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REGULAR ARTICLE

UNDERSTANDING FARMERS' SEASONAL AND FULL YEAR STALL FEEDING ADOPTION IN NORTHERN ETHIOPIA

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ABSTRACT

Adoption of stall feeding (SF) as well as choices of animals and seasons for its application were assessed in northern Ethiopia in 2015 using a household field survey. The study was conducted in 21 communities to account for differences in agro ecology and to better understand the adoption process. A Heckman selection model was used to estimate adoption and extent of adoption based on a model of technology adoption within an agricultural household framework. A Poisson model was also applied to explain the number of SF adopting seasons. Further a multinomial logit model was estimated in order to reinforce understanding of the choices. The purpose of this study was to understand the driving factors of full or seasonal SF adoption and its intensity as well as animal and seasonal choices. The study results indicate that farmers actually practicing SF in a full year are 36% while those of actual seasonal adopters are 55.6%. The choice of animals allocated to SF include cow (40%), ox (31%) and other animals (29%) of the given sample indicating feeding cow under SF takes the largest share. Similarly, the choice for season were, 65% full year, 29 % wet (summer and autumn) and 6% dry (winter and spring), implying that more than half of the sample farmers practice SF the year round. Empirical results of this study showed that result is in favour of the Boserupian hypothesis indicating that small grazing land and large exclosure are associated with a higher probability of use of SF and with a higher number of SF adopting seasons throughout the year. In a similar vein, small average village farm size stimulated full SF adoption and SF adopting seasons, Availability of labour relative to farm size and a number of breed cows significantly increased the probability of using SF by 0.01% and 66% respectively. While animal shock appeared to have a marginal effect of 14%.The finding also revealed that factors such as access to information and early exposure increased the probability of SF adoption by 18% and 6%. Similarly, the positive marginal effect of real milk price is 15%. However, SF appears to be less attractive to those farmers with more herd size relative farm size and less crop residue. Regarding the intensity of SF adoption, while total labour time, farm size positively affect the extent of SF adoption, total herd size and grazing land ratio negatively influence farmers' extent of SF adoption in all seasons.

Keywords: Adoption and intensity, stall-feeding practice, Heckman and count model, Ethiopia
JEL: Q1, Q16, Q5, Q57

INTRODUCTION

In most sub-Saharan African (SSA) countries, communal grazing lands are important sources of livestock feed (**ILRI, 2000**).Overstocking is identified to primarily drive degradation of rangelands, declining of vegetation productivity and eventually livestock productivity, and loss of resilience of the rangeland for droughts (**Lal and Stewart, 2010**). Indeed, overgrazing is reported to cause about half (49%) of the land degradation in SSA followed by deforestation (27%) (**Kirui *et al.*, 2014**). The resource loss due to land degradation in the region is huge (**Maitima, 2009**). The estimated annual costs of land degradation in Ethiopia is 3% of agricultural GDP (**Yesuf *et al*., 2008**).The role of agricultural technology is widely recognized as a key means of enhancing productivity (**Diao and Nin-Pratt, 2007**). However, many of these practices have not been widely adopted by the smallholder farmers **(Odame *et al*., 2013).**

Animal nutritionists point out that poor animal feed is the leading factors for low livestock productivity. Whereas the veterinary experts argue that poor animal health as the main constraint (**Amudavi et al., 2009**). Livestock production, in Ethiopia, is low in productivity in terms of milk and meat production per animal (**Negassa et al., 2012**). For instance, **IFAD** (2007) showed that inadequate livestock nutrition and poor feeding practices are the main reasons for low animal production. As a result, the average milk production was estimated to be 1.86 liters/cow per day and the per capita milk consumption was about 19.2 Kg/ year in Ethiopia (**FAO, 2009**).

Despite natural grazing lands are deficient in terms of nutrition quality and quantity due to drought, cattle farming is still heavily dependent on free grazing in Ethiopia (**USAID, 2013**). **Benin (2006)** indicated that increasing populations result in high demand for arable land for food production and settlement for humans, reducing the size of land available for natural grazing. An ex-closure is also responsible for shrinking grazing land

and grass production (**Mekuria *et al*., 2011**) despite the fact that it can provide economic and ecological benefits (**Babulo et al.,2009**). In addition to feed and water shortage, animal diseases due to free grazing, poor input supply, low technology use and poor marketing have been cited as extra factors constraining livestock performance (**Yilma *et al*., 2011; Gebremedhin *et al*., 2009**).

