 Effect of oxen on total farm planted area**

| Dependent variable: Total farm planted area | | |
|---|---|---|
| Variable | Model 1 | Model 2 |
| Constant | 1.3300***<br>(15.18) | 1.3421***<br>(16.66) |
| Farm size | 0.1481***<br>(126.14) | 0.1473***<br>(125.08) |
| Ox | 0.9321***<br>(7.21) | |
| Hire Ox | | 0.9395***<br>(7.77) |
| R-squared | 0.4301 | 0.4324 |
| Observations | 99 | 99 |

**Note:** OLS robust to heteroskedasticity estimations. Model 1 estimates the effect of oxen or stick on farm's bean productivity. Model 2 estimates the effect of hiring oxen on farm's bean productivity. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively. The numbers in parentheses are chi-squared values.

### 5.3 Effect of Total Farm Planted Area on Agricultural Farm Gross Income

Table (3) shows the results of an OLS robust to heteroskedasticity estimation of the effect of total farm planted area on agricultural farm gross income. This income is from the sales of beans, corn and sorghum, so the estimation controls for the farm sale prices of these crops. Total farm planted area has a positive and highly significant effect on agricultural farm gross income. That is, an increase in farm planted area by one Mz increases agricultural farm gross income by 17.35 percent[6]. Note that the estimates on crop prices are elasticities. The estimate on the price of beans is positive and highly significant and suggests that a 10 percent increase in the price of beans increases agricultural farm gross income by 1.22 percent. The estimate on the price of corn suggests that a 10 percent increase in the price of corn increases agricultural farm gross income by 0.52 percent. The estimate on the price of sorghum is negative but nonsignificant.

**Table 3. Effect of Total Farm Planted Area on Agricultural Farm Gross Income**

| Dependent variable: Ln agricultural farm gross income | |
|---|---|
| Variable | Model |
| Constant | 1.2578<br>(0.94) |
| Farm planted area | 0.1735***<br>(57.92) |
| Ln Beans price | 1.2216***<br>(12.97) |
| Ln Corn price | 0.5237**<br>(5.16) |
| Ln Sorghum price | -0.1204<br>(2.23) |
| R-squared | 0.3466 |
| Observations | 99 |

**Note:** OLS robust to heteroskedasticity estimation. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively. The numbers in parentheses are chi-squared values. Ln is the natural logarithm operator.

The results in Tables (2) and (3) suggest that there is an important link between oxen as agricultural input and agricultural farm gross income. It is likely that oxen have an important effect on agricultural farm gross income through total farm planted area. This issue is assessed in the next section.

**5.4 Effect of Oxen through Total Farm Planted Area on Agricultural Farm Gross Income**

Table (4) shows Generalized Method of Moments instrumental variable (GMM-IV) estimations of the effect of oxen through total farm planted area on agricultural farm gross income. Panel (a) shows the effect of total farm planted area on agricultural farm gross income. Panel (b) shows the estimations of total farm planted area using farm size and oxen as instruments. Panel (c) shows the over identifying restrictions tests of the null hypotheses that the instruments are valid.

Models 1 and 1.1 assess the effect of using oxen to plow the land trough farm planted area on agricultural farm gross income. In model 1, farm planted area has a positive and highly significant effect on agricultural gross income. The estimates on the price of beans and corn have a positive and highly significant effect on agricultural gross income, but the price of sorghum is negative and highly significant. In model 1.1, the estimate on Ox is not only positive and highly significant, but also is bigger than the estimate in model 1 in Table (2) above. Note that the over identifying restrictions test does not reject the null hypothesis that the instruments are valid.

Models 2 and 2.1 assess the effect of hiring oxen to plow the land through farm planted area on farm agricultural gross income. In model 2, farm planted area has a positive and highly significant effect on farm agricultural gross income. The estimates on the price of beans and corn have a positive and highly significant effect on agricultural gross income, but the price of sorghum is negative and highly significant. In model 2.1, the estimate on Hire Ox is not only positive and highly significant, but also bigger than the estimate in model 2 in Table (2) above. Note that given the over identifying restrictions test, the instruments are valid.

