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## THE RESPONSE OF FARM LABOR AND FARM PRODUCTION TO ANIMAL GRAZING AND WATER RESOURCE SCARCITY IN NORTHERN ETHIOPIA

**Purpose.** Rural households spend a large share of their daily time to search for grazing feed, water resource and collect straw by displacing labor time away from crop farming activities. This paper aims to analyze the economic effect of time spent looking for animal water and grazing areas on farm labor input and crop farm output.

**Methodology / approach.** To address our objectives, a general Cobb-Douglas production function was estimated using a unique dataset from 518 sample farmers in Tigray, Ethiopia drawing on a non-separable farm household model.

**Results.** The results favor the hypothesis of a negative relationship between crop output and resource scarcity. In aggregate, the findings confirm that reducing time spent looking for water, grazing and straw by 1 % leads to an increase in food production by 0.155 %, 0.279 % and 0.328 % respectively. Similarly, the shadow price variables are significant, have the expected negative sign and are consistent with the theory. The sign of other factors are consistent with the prediction of the economic theory.

**Originality / scientific novelty.** The noble contribution of this paper is, unlike previous studies, we collected information on the entire set of crop production, along with the distance to grazing, water and crop residue of each household. This paper considers three important resources for an animal such as grazing, water and crop residue, of which the first two have not been explored well. The use of distance level and shadow price as resource scarcity indicators is an extra benefit to the literature.

**Practical value / implications.** The results of this paper provide an interesting picture of stallholders in Ethiopia. As expected, it appears that time spent searching for animal water and feed has a significant and negative effect on labor and crop output. Our results got the evidence of a negative relationship between labor input to crop farming and resource scarcity.

**Key words:** Grazing and Water Resource Scarcity; Crop farming; General Cobb-Douglas Production Function; Tigray, Ethiopia.

**Introduction and review of literature.** Land degradation in Sub-Saharan Africa remains a substantial problem in aggravating poverty, by reducing the availability of environmental goods and services to poor rural households and by increasing the labor time needed to seek for such goods [30; 46]. In line of this, [5] highlighted that forest degradation spurs rural poverty in Sub-Saharan Africa. Rural households in developing countries heavily rely on environmental products such as fuelwood, fodder, and water to meet their daily animal water and feed requirements.

Increasing scarcity of grazing, water for an animal can be a significant burden to poor households, as grazing and water are a key factor in livestock production [33]. In Ethiopia, livestock contribution accounts for 40 %, excluding the values of draft power, manure, and transport service [4]. Ethiopia is a home of 35 million tropical livestock units (TLU), and on average, one TLU requires about 25 liters of water per day.

Despite its large population size, the contribution is said to be deteriorating [24]. Livestock production in the country depends on the quantity of grazing land and water [9]. In many studies of Africa, most farmers ranked feed shortage and water scarcity as the most leading constraints for animal rearing [10]. According to a recent survey in rural Ethiopia and South Africa, livestock production is mainly constrained by feed and water shortage, labor scarcity and lack of capital [45]. The study by [21] revealed that shortage of water and feed are common in the dry season as compared to the wet season. This sector play a role in increasing water use and water depletion thought the year [42]. The water shortage adversely affects both human and livestock. Most of the year, animals have to walk long distances in search of water. The study [8] indicated that 100 % and 27 % of survey farmers respectively perceived that feed and water shortage were the most important problems of livestock production during the dry season in Ethiopia.

The availability of crop residues and natural pasture are gradually declining as a result of crop expansion, settlement and land degradation [19]. In the dry season, farmers living in the highland areas have feed and water deficits when the natural pastures are at their lowest quantity and the supply of stored crop residues starts to diminish [40]. The report for [14] reported that out of the 16 million ha agricultural land, 75 % is used for crops while grazing land accounts for 9%. In line to this, [47] revealed that the natural grazing in Tigray is diminishing over time due to chronic degradation and shrinking the grazing land sizes. Based on [47], the estimated crop residues from cultivated land contributes only about 45 % of the animal feed demand in the region. It is stated that 73 % of the feed is provided from natural grazing, 14 % from crop residues, and the remaining 13 % from other feed sources.

