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Oxen, Agricultural Productivity and Farm Income in Nicaragua

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Oxen, Agricultural Productivity and Farm Income in Nicaragua

Abstract: This research uses survey data to assess the effect of oxen as draft animals on agricultural productivity and farm agricultural income in Nicaragua. The results show that farms that use oxen to plow the land have higher productivity of beans than farms that use stick to plant crops. On average, using oxen increases farm's beans output by 7.75 100-pound bags of beans, and hiring oxen increases farm's beans output by 8.5 100-pound bags of beans. Farms that use oxen or hire oxen to plow the land have more planted area. The impact of using oxen to plow the land through farm planted area on farm agricultural 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.

Key words: Agricultural productivity, farm income, oxen, Nicaragua

JEL codes: O13, Q10, Q18

Introduction

Nicaragua's economic growth rate during the last decade was 3.2 percent which was lower than the economic 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 still lives below the national poverty line in Nicaragua (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).

The agricultural sector represents about 20 percent of Nicaragua's gross domestic product (GDP), employs 40 percent of the population, and creates 70 percent of total exports (IDB, 2012). This sector includes two subsectors. One subsector represents commercial farms that sell their products in the export market and the other 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). 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, and Delgado, 2008). Hence, increasing agricultural productivity can increase domestic sales and exports, so farmers' income can rise and poverty can decrease in rural areas. But, 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, and that it is important to promote a more efficient use of draft animals in agriculture. Lawrence and Pearson (2002) argues that poor farmers would continue depending on draft animals, that the lack of draft animals would limit the planted area and would contribute to farmers planting late which would also add to crop failure.

Suarez, Rios, and Sotro (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 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 agricultural productivity of beans, the effect of oxen on total farm planted area, the effect of total farm planted area on farm agricultural gross income, and the effect of oxen through farm planted area on farm agricultural gross income. The results suggest that farms that use oxen or hire oxen to plow the land have higher productivity of beans and higher agricultural gross income.

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.

Household and Farm Characteristics

Based on the survey data and on the descriptive statistics of the relevant variables (see appendix 1), this section gives a description of the rural households of the municipality of La Trinidad, Esteli, Nicaragua. The sample includes 102 households from a population of about 4,313 households and also 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 own a farm. The average annual household gross income is \$1,172, of which, on average, 71 percent comes from the sales of beans, corn and sorghum. In addition, none of the households receive remittances.

Regarding the characteristics of the farm, the average size of the farm is 11.41 manzanas¹ (19.8 acres), while the farm average planted area is 3.93 manzanas. Ninety five percent of the farms use native seeds, while 98 percent of them use fertilizers. The annual average beans planted area is 4.43 manzanas, that of corn is 1.27 manzanas, and that of sorghum is 0.30 manzanas. The annual average beans yield per farm is 36.91 100-pound bags, that of corn is 23.25 100-pound bags, and that of sorghum is 3.37 100-pound bags. The average farm sale price of beans is \$34.01 per 100-pound bag, that of corn is \$9.84, and that of sorghum is \$11.45.

On the importance of oxen to the farm, none of the farms use tractors, and 86 percent of the farms use oxen to plow the land rather than using stick to plant crops. 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 manzana using oxen is 17.7 hours, while using a stick is 43.4 hours. In addition, all farmers state that because of lack of oxen they plant late, while 99 percent

¹ One manzana is equivalent to 1.74 acre.

of the farmers miss the optimum planting window. Further, the farmers argue that having oxen would allow them to increase the cultivated area by 2.43 manzanas on average.

It is also important to mention that 99 percent of the farmers state that they do not own oxen due to lack of money to pay for them. The average price of an adult ox is \$893.13, and only five percent of the farmers have access to credit, while one percent of the farmers is able to get loan to buy a couple of oxen. All farmers state that there is no program that funds oxen to farmers, and consider that it is important to have a program that could finance oxen to farmers. Further, given a scale from 1 to 10, with 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 above 9.6.

Literature review

Economic development in the developing world 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 is also mentioned 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 lack of financial means prevent poor farmers from getting access to ox teams and ox-plows. Thus, 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 it is important to promote a more efficient use of draft animals in agriculture. However, it has been reported that small farmers in developing countries do not have draft animals or have an inappropriate number of them only (Asamenew, 1991; Bangladesh Bureau of Statistics, 1986; Gryseels, 1988). Thus, the lack of draft animals may contribute to lowering yields due to late planting.