Given the significance of the estimates of the models in Table (4), the main discussion on the effect of oxen on agricultural farm gross income is based on Table (4). Given models 1 and

1.1, an increase in farm planted area by one Mz increases agricultural gross income by 18.02 percent. In addition, a 10 percent increase in the price of beans increases agricultural gross income by 1.40 percent, and a 10 percent increase in the price of corn increases agricultural gross income by 0.54 percent. However, increases in the price of sorghum decrease agricultural gross income. Note that, in model 1.1, using oxen to plow the land rather than stick to plant crops increases total farm planted area by 1.0 Mz. Therefore, the impact of using oxen to plow the land through farm planted area on agricultural farm gross income is 18.13 percent [(0.1802*100) 1.0062 = 18.13%].

**Table 4. Effect of Oxen on Agricultural Farm Gross Income through Total Farm Planted Area**

| *a. Effect of total farm planted area on agricultural farm gross income* | | | |
|---|---|---|---|
| Dependent variable: Agricultural farm gross income | | | |
| Variables | Model 1 | Variables | Model 2 |
| Constant | 0.6076<br>(0.52) | Constant | 0.4073<br>(0.35) |
| Farm planted area | 0.1802***<br>(6.91) | Farm planted area | 0.1825***<br>(7.08) |
| Ln Beans price | 1.3928***<br>(4.28) | Ln Beans price | 1.4506***<br>(4.39) |
| Ln Corn price | 0.5366***<br>(3.59) | Ln Corn price | 0.5337***<br>(3.55) |
| Ln Sorghum price | -0.1257***<br>(-7.54) | Ln Sorghum price | -0.1286***<br>(-7.68) |
| Adj. R-squared | 0.4267 | Adj. R-squared | 0.4250 |
| Obs. | 99 | Obs. | 99 |
| Dependent variable: Total farm planted area | | | |
| Variables | Model 1.1 | Variables | Model 2.1 |
| Constant | 1.6553***<br>(4.23) | Constant | 1.2271***<br>(4.42) |
| Farm size | 0.1206***<br>(4.33) | Farm size | 0.1320***<br>(5.44) |
| Ox | 1.0062***<br>(3.24) | Hire Ox | 1.4002***<br>(3.51) |
| Adj. R-squared | 0.4125 | Adj. R-squared | 0.4487 |
| Obs. | 99 | Obs. | 99 |
| *c. Over identifying restrictions test* | | | |
| Statistic | 3.68 | Statistic | 4.92 |
| P-value | 0.4512 | P-value | 0.2959 |

**Note:** GMM-IV estimations. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively. The numbers in parentheses are t-values. Ln is the natural logarithm operator.

The estimations based on models 2 and 2.1 show that an increase in farm planted area by one Mz increases agricultural farm gross income by 18.25 percent. Also, a 10 percent increase in the price of beans increases agricultural gross income by 1.45 percent, and a 10 percent increase in the price of corn increases agricultural gross income by 0.53 percent. However, increases in the price of sorghum decrease agricultural gross income. In model 2.1, hiring oxen increases total farm planted area by 1.40 Mz. Therefore, the impact of hiring oxen to plow the

land through farm planted area on agricultural farm gross income is 25.55 percent [(0.1825*100) 1.4002 = 25.55%]. The effect of hiring oxen is bigger than that of using oxen. This can be related to the fact that in our sample only 11.7 percent of the farmers own oxen, and of the 12 farmers that own oxen, only three of them own a team of two oxen, the other farmers own one ox only. Further, given a scale from 1 to 10 (10 being the most important), the farmers state that, on average, the importance of using oxen for plowing the land, increasing agricultural productivity, planting during the optimum planting window, increasing the cultivated area, and increasing household income is at least 9.6.