The critical shortage of water and feed for an animal has negative implications for agricultural production [49; 33]. One possible consequence is the reallocation of labor time from agriculture activities to searching and collecting these scarce resources. Thus, reductions in agricultural output stemming from less labor input are very likely to have detrimental welfare effect [12; 33]. Increasing resource scarcity has economic implications for poor rural households. The idea that the potential effect of scarce resources is declining agricultural output as a result of reallocating inputs away from agriculture has been initially pioneered by [12]. The literature suggests that as a result of increasing resource scarcity such as water, grazing land and feed, many households increase the time they spend on collecting these resources [15]. It is further suggested that feed and water scarcity result in lower crop productivity that further diminishes households' food supply and incomes by increasing work burden of all household members [44; 33].

The allocation of time between crop production and searching or collecting resources for energy use and feeding animal puts a considerable pressure on rural households that rely on agricultural outputs [34], causing them to devote less time to food production. The pioneer study by [12] revealed that a reallocation of time away from farm work occurs as environmental goods become scarcer in Nepal. He found that households that have higher costs of collecting environmental goods devote less time to farm activities and thus reductions in agricultural output. Likewise, [13] found that the scarcity of forest resource had a negative effect on agriculture in Nepal. The degree to which labor allocated to collecting scarce resources takes labor away from agricultural production was also directly examined by [33] in Ethiopia and show that time spent on agriculture was negatively and significantly influenced by the shadow price of fuelwood; however, scarcity of water for humans has no effect on time spent on agriculture.

The work of [29] also found that a higher degree of fuelwood scarcity is associated with a decline of time spent in farming. The findings of [44] in Kenya shows that feed scarcity increases livestock traveling distances in search of feed and water, resulting in lower livestock and crop output by increasing household' time for collection. Moreover, the effect of forest scarcity on the livelihood of rural people in Nepal was examined by [13] and found a negative effects on agriculture. An earlier study of [7] found that more time spent on scarce fuelwood was associated with negative welfare in Malawi. A very related research by [15] showed that rural households increase their labor input as a response to fuelwood shortages in Ethiopia. It is revealed that time spent on agriculture is adversely affected by fuelwood scarcity [33]. The only study directly slightly related to our work is of [34], whose result confirmed that increasing time spent for collecting dung causes farming productivity to decrease in rural Ethiopia. They concluded that agricultural productivity declines with rising time spent on collecting dung but increases with time spent on collecting straw.

From the above brief review of related works, we noted that the evidence on the effect of natural resource scarcity on agricultural output is, unfortunately, sparse. Evidence from Africa is even scarcer in the existing studies. The existing studies focus on the effect of this resource on labor allocation. Hence, this study will have a noble contribution to the sparse empirical evidence from sub-Saharan Africa [13; 26] by exclusively analyzing the economic effect of these scarce resources on household crop farm labor and crop production.

**The purpose of the article.** The research question that we want to answer is whether households' crop output falls as a result of low labor input to crop farming due to rising time allocation to searching or collecting these resources and test whether the effect of these scarce resources is stronger or weaker for income group. We intend to examine if the time allocation to these scarce resources reduces crop production by reducing labor time. To the best of our knowledge, there have been no such empirical studies dealing with this topic using rural farm dataset [44; 13].

For this purpose, a non-separable agricultural household model was developed

to be used as a framework for the analysis of farm household economics which fits into a larger family of agricultural household model (AHM) developed by [43] and later modified by [38] by integrating the time allocated to searching grazing, watering and collecting straw into the model using distance and shadow values of these resources as an indicator of scarcity<sup>1</sup>. Based on this analytical framework, an econometric estimate was presented using the NMBU-MU Tigray Rural Household Surveys (2015) dataset collected under the sponsorship of NORHED project. This analysis was conducted in order to test the hypothesis that increasing time spent on searching grazing, watering and collecting straw has a negative effect on farm labor time and crop farm production. At the same time, I also hypothesize the effect of these scarce resources is not uniform across the food production distribution.