Improving feed qualities through the use of new technologies such as forage, rotational and stall feeding (SF) are suggested as not only economically viable (**Garcia *et al*.,2008; Lenaerts, 2013; Beshir, 2014**) but also ecologically sustainable in mitigating feed shortages. Besides, **Baltenweck *et al*. (2007)** in Uganda and **Holtland (2007)** in Tanzania reported that zero grazing was more economically and environmentally viable. **Staat *et al.* (2003)** complement the profitability of SF in Kenya. Ethiopia has a grand plan to transform its economy into a green economy (**FDRE, 2011**). A transformation of the livestock sector is an important part of this plan which targets to reduce greenhouse gas emissions through increasing livestock productivity. The switch from free grazing (FG) to Stall Feeding (SF) is an important part of this transition and was introduced since 2005 (**Lenaerts, 2013; Klitzing *et al*., 2014; Benin, 2006**) in the study area. Full Stall Feeding (FSF) adoption in this paper is defined as the practice of feeding some or all animals in a restricted open homestead land in full year and Seasonal Stall Feeding (SSF) for at least one season of the year. Stall fed cattle are not allowed for free movement unless they are out for watering, ploughing and threshing purpose (**Lenaerts, 2013**). A recent study by **Klitzing *et al*. (2014)** found that fodder productivity from SF schemes is higher than from FG schemes, leading to overall livestock productivity.

However, its adoption rate remains below its expectation (**Lenaerts, 2013; FAO, 2007; Bishu, 2014**). A recent survey result by **BoARD (2012)** evidenced that 43.10% of the respondents were found to use SF in line with **Bishu (2014)** whose study revealed that 22.7% of farmers practiced SF in Tigrai region. Similarly, **Benin (2006)** indicated that adoption of SF practice is 48% in Amhara region while **De Cao *et al*. (2013)** found that 33% of the sample farmer exercise zero grazing (ZG) in Harar. While the finding of low levels of adoption is well accepted (**Lenaerts, 2013**), to our knowledge factors influencing SF adoption decision were neither properly identified nor proper empirical design was followed. This study then investigates the nuts and bolts of achieving such a transition in the highlands of northern Ethiopia.

This study aims to contribute to the understanding of the drivers that determine the adoption and intensity of adoption of SF as well as the choices of animal and season for adoption. Technology adoption has long preoccupied economists concerned with the crop productivity potential in less developed countries (LDCs). Moreover, the general theory on adoption is well developed (**Feder *et al*., 1985; Feder and Umali, 1993**).Thus, this study addresses the following research questions: Why some farmers have switched from FG to SF practice while others have not? What are the key determinants that influence farmer's decision to use and intensify SF? What determines the number SF adopting seasons? Which animals or seasons do farmers choose to apply SF?

Boserup's (1965) seminal work indicated that land constraints cause agricultural intensification. With regard to this, **Kruseman *et al.* (2006)** and **Pender *et al.* (2006)** found positive effects of land shortage on fertilizer use and labour per hectare in Tigrai region. In line to this, the first hypothesis is to test the Boserupian theory that grazing land shortage leads to more SF adoption and SF adoption is associated with the large closed area.

The recent findings from **Gunte (2015)** revealed that low adoption of improved forage is caused by farmers' resources scarcity such as labour and farm size. Hypothesis in line to this is that individuals with more labour and breed cows are likely to adopt SF whereas individuals with more herd size and less crop residue are less likely to adopt SF. Further we propose that early exposure to SF and information has a positive effect on farmers' adoption and intensity. In line with Boserupian hypothesis, the finding suggests that grazing land shortage increased SF adoption and number of SF adopting seasons. We found that factors such as access to information, literacy rate, and availability of labour, the number of breed cows, animal shock and exposure to SF significantly and positively influenced SF adoption and its intensity. However, SF appears to be less attractive to those farmers with more herd-size and less crop residue, particularly to those that are with a longer distance to animal water and crop-residue sites.

The research will contribute to the body of existing literature in livestock feeding management, there is little if any that has been published on factors influencing adoption of stall feeding. To our knowledge this is the first study to carefully investigate the annual and seasonal adoption of SF and its intensity in Ethiopia and perhaps in sub-Saharan Africa. The objective is to identify constraints to adoption and intensity of adoption and assess the potential for improving policies by alleviation of the constraints to stimulate adoption of more productive and sustainable crop-livestock systems. Some constraints may be hard and impossible to change and one has to work around them but others may be soft and can be addressed in a feasible strategy that takes agro-ecological and socio-economic variation into account.