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, that the lack of draft animals would limit the planted area and would contribute to farmers planting late which would add to 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 and 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.

An interesting case on the use of draft animals is related to agricultural system of Cuba. Funes-Monzote (2007) reports that agriculture in Cuba faced the strongest crisis in the early 1990s due to the lost support from the former Soviet Union, but this led to the development of an alternative national agricultural model. The modernization of agriculture in Cuba caused an increase in the number of tractors. The number of agricultural tractors increased from 7,000 in 1960 to 70,000 in 1990, but 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 was the supplier of agricultural equipment, parts and fuel to Cuba. So, the Cuban government transformed the large government controlled 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). In addition, a study that focused 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, Rios, and Sotto, 2005).

More recently, Cajina and Moreno (2013) conducted a description of corn production over the period 2001-2013 in Nicaragua and used analysis of variance and multinomial regression analysis to explain corn yields. Based on data for the 2012-2013 crop season, they report that the highest corn yields were achieved on farms that used tractors, and that tractors were used in 4.1 percent of the farms, oxen were used in 29.7 percent of the farms, and a stick (a hand tool) was used in 66.2 percent of the farms. However, they argue that their estimations may suffer from omitted variable bias. 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 and Wiebold, 2013). So, lack of oxen may contribute to late planting, missing the optimum planting window, and lowering yields.

The above literature review suggests that draft animals such as oxen are an important component of the agricultural systems in developing countries. Thus, it is important to empirically assess the effect of oxen on agricultural productivity. This research aims to assess the effect of oxen in agricultural productivity and farm agricultural income in Nicaragua.

Methodology and Data

Methodology and Data

The proposed methodology is about a set of equations to estimate the effect of oxen on farm agricultural productivity of beans, the effect of oxen on total farm planted area, the effect of total

farm planted area on farm agricultural gross income², and the effect of oxen through farm planted area on farm agricultural gross income.

Equation (1) assesses the effect of oxen on farm agricultural productivity of beans; that is

$$Y = f(Ab, L, Fs, Ox) \quad (1)$$

where Y is farm's beans output, Ab is beans planted area in manzanas in the farm, L is total labor used to cultivate one manzana of beans, Fs is farm size in manzanas, and Ox is a dummy variable 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) assesses the effect of oxen on farm planted; that is

$$Af = f(Fs, Ox) \quad (2)$$

where Af total farm's planted area in manzanas and the other variables are as defined above.

Equation (3) assesses the effect of planted area on farm agricultural gross income; that is

$$If = f(Af, LnPb, LnPc, LnPs) \quad (3)$$

where If is farm's gross agricultural income, Af is total farm's planted area, $LnPb$ is farm's sale price of beans, $LnPc$ is farm's sale price of corn, and $LnPs$ is farm's sale price of sorghum.

Equations (2) and (3) suggest that oxen play some role in farm gross agricultural income. Given this link, we also estimate Equations (2) and (3) together to assess the effect of oxen through farm planted area on farm gross agricultural income.

Data

This research uses survey data. The survey was administered twice to farmers. 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. 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. Given the quality of the data, this research uses the data from the follow-up survey. The survey includes 74 questions on household and farm information. The 103 farmers are a sample that represents 4,313 rural households. The farmers in the sample are affiliated with the MCN-LT which is a non-profit organization that aims to contribute to improving the wellbeing of people. Monetary values in Nicaragua's currency were converted to nominal dollars using the average of the 2017 November and

² 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.

December daily exchange rate of the Nicaraguan Cordoba against the U.S. dollar³. Descriptive statistics of the relevant variables are in Appendix 1. A copy of the survey is in Appendix 2.

Results

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

Oxen and farm agricultural productivity of beans

The results of assessing the effect of oxen on farm agricultural productivity of beans are shown in Table (1). These are OLS robust to heteroskedasticity estimations. Model 1 assesses the effect of using oxen to plow the land against using stick to plant the crops on a farm. The variable Ox is a dummy that takes value of 1 for a farm that 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 beans output by 7.75 100-pound bags of beans. This also suggests that farms that use oxen are more productive than farms that use stick to plant. In our sample, 86 percent of the farmers use oxen to plow the land. In addition, beans planted area and total hours of labor to cultivate a manzana of beans have positive and significant effect on farm productivity of beans. Model 2 assesses the effect of hiring oxen to plow the land on farm agricultural productivity of beans. 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 beans output by 8.5 100-pound bags of beans. This also suggests that farms that hire oxen to plow the land are more productive than farms that do not do it. In our sample, 84 percent of the farmers hire oxen to plow the land. In addition, beans planted area, total hours of labor to cultivate a manzana of beans, and farm size have positive and significant effect on farm productivity of beans. It is important to mention that none of the farmers in our sample use tractors to plow the land, and that they consider that using oxen to plow the land and to increase productivity have levels of importance at least of 96 percent (see appendix 1).