The noble contribution of this paper is, unlike previous studies, we collected information on the entire set of crop production, along with the distance to grazing, water and crop residue of each household. The only studies that consider the effects of scarce environmental goods on agricultural labor input are of [12], [29] in Nepal and [33] in Ethiopia but these studies did not directly investigate the effect of time spent on the collection of fuelwood, leaf fodder, dung and grass on crop production. This paper tries to examine the effect of these scarce resources on labor to agriculture and agricultural output, which is ultimately what policy-makers seek to know as suggested by [26]. Second, this paper considers three important resources for an animal such as grazing, water and crop residue, of which the first two have not been explored well. The use of distance and shadow price as resource scarcity indicators is an extra benefit to the literature. Ethiopia is an interesting case for the purpose of this study. From a practical and policy perspective, it is relevant to understand how farmers respond to these scarce resources.

**Material and method.** *Study Area and Dataset.* The study is conducted in Tigray region, the northern part of Ethiopia by randomly selecting 632 sample households. The study consisted of 21 villages stratified by agroecology and socio-economic indicators to get variations on population density and market access during the initial baseline<sup>2</sup>. We used a cross-sectional data from NMBU-MU Tigray Rural Household Survey (NM-TRHS) collected in 2015 on a randomly selected 632 sample households. Table 1 presents the basic socio-economic characteristics of 518 farm households drawn from a total of 632 sample farmers. For this study, the need for information regarding livestock activity restricted us to use only 518 livestock owner-farmers.

*Econometric Model Specification.* This paper draws on the AHM which provides a holistic framework to analyze the economic effect of resource scarcity on labor to crop farming and monetary value of crop production in the farm household. Based on the reduced form equations derived from AHM, we first model labor

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<sup>1</sup> See for a similar approach in the work of (Cooke, 1998; Cooke et al., 2008 and Baland et al., 2010).

<sup>2</sup> This dataset has been used by Holden et al. (2009, 2011).

allocation to crop farming as a function of resource scarcity and household characteristics following [12] and [33]. The choice of functional form for the estimation of the crop production function with respect to different inputs has gained substantial attention in the economic literature. With regard to estimation, the production function is mostly estimated using the Cobb-Douglas production function since the output is a simple function of labor and capital. However, this does not allow other variables than just the two which can significantly affect production such as fertilizer and land. For this reason, the General Cobb-Douglas (GCD) production function developed by [17] was adopted in order to incorporate these variables into the production function.

The GCD production function that satisfies the non-negative, non-decreasing, continuous and quasi-concave properties of standard production function is denoted by

$$Q = m \prod_{i=1}^n \prod_{n=j}^n \left( \frac{1}{2}x_i + \frac{1}{2}x_j \right)^{\alpha_{ij}} \quad (1)$$

Where  $Q$  is output,  $x_1, \dots, x_n$  are quantities of the  $n$  inputs,  $m > 0$ ,  $\alpha_{ij} = \alpha_{ji}$  and  $\sum_{i=1}^n \sum_{j=1}^n \alpha_{ij} = 1$  (This is the assumption of a constant return to scale). Assuming that  $\alpha_{ij} = 0$  for all  $i \neq j$ , and taking the natural log of equation (1) produces a standard Cobb-Douglas equation with many inputs, which is to be estimated in its natural log form:

$$\ln Q = \alpha_0 + \sum_{i=1}^n \alpha_i \ln x_i + e \quad (2)$$

Where  $\alpha_0 = \ln m$  ( $m$  is the constant term in equation (1), and  $e$  is the error term. The GCD production function is often criticized for being restrictive due to its assumptions of constant returns to scale (CRTS) and perfect competition in both input market and output market even if it handles a large number of inputs. Its assumptions make it difficult to measure technical efficiency levels and growth effectively. But the assumption about market does not significantly affect the estimation power of Cobb-Douglas production function as long as factors are paid according to their relative shares [36]. In addition, [35] argued that GCD can be estimated by relaxing the CRTS assumption and then test whether the summation of the coefficients is significantly different from one using the standard econometric procedure.

**Results and discussion.** *Descriptive Statistics:* the dependent variables in this paper are labor time for crop farming and aggregate household agricultural production or monetary value of all crops produced during the survey production season. Multiple crop outputs are aggregated into a single output measure using the medians of their reported village's prices within each village following [20], [25] and [27]. An average household owns a production capital worth about 639 birr and has produced an average agricultural output of worth 41,645 birr in the year, with an average total income including off-farm, transfer and business to be 49,426 birr. In addition, on average each household had 684 labor hour used for crop production.