LITERATURE OVERVIEW

Free grazing is a dominant form of livestock rearing in Ethiopia. Most of the grazing lands are grazed and trampled by livestock year round with no resting. This causes in soil compaction and land degradation and hence low quantity and quality of feed (**Nyssen *et al*., 2007**).The expansion of improved feeding has been suggested by policy makers with the objectives of (1) increasing cattle and fodder productivity; (2) halting land degradation, and (3) generating income. SF or ZG have been widely recommended and was practiced in the highlands of Kenya and Tanzania (**Gass and Sumberg, 1993**) as well as Ethiopia (**Lenaerts, 2013; Klitzing *et al*., 2014; Bishu, 2014**) while its pace of coverage was slower-than-anticipated.

The practice of SF in Uganda was found to be economically and ecologically sustainable (**Garcia *et al*.,**

2008). A study by **Funte *et al*. (2009)** showed that ZG practices are successful in Harar but low in Tigrai and southern regions.

This is mainly caused by shortage of feed in both quantity and quality, supplementary feeds; low level of awareness towards zero grazing; culture of keeping high number of livestock; introduction of zero grazing without prior arrangement and awareness creation; introduction of zero grazing at household level not at village level (**Gebreyohannes *et al*.**, 2011). **De Cao *et al*. (2013)** revealed that ZG is a potentially useful practice against low productivity and limited feed availability. According to **Bishu (2014)** and **Ahmed *et al*. (2004)**, SF is believed not only to improve the productivity of animals but also to protect against transmissible diseases; minimize soil erosion, and conserve manure to enrich soils. Benin (2006) who looked at the adoption of SF in Ethiopia indicated that SF is positively influenced by access to credit, a number of breed cows and land distribution. Similarly, **Gebremedhin et al. (2003)** and **Beshir (2014)** showed that household resource endowment, especially land and labour, herd size and distance to road were key factors influencing forage technology adoption in the highlands of Ethiopia while **Baltenweck *et al*. (2007)** reported that farming experience and distance to road were significant factors of residue feeding adoption. A recent study of **Gunte (2015)** forage adopters had more family labour, reside closer to markets and had better access to information compared to non-adopters in Ethiopia.

The finding from **Turinawe *et al*. (2011)** in Uganda proved that a number of improved cows had a positive significant relationship with the use of forage technology. **Benin (2006)** also found that almost 80 percent of the farmers that adopted improved breeds also adopted SF, and multiple regression analysis by **Winsten *et al*. (2000)** confirmed that farmers using confinement feeding were more likely to use milk enhancing technologies than using extensive feeding in the USA. This implies that SF performs best when it is complemented by other related technologies and those who have improved cow are likely to adopt SF. **Foltz and Lang (2003)** in the study of rotational grazing adoption found that rotational grazing adopters have more education and less land holding size in the US.

The positive role of information diffusion about the new technology through media in the adoption of new technologies are also well documented in the literature (**Feder and Umali, 1993**). **Wünscher *et al*. (2004)** noted the adoption rate of improved forage was found to be low, and lack of information about the use hinder adoption in Costa Rica. The social network may also enable farmers to learn about benefits of new practice from their peers, or respond to their peers' experience so that facilitating the adoption of new practice (**Conley and Udry, 2010**). Transfer income received from the personal social network may facilitate the adoption of a new practice by overcoming cash constraints: this possibility has not been considered in the adoption decision with an exception to the work of **Hogset (2005)** in Kenya.

The effect of wealth depends on the nature of rural market imperfections (Pender and Kerr, 1996).When labour markets are imperfect, households endowed with high family labour are able to meet the high labour demand of SF practice. Similarly, given the missing markets for improved feed, wealthier households endowed with more assets are able to invest more in this practice. Economic theory states that holding other things fixed, a higher price for milk and meat will increase the net return of better farming practice, but higher input prices (e.g. wage rates, feed) would reduce the returns and hence the incentive to use this practice. Finally, **Nalunkuuma *et al*. (2013)** estimated adoption of ZG in Kenya and the results obtained revealed that adoption of ZG was positively affected by age, year of schooling, wealth, dependency ratio, the number of cross breed cows and school children.