The results from Table (4) suggest that farms that use oxen or hire oxen to plow the land have higher agricultural gross income. In addition, given the results from Table (1), farms that use oxen have higher bean yields. Thus, by using oxen or hiring oxen to plow the land, agricultural productivity of beans increases as well as farm agricultural gross income. These results, again, give support to earlier research that suggests that that hiring ox teams is very common and that the use of oxen in agriculture allows for decreasing land preparation time and for increasing planted area and labor productivity (Kjaerby, 1983); that draft animals make an important contribution to crop production and income (Sansoucy, 1995); that small farmers in developing countries do not have draft animals or have only an inappropriate number of them (Asamenew, the Bangladesh Bureau of Statistics, and Gryseels as cited in Sansoucy et al., 1995); and in the case of corn production in Nicaragua, farms that used oxen had higher corn yields than those that used a stick to plant corn (Cajina & Moreno, 2013).

The negative and significant effect of the price of sorghum on agricultural farm gross income can be associated with the following facts given our data. The average farm sale price of sorghum ($11.45) is lower than that of beans ($34.01), but higher than that of corn ($9.84). Also, out of the 102 farms in the sample, only 25 farms produce sorghum. Further, sorghum is a substitute in production that competes with beans and corn for planted area in the farm, so farmers may prefer to plant more beans given the higher bean price. The annual bean planted area is 452 Mz, that of corn is 130.5 Mz, and that of sorghum is 30 Mz, so the most important crop is beans. The average farm output for beans is 36.9 100-pound bags, for corn is 23.25 100-pound bags, and for sorghum is 3.37 100-pound bags. Thus, it is likely that agricultural farm income can increase by increasing output of beans and corn, but it can decrease by increasing sorghum production.

## 6. Conclusions

This research uses survey data to assess the effect of oxen as draft animals on agricultural productivity and farm agricultural income. Specifically, it assesses the effect of oxen on farm's bean productivity, the effect of oxen on farm planted area, the effect of farm planted area on agricultural farm gross income, and the effect of oxen through farm planted area on agricultural farm gross income.

The results show that farms that use oxen to plow the land have higher bean yields than farms that use stick to plant beans. On average, using oxen increases farm's bean output by 7.75 100-pound bags, and hiring oxen increases farm's beans output by 8.5 100-pound bags. Farms that use oxen or hire oxen to plow the land have more planted area. A very important finding is that oxen have a positive and significant impact on agricultural farm gross income through farm planted area. The impact of using oxen to plow the land through farm planted area on agricultural farm gross income is 18.13 percent, and the impact of hiring oxen to plow the land through farm planted area on farm agricultural gross income is 25.55 percent. The positive impact of oxen on bean yields allows rural households to increase their food availability which is related to the sustainable development goal "End Hunger". In addition, the positive impact of oxen through planted area on agricultural farm gross income allows rural

households to increase their income which is related to reducing poverty in rural areas and to the sustainable development goal "End Poverty".

The policy implications of this research are related to the use of oxen to contribute to increasing agricultural productivity and farm income in Nicaragua. Therefore, it will be important to develop an agricultural program that promotes the use of oxen in agriculture. In addition, given that farmers argue that they do not own oxen because of the lack of money or funding, it would be important to develop an agricultural program that could finance oxen to farmers.

**Acknowledgments**

We thank Dr. Yoshi Fukasawa for his contribution to this research. He passed away on February 11, 2018. His contributions to the preparation of the grant proposal for this research project and the conference presentation of the initial version of this paper were very significant. He was a colleague, a mentor, and a true friend. We were very fortunate because this project was a great opportunity to work with Dr. Fukasawa.

The views expressed in this research are those of the authors and do not necessarily reflect the views of the institutions they represent. We thank Midwestern State University and the Office of Sponsored Programs and Research for the grant that sponsored this research and the travel to Nicaragua. We thank the Movimiento Comunal Nicaraguense-La Trinidad for helping us administer the survey to the farmers, and for all the help they offered us. We thank Dr. Kathryn M. Zuckweiler, the Nicaraguan farmers, Mrs. Ceferina Fuentes Centeno, Mr. Jocsan Moreno, and all the volunteers that helped us administer the survey.

**References**

Agosin, M., Bolaños, R., & Delgado, F. (2008). *Nicaragua: A la búsqueda del crecimiento perdido* (Serie Documentos de Trabajo 275). Universidad de Chile, Santiago, Chile. Retrieved from http://repositorio.uchile.cl/handle/2250/144298.