*Table 1*

**Descriptive and Summary Statistics (N=518)**

| Variables                    | Description                                    | Mean   | SD     |
|------------------------------|--|--------|--------|
| <b>Dependent Variables</b>   |  |        |        |
| Output                       | Monetary value of crop production <sup>a</sup> | 41,645 | 87,517 |
| Income                       | Monetary value of total income <sup>b</sup>    | 49521  | 92,642 |
| <b>Independent Variables</b> |  |        |        |
| ShadowPW                     | Shadow price of water                          | 147.6  | 204.9  |
| ShadowPG                     | Shadow price of grazing                        | 205.0  | 282.0  |
| ShadowPF                     | Shadow price of straw                          | 12.52  | 18.96  |
| WaterD                       | Time to reach for water in minute              | 74.85  | 65.54  |
| GrazingD                     | Time to look for grazing in minute             | 91.12  | 83.44  |
| FeedD                        | Time to collect straw in minute                | 576.55 | 557.87 |
| Family size                  | Household family size                          | 5.873  | 2.413  |
| Age                          | Household head age in years                    | 56.83  | 15.20  |
| Gender                       | 1= Male  | 0.743  | 0.437  |
| Education                    | 1= Literate                                    | 0.326  | 0.469  |
| TLU                          | Herd size in TLU                               | 3.919  | 3.199  |
| Market distance              | Distance to market in minute                   | 82.30  | 54.79  |
| Shocks(2012-2014)            | Number of shocks due to theft, flood, death    | 0.577  | 0.826  |
| Irrigation                   | 1=access to irrigation                         | 0.258  | 0.438  |
| Information                  | 1 if hh had access to TV, radio& mobile        | 0.417  | 0.494  |
| Water harvest                | 1=access to well and ponds                     | 0.0193 | 0.138  |
| Location                     | 1= highland(>2500masl)                         | 0.0637 | 0.244  |
| HiredL                       | 1=hired labor                                  | 0.3880 | 0.487  |
| Oxen                         | Number of oxen                                 | 1.930  | 1.045  |
| area                         | Total cultivated land in tsmdi <sup>c</sup>    | 4.447  | 3.138  |
| Family labor                 | Total adult family labor in man day            | 85.52  | 69.33  |
| Fertilizer                   | Total fertilizer used in KG                    | 68.55  | 49.24  |
| Manure                       | Total manure used in KG                        | 775.6  | 1,585  |
| Farm tool                    | Total monetary value of farm tool <sup>d</sup> | 639.1  | 1,451  |

*Notes.* <sup>a</sup> it includes crop, fruit and vegetable production;

<sup>b</sup> it includes income from Agriculture, off-farm, transfer and safety net;

<sup>c</sup> one Tsmdi is approximated to one-fourth hectare;

<sup>d</sup> total monetary value of all farm implements such as plough parts ,hoe, cart, sickle, spade.

*Source:* author's research.

Despite straw has a local market price and is therefore relatively easy to value, grazing land and water, however, are challenging to value because they are not traded and have no market price; thus, their prices are a shadow price [32]. Shadow prices are assumed to reflect better the economic scarcity of environmental goods to a household [12]. For this reason, first, we use walking distance to measure grazing, water and crop residue using the similar method used by [3] and [38] as a proxy indicator of the scarcity of these resources. On average, the households spend 75 minutes to reach a water source for animal and 91 minutes to search for communal grazing land daily, maximum time reaching up to 6 hours for water site and 8 hours for grazing land in the data. Besides, the average time spent on collecting straw by the households is 576.6 minutes, ranging from a minimum value 18 to maximum value of 6000 minutes.

Second, following to [6; 12; 33], the shadow price of searching for grazing, and water as well as collecting crop residue for animal is calculated by the time taken to

search for grazing land and water per animal or to collect crop residue per its amount collected multiplied by the village median adjusted<sup>3</sup> off-farm wage. In this paper, we take the wage rate at the village level and thus there is no variation in wages for households living within the same village. In this way, we produce a household specific shadow price of searching grazing land or water and collecting straw. Using this data in Table 1, the average shadow price for animal watering is about 147 Ethiopian currency (ETB) per day which is equivalent to the average daily rural wage rate in the region. On average, the opportunity cost of searching grazing is 205 ETB per day, which is greater than the opportunity cost of water and straw. This is not surprising, as rural farmers usually spend a huge amount of time in searching grazing than watering. As expected, the shadow price of collecting a straw is 12 ETB per trip.