Theoretical Framework

Integrated crop–livestock production is an important economic activity that promotes and sustains people's livelihoods in developing countries (**Herrero *et al*., 2010; Ryschawy *et al*., 2012**). In mixed crop–livestock farming systems, farmers use crop residue (R) as a key source of livestock feeding due to the expansion of cropland and low productivity of natural pastures (**Alkemade *et al*., 2012**). Moreover, labour is important input used for collecting R collection and transportation from the field to the homestead (**Jaleta *et al*., 2013**). Yet population pressure increased income and settlement expansion in LD tend to increase the pressure on this farming system. Adopting more resilient, intensive and sustainable mixed crop–livestock production systems seem to be indispensable to cope up with this pressure and attain the rising demand for food, feed at the smallest damage to natural resources (**Kassam *et al*., 2010**).

In this section, we try to distinguish between traditional farmers who uses a lower productivity technology and those who adopt improved technology that generates higher payoffs or yields using a theoretical framework which fits into a larger family of Agricultural household model (AHM) developed by **Singh, Squire, and Strauss (1986)** and later modified by **Huffman (1991)** that accommodate technology adoption decision. Sub-Saharan Africa's smallholder farming system is characterized by semi-commercial farms that produce multiple crops either for home consumption or market sale using both own and purchased inputs (**Muyanga & Jayne, 2014**). In Ethiopia, for instance, cattle farming mainly relies on family labour or hired labour, own produce or purchased crop residue, local or cross breed cows and improved feed or traditional feed under imperfect market conditions. This shows that production behaviour cannot be analysed without analysing the consumption side of the model (**de Janvry *et al*., 1991**).

In LDCs, markets may fail due to a variety of transaction costs, including high transportation costs, the opportunity cost of time involved in selling and buying, and risk associated with uncertain prices and the uncertain biophysical environment (**de Janvry *et al*., 1991**). In the present study, market failures are assumed to be associated with transaction costs such as high transportation costs in the output markets and incomplete or missing input markets. When some prices (whether in the output or input markets) faced by the household are endogenous, the profit maximization approach becomes inappropriate for

analysing production decisions. Institutional weaknesses in developing economies also contribute towards rendering information about new technologies imperfectly, adding another source of non-separability of production and consumption to household decision making. During the green revolution, most of the theoretical approaches developed to analyse seed and fertilizer adoption were based on profit maximization in the context of risk aversion. In this study, a utility maximization framework under market imperfections is assumed to be the objective underlying the household choice of livestock farming technology within the framework of household utility model following the work of Singh et al. (1986).

The model developed in this paper diverges from the previous works in many ways. First, the agricultural household framework is a base from which the optimal adoption decisions is derived for analysing the effect of market constraints on adoption decisions and the role of social network in overcoming these constraints. A theoretical model which captures technology adoption is unfortunately rare in general and particularly for this subject. Second, the relevance of Boserupian theory is introduced in the model to analyse the role of population pressure or feeding scarcity on technology adoption and intensification. Third, variables such as network, information, distance to water and grazing are accounted in the model, which makes this model unique in its nature than the previous farm household models. Full explanation of the theoretical model is given in the appendix.

DATA AND METHODS

Description of the Study Area and Data

The study is conducted in Tigrai region, the northern part of Ethiopia by randomly selecting 632 sample households. This study used a cross-sectional data from Tigrai Rural Household Survey (TRHS) dataset collected in 2015. TRHS includes a panel of five rounds conducted in 1997/98, 2000/01, 2002/03, 2005/06 and 2014/2015. The available panel dataset provides comprehensive household and plot level data. A cross-sectional data for the year 2014/2015 was extracted from the survey for this thesis. Although the survey covered a total sample size of 632 farmers, this study used a sample of 518 livestock owner farmers of which 187 farmers were practicing SF in a full year and the rest 331 were non-adopters.