Ashley, S. & Sandford, J. (2008). Livestock livelihoods and institutions in the IGAD region. IGAD LPI Working Paper No. 10-08.

Cajina, R. C., & Moreno, R. B. (2013). *Caracterización del cultivo de maíz en Nicaragua: Un análisis de varianza de los determinantes del rendimiento* (Documentos de Trabajo 033). Banco Central de Nicaragua, Managua, Nicaragua.

Coulter, J. (2012). Planting date considerations for corn. Minnesota Crop News. University of Minnesota. Retrieved from http://blog-crop-news.extension.umn.edu/2012/03/planting-date-considerations-for-corn.html.

Funes-Monzote, F. (2007). Towards sustainable agriculture in Cuba. Retrieved from https://www.researchgate.net/profile/F_Funes-Monzote/publication/240635546_Towards_sustainable_agriculture_in_Cuba/links/00b7d52ba3408d6ca0000000.pdf.

Gifford, R.C. (1992). *Agricultural engineering in development: Mechanization strategy formulation: Concepts and principles* (Vol. 1). FAO, Rome.

Inter-American Development Bank. (2008). *Nicaragua-Programa de apoyos productivos agroalimentarios (NI-L1020): Propuesta de préstamo*. Retrieved from https://www.iadb.org/es/project/NI-L1020.

Inter-American Development Bank. (2012). *Country program evaluation Nicaragua 2008-2012*. Inter-American Development Bank, New York. Retrieved from https://publications.iadb.org/handle/11319/5812.

Kjaerby, F. (1983). *Problems and contradictions in the development of ox-cultivation in Tanzania* (Research report 66). Scandinavian Institute of African Studies, Uppsala Centre for Development Research, Copenhagen.

Lawrence, P. R., & Pearson, R. A. (2002). Use of draught animal power on small mixed farms in Asia. *Agricultural Systems*, 71(1), 99-110.

Myers, B., & Wiebold, W. J. (2013). Planting date 2013. Integrated pest and crop management. University of Missouri. Retrieved from https://ipm.missouri.edu/IPCM/2013/4/Planting-Date-2013/

Nafziger, E. (2008, April). Thinking about corn planting date and population. *The Bulletin*, 2(7), University of Illinois. Retrieved from http://bulletin.ipm.illinois.edu/article.php?id=890.

Rios, A. (1999). Improving animal traction technology in Cuba. In Starkey P. & Kaumbutho P. (Eds.). *Meeting the challenges of animal traction*. A resource book of the Animal Traction Network for Eastern and Southern Africa (ATNESA). Intermediate Technology Publications, London.

Sansoucy, R. (1995). Livestock-a driving force for food security and sustainable development. *World Animal Review*, 84/85(2).

Sansoucy, R., Jabbar, M. A., Ehui, S., & Fitzhugh H. (1995). Keynote paper: The contribution of livestock to food security and sustainable development. In Wilson R. T., Ehui S., & Mack S (Eds.). *Livestock Development Strategies for Low Income Countries.* FAO/International Livestock Research Institute, Nairobi, Kenya.

Starkey, P. (2010). Livestock for traction: World trends, key issues and policy implications. AGA Working Paper Series. FAO, Rome.

Suarez, J., Rios, A., & Sotto, P. (2005). El tractor y la tracción animal. *Revista Ciencias Técnicas Agropecuarias*, 14(2), 40-44.

Ward, G. M., Sutherland, T. M., & Sutherland, J. M. (1980). Animals as an energy source in third world agriculture. *Science*, 208, 570-574.

World Bank. 2012. *Nicaragua - Country partnership strategy for the period FY13-FY17 (English)*. Washington, DC: World Bank. Retrieved from http://documents.worldbank.org/curated/en/828301468290161276/Nicaragua-Country-partnership-strategy-for-the-period-FY13-FY17.