*Estimation of Resource Scarcity on Monetary Value of Aggregate Production.* For the sake of reliable estimation, outliers are removed from the dataset. Thus, 9 distorting observations were dropped from the dataset in food production estimation. In order to estimate production sector of the farm households, we used ordinary least square (OLS) on the log-transformed form of the GCD production function. The dependent variable is the monetary sum of all crops produced during the survey harvesting season. The estimates of the production function using walking distance and shadow values of water, grazing land and straw are presented in Tables 2 and 3. In general, the estimation shows that all explanatory variables exhibit significant and theoretically expected signs.

Variables of interest in this paper are time spent on looking at water and straw resources included so as to capture the effect of resource scarcity on agricultural production. The first column of Table 2 presents the estimation of log output with water scarcity taken into account as do the second and the third columns, putting grazing land and straw collection into consideration. The result is in favor of our hypothesis. As expected Column (1) of Table 2 indicated that time spent on animal water source is found to be negative significant, suggesting that a 1 % increase in time spent looking for water decreases agricultural production by 0.155 %, and time spent on searching grazing have stronger effect than this variable as shown in Column (2) i.e., a 1 % increase in time spent searching for grazing decreases agricultural output by 0.279 %. Another scarcity related variable is time spent for collecting straw which significantly resulted in a negative sign, implying that farmers that spend 1% more minute for collecting straw produce about 0.328 % less output (Column 3). The output effect obtained here support the claim that time spent for searching scarce resources displace labor time from production activity and hence reduce output [13; 15; 33; 44; 37]. For comparison purpose, the estimates of the effect of this resource scarcity on crop output value are also presented in Table 3 using their shadow prices.

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<sup>3</sup> In order to adjust for big variation in the wage rate among villages of the region, the wage rate is adjusted using a general informal rural labor conversion factor, 0.98.

In line with our expectation, we found that water scarcity reduces crop output value.

*Table 2*

**OLS Estimation of log Monetary Value of Aggregate Agricultural Production**

| Variables         | Walking Distance      |                       |                       |
|-------------------|-----------------------|-----------------------|-----------------------|
|                   | lnoutput              | lnoutput              | lnoutput              |
| Ln (area)         | 0.278***<br>(0.0595)  | 0.304***<br>(0.0579)  | 0.201***<br>(0.0523)  |
| Ln (manure)       | 0.0854**<br>(0.0369)  | 0.0857**<br>(0.0363)  | 0.0501<br>(0.0324)    |
| Ln (oxen)         | 0.228**<br>(0.0973)   | 0.248***<br>(0.0951)  | 0.186**<br>(0.0851)   |
| Ln (fertilizer)   | 0.145**<br>(0.0665)   | 0.174***<br>(0.0652)  | 0.150***<br>(0.0581)  |
| Ln (seed value)   | -0.0992**<br>(0.0490) | -0.0847*<br>(0.0479)  | -0.0842**<br>(0.0428) |
| Ln (family labor) | 0.353***<br>(0.0650)  | 0.306***<br>(0.0641)  | 0.197***<br>(0.0581)  |
| Hired labor (1/0) | 0.472***<br>(0.0928)  | 0.481***<br>(0.0907)  | 0.307***<br>(0.0822)  |
| Location (1/0)    | -0.493***<br>(0.174)  | -0.453***<br>(0.169)  | -0.544***<br>(0.150)  |
| Ln (farm tool)    | 0.0566**<br>(0.0254)  | 0.0561**<br>(0.0249)  | 0.0162<br>(0.0224)    |
| Ln (mktdistance)  | 0.0745<br>(0.0551)    | 0.0808<br>(0.0538)    | -0.000798<br>(0.0485) |
| Info (1/0)        | 0.0959<br>(0.0851)    | 0.0549<br>(0.0836)    | 0.0264<br>(0.0746)    |
| Well (1/0)        | -0.260<br>(0.299)     | -0.218<br>(0.292)     | -0.0514<br>(0.261)    |
| ln (shocks)       | -2.160***<br>(0.321)  | -2.091***<br>(0.311)  | -1.932***<br>(0.278)  |
| Irrigation (1/0)  | 0.0627<br>(0.0980)    | 0.0931<br>(0.0955)    | -0.0440<br>(0.0860)   |
| Education (1/0)   | 0.284***<br>(0.0904)  | 0.246***<br>(0.0887)  | 0.243***<br>(0.0790)  |
| Ln (WaterD)       | -0.155***<br>(0.0475) |                       |                       |
| Ln (GrazingD)     |                       | -0.279***<br>(0.0471) |                       |
| Ln (FeedD)        |                       |                       | -0.328***<br>(0.0254) |
| Constant          | 6.873***<br>(0.500)   | 7.383***<br>(0.492)   | 9.496***<br>(0.476)   |
| Observations      | 509                   | 508                   | 509                   |
| R-squared         | 0.394                 | 0.423                 | 0.538                 |