The summary of all variables are presented in Table1. Table 1 showed that the percentage of users and non-users in the full year round were 36.10% and 63.9 % with a mean intensity ratio of 0.779. However, farmers practicing SF at least in one season account 55.6 %, whereas those non-users were 44.4% with an intensity ratio of 0.63. The average grazing area is less than 210 ha per 1839 household heads including the total area of 685 ha. The average grazing to household ratio is 0.0013km^2 for users compared to 0.0019 km^2 for non-users. One km^2 grazing land is available for at least 2506 SF users and serves 3289 non-user farmers. The average village farm size is 875.9 ha for users as compared to 1245.8 ha for non-users. The result also indicated that the mean family size of adopting farmers is 6.3, with an average age of 55.3 years. On average, farmers who adopt SF spend 28.3 and 24 minutes to travel to the nearest road service and animal water site while non-users have more record of walking time. SF users owned a herd size of 6 TLU units with a mean of 1.24 milking cows while those non-users of SF owned about 6.1 TLU units with a mean of 1.29 milking cows.

Farmers using SF had higher mean labour time of 610 hours than the non-users with only 303 hours per week. Farmers using SF also spend 62.3 minutes than non-users with only 54.9 minutes per day to reach free grazing land. SF users, on average, get 1509 ETB as transfer income from friends and/or relatives as a proxy for social network compared to mean of 1336 ETB for non –users. Besides, the average crop residue collecting time for SF users was also smaller (767 min) than non-users (911 min). In relation to the exposure, on average SF users had 4.3 years' experience than non–users with 3.2 years. Moreover, the two groups are different by farm size relative to village farm size, showing 0.003 ha for users and 0.002ha for non-users.

Among male farmers, 76% are non-adopters and 84% are adopters. SF users had a significantly higher literacy level (46%) than that of non-users (37%). SF users own breed cows, on average 9 times higher than that of non-users. Adopters of SF seem to have higher mean value (28%) in terms of animal shock exposure. Moreover, 20% of the farmers reported to having access to information via radio, TV or mobile, of which 31% of them were found to be SF users.

Econometric Model of Adoption

In this section, the econometric model for estimating adoption and intensity is specified. Regarding the structure of the adoption model, a vast literature has focused on the adoption of agricultural techniques applying models that fall into static and dynamic categories (**Marra *et al.*, 2003**). Due to the cross section nature of data we apply the static model as it is more widely used. We partly overcome its disadvantage by taking adoption as a sequential, multi -stage process, as suggested by **De Graaff *et al.* (2010)**.The model suggested in this literature is a two-stage model consisting of the following stages: (1) the decision to adopt or not, and (2) intensity of adoption.

Adoptions at the farm level indicate farmers' decisions to use a new technology (**Feder *et al.*, 1985**). In this case, the full year and seasonal SF adoption are quantified using a binary variable (1.0) and intensity of SF by continuous variables such as share of cattle under SF to describe the extent of adoption. Empirically, continuous decisions have been measured in terms of proportion, scale or intensity of use and in some cases, more than one continuous measure is used to reveal important information about the adoption behaviour (**Smale and Heisey, 1993**).

Table 1. Descriptive statistics of explanatory variables

Variables	(Non-users=331) Mean1	(users=187) Mean2	(Diff) 1-2	(T-test) P-value
Explanatory variables				
Family size (number)	5.659	6.251	-0.593	0.007
Household head age(years)	57.66	57.27	0.394	0.774
Distance to road(walking minutes)	34.38	28.27	6.111	0.050
Distance to animal water site(walking minutes)	32.90	24.10	8.796	0.000
Ratio of total herd size to farm size(TLU/hectare)	6.101	6.006	0.094	0.922
Total number of Cows	1.287	1.241	0.046	0.732
Log transfer income(ETB)[a]	7.704	7.731	-0.027	0.739
Labour for rearing cattle per week/farm size(hr/hectare)	303.6	610.1	-306.5	0.000
Feed used per year (donkey load)	94.60	80.44	14.16	0.009
feed demand per year(donkey load)	77.88	70.57	7.314	0.074
Distance to grazing land(walking minute)	54.85	62.77	-7.917	0.031
Mean village wage(ETB)	157.4	124.2	33.21	0.000
Milk price/village wage(ratio)	0.300	0.419	-0.119	0.055
Exposure to SF in years	3.214	4.332	-1.117	0.000
Feed transport time (minutes)	911.1	767.1	143.9	0.005
HH farm size relative to Tabia farm size(hectare)	0.002	0.003	-0.001	0.013
Network- cash assistance from relatives/friends (ETB)	1,336	1,509	-172.4	0.702
Grazing area to household ratio(Km^2)	0.0019	0.0013	0.001	0.041
Average community farm size (hectare)	1245.8	875.9	369.8	0.000
Closed area to households ratio(hec)	0.521	0.589	-0.068	0.237
HH head sex (male=1)	0.764	0.840	-.0752	0.043
HH head Education (literate=1)	0.372	0.455	-.0829	0.0646
Improved cows (breed=1)	0.0121	0.112	-0.100	0.000
Animal shock(shock=1)	0.157	0.283	-0.126	0.001
Farm capital(cart, cattle &fodder shed=1)	0.260	0.422	-0.162	0.000
Access to formal credit (yes=1)	0.242	0.283	-0.042	0.297
information(TV, radio & mobile=1)	0.136	0.305	-0.168	0.000
Dependent variables				
Full SF adoption (SF in full year round) (0,1)	63.90	36.10		
Seasonal adoption (SF at least in one season)(0,1)	44.40	55.60		
Share of cattle under SF in full year(ratio)		0.779		
Share of cattle under SF in season(ratio)		0.631		
1=If household feed only cows under SF		0.399		
2=If household feed only ox under SF		0.313		
3=If household feed others under SF		0.288		
1= if household practice SF in dry(winter& spring)		0.066		
2 =if household practice SF in wet(summer & autumn)		0.285		
3= if household practices SF the whole year		0.649		