**Appendix 1. Descriptive Statistics**

| Variable | N | Mean | Std Dev | Min | Max |
|---|---|---|---|---|---|
| Annual gross income $ | 102 | 1171.6 | 892.5 | 163.0 | 4890.8 |
| Share of sale of beans, corn and sorghum in annual gross income | 102 | 71.1 | 30.3 | 10.0 | 100.0 |
| Farm size in Mz | 102 | 11.4 | 10.4 | 0.0 | 60.0 |
| Farm planted area | 102 | 3.9 | 2.1 | 1.0 | 12.0 |
| Beans planted area in season 1 | 102 | 2.4 | 1.4 | 0.0 | 6.0 |
| Corn planted area in season 1 | 102 | 1.3 | 0.8 | 0.0 | 5.0 |
| Sorghum planted area in season 1 | 102 | 0.1 | 0.4 | 0.0 | 2.0 |
| Beans planted area in season 2 | 102 | 2.1 | 1.3 | 0.0 | 6.0 |
| Corn planted area in season 2 | 102 | 0.0 | 0.0 | 0.0 | 0.5 |
| Sorghum planted area in season 2 | 102 | 0.1 | 0.5 | 0.0 | 3.0 |
| Hours of family labor to cultivate one Mz of beans | 102 | 85.4 | 26.3 | 0.0 | 170.0 |
| Hours of hired labor to cultivate one Mz of beans | 102 | 69.3 | 39.0 | 0.0 | 170.0 |
| Annual beans output in | 102 | 36.9 | 26.2 | 0.0 | 160.0 |

| | | | | | |
|---|---|---|---|---|---|
| 100-pound bags | | | | | |
| Price of 100-pound bags of beans $ | 102 | 34.0 | 4.7 | 22.8 | 52.2 |
| Annual corn output in 100-pound bags | 102 | 23.3 | 23.0 | 0.0 | 180.0 |
| Price of 100-pound bags of corn $ | 102 | 9.8 | 2.5 | 6.5 | 22.8 |
| Annual sorghum output in 100-pound bags | 102 | 3.4 | 7.1 | 0.0 | 35.0 |
| Price of 100-pound bags of sorghum $ | 102 | 11.4 | 2.5 | 0.0 | 22.8 |
| Hours to plant one Mz using oxe | 102 | 17.7 | 4.2 | 10.0 | 32.0 |
| Hours to plant one Mz using stick | 102 | 43.4 | 12.5 | 16.0 | 80.0 |
| Increase in planted area if having oxen | 102 | 2.4 | 1.2 | 1.0 | 7.0 |
| Price of adult ox $ | 102 | 893.1 | 78.8 | 652.1 | 1141.2 |
| Importance of having oxen to plow the land, 1 to 10* | 102 | 9.6 | 0.6 | 8.0 | 10.0 |
| Importance of having oxen to increase productivity, 1 to 10* | 102 | 9.9 | 0.3 | 8.0 | 10.0 |
| Importance of having oxen to plant in optimum planting window, 1 to 10* | 102 | 9.9 | 0.3 | 8.0 | 10.0 |
| Importance of having oxen to increase cultivated area, 1 to 10* | 102 | 9.9 | 0.3 | 8.0 | 10.0 |
| Importance of having oxen to increase income, 1 to 10* | 102 | 10.0 | 0.2 | 9.0 | 10.0 |

**Note:** * means that 10 is the most important value.

† Deceased February 11, 2018.

[1] The initial version of the paper was presented at the 2018 Southern Agricultural Economics Association Annual Meeting, February 2-6, 2018, Jacksonville, Florida. It may be downloaded at http://ageconsearch.umn.edu/record/266599?ln=en

[2] One manzana is equivalent to 1.74 acre.

[3] Farm gross income is estimated by multiplying total farm output of beans, corn and sorghum by their respective farm sale prices. This measure may underestimate farm gross income, but these three crops are the main source of income of these farms.

[4] The November-December 2017 daily average exchange rate of the Nicaraguan Cordoba against the U.S. dollars was C$30.67=$1.00. This was computed using data from the website of the Central Bank of Nicaragua.

[5] The first season last from May 15th to mid-August and the second season last from August 15th to mid-November.

[6] The percentage change in income is computed as $\%\Delta y = (\hat{\beta} * 100)\Delta x$