*Notes.* \*\*\*, \*\*, \*Implies that the estimated parameters are significantly different from zero at 1, 5, and 10% significance level respectively. Figures in parentheses are standard errors.

*Source:* author's research.



The results suggest that a 10 % increase in the shadow price of reaching water for animal results in a 0.74 % decrease in agricultural output value. The effect is lower as compared to the effect of distance value in Table 2. Agricultural crop value also decreases as the shadow price for searching grazing land increases; on average, a rise in 10 % in the shadow price of reaching grazing land implies a fall of 0.9 % in crop output produced. The significant and large effect of grazing scarcity on the crop output is because farmers with larger large cattle require more labor time for searching better grazing.

The strongest negative significant result on any of the shadow prices is for the straw shadow price. The coefficient on the shadow price of collecting straw indicates that a 10% in shadow price reduces crop output by 1.5 %. This is consistent to the idea that the potential effect scarce resources is declining agricultural output as a result of reallocating inputs away from agriculture [13; 33; 34], which further support the downward spiral hypothesis that resource degradation lead to poverty [2; 48].

The estimated coefficient for land (0.278, 0.304 and 0.201) shows that when landholding increase by 1 % agricultural production increases, on average, by almost 0.3 %, implying that land is a vital input of agriculture. The result is similar to what it was found by [39] in Tanzania. As expected fertilizer and manure use are found to be significant and positive variables indicating that a 1 % increase in fertilizer and manure use leads to a 0.145 and 0.085 % increase in agricultural outputs incongruent to the studies conducted by [16; 18], whose result revealed that fertilizer and manure use positively and significantly affected food production in Ethiopia. In Ethiopia, the ox is the main capital input and can be considered as an equivalent substitute for the uses of the tractor. In this paper, the number of oxen is found to be significant, leading to a 0.23 % increase in the agricultural output. A similar result is found in the study of [33] who found a positive effect of ox input on food crop productivity in Ethiopia.

In line with the predictions of economic theory, a 1 % increase in man-day labor causes to increase farm output by about 0.353 %, a finding that is consistent with the notion that labor has a positive effect on production [18; 1] but the coefficient on seed input contrasts with the findings by [18] in Ethiopia and [11] in Tanzania. Farmers hiring an extra labor seems to increase their production value by 0.481 %, confronting with the result of [39] whose result revealed a negative relation. Another capital input included in the analysis is production capital which is the monetary value of farm tools. A 1 % increase in production capital has the ability to increase agricultural output by 0.056 %. This finding supports the earlier study by [39].

Not surprisingly, we found that an increase in shock has a quite large detrimental effect of food production (-2.16 %) which is consistent with a previous study [1] who confirmed a negative effect of drought or illness shock on production. The variable representing education of the farmer is positive and significantly different from zero, suggesting that more educated farmers are more likely to produce more in favor of [1] result.