Source: own compilation, 2016: [a] cash assistance from relatives/friends plus safety net: 1 $USD ≈ 21 Ethiopian Birr (ETB)

We assume that farmers have objectives other than profit maximization, thus their choice of adoption for SF is modelled based on the random utility maximization model following **McFadden (1981)**. More precisely, the technical estimation explained in the study of **Misra *et al.* (1993)** gives a general guideline for applying random utility maximization model to estimate the model. Recalling from the theoretical model in section three, the farmer chooses to adopt SF practice if $Y^* = E[(\pi^1)] - E[(\pi^0)] > V$. $Y^*$is a latent variable for each farmer that defines their propensity to adopt a new practice that can be expressed by Eq. 1.

$$Y^* = X_i\beta + \varepsilon_{ji} \quad (1)$$

X_i indicates the vector of regressors, β is a vector of parameters to be estimated and $\varepsilon_i$is an error term. Then the binary choice is defined by assuming a probability density function and letting the random variable (Eq. 2).

$$Y_i = 1 \quad if \quad X_i\beta + \varepsilon_{ji} > t$$
$$Y_i = 0 \quad if \quad X_i\beta + \varepsilon_{ji} \leq t \quad (2)$$

Where: Y_i is the probability of the adoption of SF or alternatively, Y_i could be a censored variable indicating the intensity of adoption of SF (e.g., share of cattle under SF practice), and t is a threshold level that can take a value of zero. Then, β vector was estimated in an asymptotically efficient method maximizing the log-likelihood function based on probit (0, 1) model **(Shapiro, 1990).** Our interest to estimate intensity conditional on the adoption decision dictates us to choose Heckman's two-stage procedure

(**Smale *et al*., 1994**). Thus, the Heckman's selection model two-stage procedure is specified by:

$$\begin{aligned} &Y_{1i} = X_1\beta_1 + \varepsilon_1 \\ &Y_{1i} = 1 \quad if \quad X_1\beta_1 + \varepsilon_1 > t \\ &Y_{1i} = 0 \quad if \quad X_1\beta_1 + \varepsilon_1 \leq t \\ &Y_{2i} = X_2\beta_2 + \varepsilon_2 \; if Y_{1i} = 1 \\ &\mathrm{Var}(\varepsilon_1) = 1, \mathrm{Var}(\varepsilon_2) = \sigma^2 \text{ assuming } \mathrm{corr}(\varepsilon_1, \varepsilon_2) = \rho \end{aligned} \quad (3)$$

Depending on the specification, Y_{2i} in the second equation is observed when Y_{1i}equal to one, indicating that the second-stage equation uses the subsample of farmers that adopt the SF technology. Therefore, the second-stage equation, in our case, was estimated using Heckman's selection model second stage. Heckman's two stage procedure is suggested, which allows for a probit equation to be estimated using information from the whole sample and the inverse mills ratio computed from fitted values (**Hall, 1994**). In the second stage, equations were estimated with the calculated inverse mills ratio function from the probit residuals as an exogenous variable not only to guarantee convergence but also to fix the problem of omission in the nonlinear functions of the right-hand side variables. For the sake of comparison, a Poisson model on the number of SF adopting seasons was also used based on **Greene(2008)** and **Long & Freeses' (2003)** method.