The results from Table (1) are in line with Cajina and Moreno (2013) who describe the first season⁴ corn productivity in Nicaragua during the period 2001-2013 and report that corn productivity 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. Cajina and Moreno (2013) also report that only 3.9 percent of the farms used tractors in the production of corn. In addition, the results on the effect of hiring oxen to plow the land on agricultural productivity of beans gives support to Kjaerby's (1983) study that reported that farmers borrowed ox teams and plows and that hiring ox teams was very expensive, but it was very common. Further, Sansoucy (1995) argues that draft animals make an important contribution to

³ 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.

⁴ The first season last from May 15th to mid-August and the second season that last from August 15th to mid-November.

crop production and income, and that it is important to promote a more efficient use of draft animals in agriculture.

Table 1 Effect of oxen on farm agricultural productivity of beans

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

Note: OLS robust heteroskedastic estimations. Model 1 estimates the effect of oxen or stick on farm's beans productivity. Model 2 estimates the effect of hiring oxen on farm's beans productivity. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively. Number in parentheses are chi-squared values. Ox is a dummy variable that takes value of 1 for a farm that uses oxen to plow the land and zero if uses a stick to plant. Hire Ox is a dummy variable that takes value of 1 for a farm that hires oxen if it does not own oxen and zero if the farm does not hire oxen.

Oxen and total farm planted area

The results of OLS robust to heteroskedasticity estimations that assess 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 against using stick to plant the crops on a farm on total farm planted area. The estimate on Ox is positive and significant at the 10 percent level and suggests that, on average, using oxen to plow the land increases farm's total planted area by 0.93 manzanas. This also suggests that farms that use oxen to plow the land have more planted area relative to the farms that use stick to plant. Farm size also 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 is positive and highly significant and suggests that, on average, hiring oxen to plow the land increases farm's total planted area by 0.94 manzanas. This also suggests that farms that hire oxen to plow the land have more planted area relative to the farms that do not do it. Farm size also has a positive and significant effect on total farm planted area. This results are in line with Kjaerby's (1983) study that highlights that the use of oxen in agriculture allows for decreasing land preparation time and for increasing planted area and labor productivity. It is important to mention that none of the farmers in our sample use tractors to plow the land, and that they consider that using oxen to increase cultivated area has a level of importance of 99 percent (see appendix 1).

Table 2 Effect of oxen on farm planted area

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

Note: OLS robust heteroskedastic estimations. Model 1 estimates the effect of oxen or stick on farm's beans productivity. Model 2 estimates the effect of hiring oxen on farm's beans productivity. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively. Number in parentheses are chi-squared values. Ox is a dummy variable that takes value of 1 for a farm that uses oxen to plow the land and zero if uses a stick to plant. Hire Ox is a dummy variable that takes value of 1 for a farm that hires oxen if it does not own oxen and zero if the farm does not hire oxen.

Total farm planted area and farm agricultural gross income

Table (3) shows the results of an OLS robust to heteroskedasticity estimation of the effect of total farm planted area on farm agricultural gross income. This income comes from producing and selling beans, corn and sorghum, so the estimation controls for the farm sale prices of these crops. Farm planted area has a positive and highly significant effect on farm agricultural gross income. That is, an increase in farm planted area by one manzana increases farm agricultural gross income by 17.35 percent⁵. The estimates on the price of crops 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 farm agricultural output by 1.22 percent. The estimate on the price of corn suggests that a 10 percent increase in the price of corn increases farm agricultural output by 0.52 percent. The estimate on the price of sorghum is negative but nonsignificant.

The results in Tables (2) and (3) suggest an important link between the role of oxen as agricultural input and farm agricultural gross income. Oxen may have some important effect on farm agricultural gross income through farm planted area. This issue is assessed in the next section.