Table 3

**OLS Estimation of log Monetary Value of Aggregate Agricultural Production**

| Variables         | Shadow Price           |                        |                       |
|-------------------|------------------------|------------------------|-----------------------|
|                   | lnoutput               | lnoutput               | lnoutput              |
| Ln (area)         | 0.303***<br>(0.0593)   | 0.321***<br>(0.0593)   | 0.281***<br>(0.0587)  |
| Ln (manure)       | 0.0848**<br>(0.0370)   | 0.0834**<br>(0.0368)   | 0.0752**<br>(0.0366)  |
| Ln (oxen)         | 0.208**<br>(0.0978)    | 0.210**<br>(0.0972)    | 0.199**<br>(0.0966)   |
| Ln (fertilizer)   | 0.146**<br>(0.0666)    | 0.158**<br>(0.0664)    | 0.155**<br>(0.0658)   |
| Ln (seed value)   | -0.127**<br>(0.0498)   | -0.131***<br>(0.0495)  | -0.125**<br>(0.0488)  |
| Ln (family labor) | 0.352***<br>(0.0651)   | 0.336***<br>(0.0650)   | 0.330***<br>(0.0646)  |
| Hired labor (1/0) | 0.448***<br>(0.0934)   | 0.449***<br>(0.0928)   | 0.430***<br>(0.0924)  |
| Location (1/0)    | -0.502***<br>(0.174)   | -0.508***<br>(0.172)   | -0.562***<br>(0.170)  |
| Ln (farm tool)    | 0.0525**<br>(0.0255)   | 0.0527**<br>(0.0254)   | 0.0399<br>(0.0255)    |
| Ln (mktdistance)  | 0.0687<br>(0.0553)     | 0.0725<br>(0.0549)     | 0.0641<br>(0.0546)    |
| Info (1/0)        | 0.0524<br>(0.0862)     | 0.0234<br>(0.0869)     | 0.0523<br>(0.0847)    |
| Well (1/0)        | -0.234<br>(0.299)      | -0.206<br>(0.298)      | -0.226<br>(0.296)     |
| ln (shocks)       | -2.036***<br>(0.319)   | -1.969***<br>(0.318)   | -1.990***<br>(0.315)  |
| Irrigation (1/0)  | 0.0788<br>(0.0979)     | 0.0960<br>(0.0975)     | 0.00707<br>(0.0983)   |
| Education (1/0)   | 0.267***<br>(0.0906)   | 0.249***<br>(0.0905)   | 0.283***<br>(0.0894)  |
| Ln (ShadowPW)     | -0.0739***<br>(0.0240) |                        |                       |
| Ln (ShadowPG)     |                        | -0.0944***<br>(0.0253) |                       |
| Ln (shadowPF)     |                        |                        | -0.154***<br>(0.0333) |
| Constant          | 6.765***<br>(0.492)    | 6.904***<br>(0.493)    | 7.020***<br>(0.486)   |
| Observations      | 509                    | 509                    | 509                   |
| R-squared         | 0.393                  | 0.398                  | 0.407                 |

Notes. \*\*\*, \*\*, \*Implies that the estimated parameters are significantly different from zero at 1, 5, and 10 % significance level respectively.

Figures in parentheses are standard errors.

Source: author's research.

**Conclusions.** In rural farms, households spend a large share of their daily time on searching animal grazing and water as well as collecting crop residue. This directly impacts farm production by displacing labor from production activity. This study analyzes the economic implication of animal water and feed scarcity on labor farming and farm production in North Ethiopia. To address our objectives, a general Cobb-Douglas production function was developed and estimated using a unique dataset from 518 sample farmers.

As expected, it appears that time spent searching for water and feed has a significant and negative effect on crop output. In aggregate, decreasing time spent searching for water and grazing by 1 % leads to an increase in food crop output by 0.155 % and 0.279 % respectively, and an increment of 0.328 % in food production is achieved by 1 % reduction in straw collecting time. Similarly, the shadow price variable are significant, have the expected negative sign and is consistent with the theoretical predictions in that reduction of 0.0739 %, 0.0944 % and 0.154 % in crop output are reported by a 1 % increase in the shadow price of water, grazing and straw respectively. Depending on results from the quantile regression, the effect of water and feed scarcity is not uniform across the food production distribution.

In general, this study can be helpful for policymakers working to alleviate animal water and feed problems in Ethiopia to justify their actions with an empirical result. Based on the empirical results presented, two areas of policy intervention can be emerged as relevant: The first involves policies that facilitate easier access to animal water tap by advocating for emergency relief. The second area of policy intervention involves the introduction of more efficient animal feed management strategy with new livestock technologies that improve cattle production and reduce land degradation. Given the evidence in this paper, it appears that policies that seek to promote information via TV and radio would be useful in enhancing household level food security. A further research should focus on adopting an approach using welfare indicators and longitudinal data.

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