⁵ The percentage change in income is computed as $\% \Delta y = (\hat{\beta} * 100) \Delta x$

Table 3 Effect of farm planted area on farm agricultural gross income

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

Note: OLS robust heteroskedastic estimations. ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively. Number in parentheses are chi-squared values. Ln is the natural logarithm operator.

Oxen, farm planted area and farm agricultural 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 farm agricultural gross income. Panel (a) shows the effect of farm planted area on farm agricultural income. Panel (b) shows estimations of total farm planted area using farm size and oxen as instruments. Panel (c) shows the over identifying restrictions tests of the null hypothesis that the instruments are valid.

Models 1 and 1.1 assess the effect of using oxen to plow the land through farm planted area on farm agricultural gross income. In model 1, 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 farm agricultural gross income, but the price of sorghum has a negative and highly significant effect. In model 1.1, the estimate on ox increases and is positive and highly significant, which is an improvement relative to the estimate in model 1 in Table (2) above. 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 farm agricultural gross income, but the price of sorghum has a negative and highly significant effect. In model 2.1, the estimate on Hire Ox increases and is positive and highly significant relative to the estimate in model 1 in Table (2) above. The over identifying restrictions test does not reject the null hypothesis that the instruments are valid.

Table 4 Effect of oxen on agricultural gross income through planted area

a. Effect of total farm planted area on farm agricultural gross income

Dependent variable: Farm agricultural gross income			
Variables	Model 1	Variables	Model 2
Constant	0.6076 (0.52)	Constant	0.4073 (0.35)
Farm planted area	0.1802*** (6.91)	Farm planted area	0.1825*** (7.08)
Ln Beans price	1.3928*** (4.28)	Ln Beans price	1.4506*** (4.39)
Ln Corn price	0.5366*** (3.59)	Ln Corn price	0.5337*** (3.55)
Ln Sorghum price	-0.1257*** (-7.54)	Ln Sorghum price	-0.1286 (-7.68)
Adj. R-squared	0.4267	Adj. R-squared	0.4250
Obs.	99	Obs.	99

b. Effect of oxen on total farm planted area

Dependent variable: Farm planted area			
Variables	Model 1.1	Variables	Model 2.1
Constant	1.6553*** (4.23)	Constant	1.2271*** (4.42)
Farm size	0.1206*** (4.33)	Farm size	0.1320*** (5.44)
Ox	1.0062*** (3.24)	Hire Ox	1.4002 (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. Number in parentheses are t-values. Ox is a dummy variable that takes value of 1 for a farm that uses oxen to plow the land and zero if uses a stick to plant. Hire Ox is a dummy variable that takes value of 1 for a farm that hires oxen if it does not own oxen and zero if the farm does not hire oxen. Ln is the logarithm operator.

Given the significance of the estimates in the models in Table (4), the main discussion on the effect of oxen on farm agricultural gross income is based on Table (4). Given models 1 and 1.1, an increase in farm planted area by one manzana increases farm agricultural gross income by 18.02 percent. The estimates on the prices of beans and corn increase. A 10 percent increase in the price of beans increases farm agricultural output by 1.40 percent, and a 10 percent increase in

the price of corn increases farm agricultural output by 0.54 percent. However, increases in the price of sorghum decrease farm agricultural gross income. In model 1.1, using oxen to plow the land rather than stick to plant crops increases total farm planted area by 1.0 manzanas. Therefore, the impact of using oxen to plow the land through farm planted area on farm agricultural gross income is 18.13 percent $[(0.1802 \times 100) \times 1.0062 = 18.13\%]$.

The estimations based on models 2 and 2.1 show that an increase in farm planted area by one manzana increases farm agricultural gross income by 18.25 percent. The estimates on the prices of beans and corn also increase. A 10 percent increase in the price of beans increases farm agricultural output by 1.45 percent, and a 10 percent increase in the price of corn increases farm agricultural output by 0.53 percent. However, increases in the price of sorghum decrease farm agricultural gross income. In model 2.1, hiring oxen increases total farm planted area by 1.40 manzanas. Therefore, the impact of hiring oxen to plow the land through farm planted area on farm agricultural gross income is 25.55 percent $[(0.1825 \times 100) \times 1.4002 = 25.55\%]$. The impact of hiring oxen is bigger than that of using oxen. This may 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. It is important to mention that given a scale from 1 to 10, with 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 above 9.6.

The results from Table (4) suggest that farms that use oxen or hire oxen to plow the land have higher gross income. In addition, given the results from Table (1), farms that use oxen have higher productivity of beans. 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, are in line with earlier research that suggests that the use of oxen in agriculture allows for decreasing land preparation time and for increasing planted area and labor productivity, and that hiring ox teams is very common (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 an inappropriate number of them only (Asamenew, 1991; Bangladesh Bureau of Statistics, 1986; Gryseels, 1988); and in the case of corn production in Nicaragua, the highest yields were achieved on farms that used tractors, and that tractors were used in 4.1 percent of the farms, oxen were used in 29.7 percent of the farms, and a stick was used in 66.2 percent of the farms.

The negative and significant effect of the price of sorghum on farm agricultural 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). Out of the 102 farms in the sample only 25 farms produce sorghum. Sorghum is a substitute in production that competes with beans and corn for area planted on a farm, so farmers may prefer to grow more beans given the price difference. The annual beans planted area is 452 manzanas, that of corn is 130.5 manzanas, and that of sorghum is 30 manzanas, so the most important crop is beans. The average output per farm 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. Therefore, agricultural farm income can increase with increasing output of beans and corn.

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 agricultural productivity of beans, the effect of oxen on farm planted area, the effect of farm planted area on farm agricultural gross income, and the effect of oxen through farm planted area on farm agricultural gross income.

The results show that farms that use oxen to plow the land have higher productivity of beans than farms that use stick to plant crops. On average, using oxen increases farm's beans 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 farm agricultural gross income through farm planted area. The impact of using oxen to plow the land through farm planted area on farm agricultural 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 beans output allows households to increase their food availability which is also related to the sustainable development goal "End Hunger". In addition, the positive impact of oxen through planted area on farm agricultural gross income allows households to increase their income which is also 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 lack of money or funding, it will be important to develop an agricultural program that can finance oxen to farmers.

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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 manzanas	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 manzana of beans	102	85.4	26.3	0.0	170.0
Hours of hired labor to cultivate one manzana of beans	102	69.3	39.0	0.0	170.0
Annual beans output in 100-pound bags	102	36.9	26.2	0.0	160.0
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 manzana using oxen	102	17.7	4.2	10.0	32.0
Hours to plant one manzana 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.

Appendix 2 Questionnaire

Survey: The role of oxen as draft animals in the agricultural system of Nicaragua

Your participation is voluntary and you can withdraw from the survey at any time. This survey is administered to household heads only and does not collect any personal information. Thank you for your contribution to this research project.

I. Household Information

1. What is the name of your community? _____
2. How many households are in your community? _____
3. Are you a beneficiary of the Zero Hunger program? yes _____, no _____
4. Are you a beneficiary of the Agro-food Support program? yes _____, no _____
5. What is your age? _____ years old.
6. Are you married? yes _____, no _____
7. What is your gender? Male _____ Female _____
8. What is the number of people in your household? _____
9. What is your education level? Primary (years) _____, Secondary (years) _____, Tertiary (years) _____
10. What is the number of children in the household? 0-5 years of age _____, 6-10 years of age _____, 11-15 years of age _____, and 16-21 years of age _____
11. What is the number of children attending school? Primary _____, secondary _____, tertiary _____
12. What is the number of people older than 21 years of age in the household including the household head?
13. What is your annual gross income? \$ _____
14. What is the share of the sales of beans, corn and sorghum in your annual gross income? _____%

II. Farm Information

15. Do you own the farm? Yes _____, no _____
16. What is the size of your farm? _____ Mz. (Mz: manzana, 1 Mz = 0.7 hectare).
17. What is the total planted area in the farm? _____ Mz
18. Do you grow organic crops? yes _____, no _____
19. How many Mz do you have for environmental conservation? _____ Mz
20. What type of seed do you use? Native _____, improved seed _____
21. Do you use fertilizers? yes _____, no _____
22. What was the total planted area during the first season for? beans _____ Mz, corn _____ Mz, and sorghum _____ Mz
23. What was the total planted area during the second season for? beans _____ Mz, corn _____ Mz, and sorghum _____ Mz
24. What are the costs for planting one Mz of beans? seed \$ _____, labor \$ _____, chemicals \$ _____ (Fertilizer, Insecticide, etc.), oxen \$ _____
25. What is the amount of labor used to plant one Mz of beans? family labor _____ hrs, hired labor _____ hrs

26. What are the costs for planting one Mz of corn? seed \$_____, labor \$_____, chemicals \$_____
(Fertilizer, Insecticide, etc.), oxen \$_____
27. What is the amount of labor used to plant one Mz of corn? family labor ___hrs, hired labor ___hrs
28. What are the costs for planting one Mz of sorghum? seed \$_____, labor \$_____, chemicals \$_____
(Fertilizer, Insecticide, etc.), oxen \$_____
29. What is the amount of labor used to plant one Mz of sorghum? family labor ___hrs, hired labor ___hrs
30. What is the annual amount of beans? produced ___qq, consumed ___qq, sold _____, seed _____lbs (1qq=hundred pound bag)
31. What is the sale price of 1qq of beans? \$_____
32. What is the annual amount of corn? produced ___qq, consumed ___qq, sold _____, seed _____lbs (1qq=hundred pound bag)
33. What is the sale price of 1qq of corn? \$_____
34. What is the annual amount of sorghum? produced ___qq, consumed ___qq, sold _____, seed _____lbs (1qq= hundred pound bag)
35. What is the sale price of 1qq of sorghum? \$_____
36. Did sell your crops to middlemen? yes_____, no_____
37. Did sell your crops directly to consumers? yes_____, no_____
38. Did sell your crops to supermarkets? yes_____, no_____
39. Did sell your crops to convenient stores? yes_____, no_____
40. Do you use tractor to plow the land? yes_____, no_____
41. Do you use oxen to plow the land? yes_____, no_____
42. Do you use stick to plant? yes_____, no_____
43. Do you do sharecropping? yes_____, no_____
44. What is the amount of cattle heads you own? _____ heads
45. How many oxen do you own? _____
46. If you do not own oxen, do you hire oxen? yes_____, no_____
47. If you hire oxen, how do you pay for that? Sharecropping yes_____, no_____, money yes_____, no_____, labor yes_____, no_____, other yes_____, no_____
48. If you do not own oxen, do you do sharecropping? yes_____, no_____
49. How many hours will take you to plant a Mz using? Oxen _____hrs, stick_____hrs
50. If you have oxen, how many years will you keep them on the farm? _____years
51. If you do not own oxen, are you planting late? yes_____, no_____
52. If you do not own oxen, do you miss the optimum planting window? yes_____, no_____
53. If you have oxen, what will be the increase in cultivated land? _____Mz
54. Why do you not have oxen? Have no money to buy them yes_____, no_____, have no enough land to keep them yes_____, no_____, other reason yes_____, no_____
55. How much is an adult ox? \$_____
56. Do you have access to credit? yes_____, no_____
57. Are you able to get a loan to buy a couple of oxen? yes_____, no_____
58. What is the appropriate age of a young ox to be trained for plowing land? _____ years
59. How much is a young ox that can be trained for plowing land? \$_____

60. How long will it take you to train a young ox? _____ months
61. Do you know how to train oxen for plowing the land? yes____, no____
62. Is there any program that finances oxen to farmers? yes____, no____
63. Do you consider important to have a program that finance oxen to farmers? yes____, no____
64. If you do not have oxen, will you participate in a program that requires you to train four oxen during a period of four years given that you will be compensated with two young oxen at the beginning of the fifth year? yes _____, no _____
65. How many households in your community do you consider need a couple of oxen?
66. Rate the importance of having oxen for plowing using a scale from 1 to 10, with 1 being the lowest and 10 the highest _____.
67. Rate the importance of having oxen for increasing agricultural productivity using a scale from 1 to 10, with 1 being the lowest and 10 the highest _____.
68. Rate the importance of having oxen for planting during the optimum planting window using a scale from 1 to 10, with 1 being the lowest and 10 the highest _____.
69. Rate the importance of having oxen for increasing the cultivated area in your farm using a scale from 1 to 10, with 1 being the lowest and 10 the highest _____.
70. Rate the importance of having oxen for increasing household income using a scale from 1 to 10, with 1 being the lowest and 10 the highest _____.
71. List the three main factors that prevent you from having a couple of oxen, the first one being the most important and the third one the least important: 1 _____, 2____, 3_____
72. Do you consider that you need a more efficient plow than the wooden one you use? Yes____, no____
73. Are you willing to replace the wooden plow with one that will help you plant a Mz faster? Yes____, no_____
74. Do you receive remittances? yes _____, no _____