In order to reinforce understanding of animal or seasonal choice, we estimated a multinomial logit model (MNL) that is commonly used in an adoption decision study involving multiple choices. The advantage of using a MNL model than MNP model is its computational simplicity in calculating the choice probabilities that are expressible in analytical form (**Tse, 1987**). Let A_i be a random variable representing the choice of animal or season by the farmer. Assuming each farmer faces a set of mutually exclusive choices which depend on a number of farm attributes, socioeconomic characteristics and other factors X. The MNL model for animal or season choice specifies the following relationship between the probabilities of choosing optionA_i, and the set of explanatory variables X as **Greene (2003)** (Eq. 4).

$$Pr(A_{i=j}) = \frac{e^{\beta_j' X_i}}{\sum_{k=0}^{j} e^{\beta_k' X_i}}, \text{ j= 0,1…J} \quad (4)$$

Where β_j is a vector of coefficients on each of the independent variables X. Equation (4)can be normalized to remove indeterminacy in the model by assuming that β_0 =0 and the probabilities can be estimated as Eq.5.

$$Pr(A_{i=j}|X_i) = \frac{e^{\beta_j' X_i}}{1+\sum_{k=1}^{j} e^{\beta_k' X_i}}, \quad \text{j=0, 1…J; } \beta_0\text{=0} \quad (5)$$

Estimating equation (5) yields the J log-odds ratios where the dependent variable is the log of one alternative relative to the base alternative (Eq.6).

$$\ln\left(\frac{P_{ij}}{P_{ik}}\right) = X_i'(\beta_j - \beta_k) = X_i'\beta_j, \text{ if } \; k = 0 \quad (6)$$

The difficulty to interpret MNL coefficients makes the association of β_j with the j^{th} outcome misleading. To interpret the effects of explanatory variables on the probabilities, marginal effects are usually derived adapting **Greene (2003)** (Eq.7).

$$\theta_j = \frac{\partial P_j}{\partial X_i} = P_j\left[\beta_j - \sum_{k=}^{j} P_k\beta_k\right] = P_j(\beta_j - \bar{\beta}) \quad (7)$$

Where the marginal effects measure the expected change in probability of a particular choice being made with respect to a unit change in an explanatory variable (**Long, 1997**). The signs of the marginal effects and respective coefficients may be different, as the former depend on the sign and magnitude of all other coefficients.

RESULTS

The empirical results of this paper are presented in two subsections, where the first part mainly presents the empirical result of adoption and adopting seasons using probit and count models respectively. The second is mainly devoted to the results of intensity of adoption.

Adoption of Stall Feeding

Estimation of the first stage binary probit and count model explained the behaviour of SF practice usage and the number of SF adopting seasons by cattle farmers. Variables included in the analysis of the use of SF practices were selected based on the theoretical model developed in section 3. Marginal Effects (ME) and Incident Rate Ratio (IRR) computed for the use decision and a number of SF adopting seasons are presented in Table 2. An identical set of explanatory variables were used for all estimation revealing how these variables vary in terms of direction, magnitude and significance in influencing adoption decision.

The results from the probit model explaining the adoption of SF practice correctly predicted 80% of the responses (Table 2). The χ^2 for the log likelihood test of the hypothesis that the repressors have zero influence on farmers' adoption was significant. Thus, the hypothesis that the variables have no explanatory power was rejected. Results of the Likelihood Ratio test and the Wald test showed that the inclusion of grazing land, farm, and herd size, enclosure, labour, animal water and feed, shock exposure and the number of the breed increased the model fit significantly. This was consistent with the hypothesis that there exists a strong relationship between these variables and the SF adoption.

Econometric findings from Table 2 confirmed that all five groups of variables derived from the theoretical model shape the decision to adopt SF practices. The results show that small grazing land per household induces adoption and intensity of SF. As grazing land decreases by one-square kilometer, adoption of FSF and SSF are increased by 32% and 91% whereas the number of SF adopting season increased by about 1.4 %. This reflects that smaller grazing is associated with the more intensive use of SF; thereby providing more evidence for the Boserupian theory of population-induced intensification.

Table 2. First stage Heckman Estimation of full year (FSF) and Seasonal (SSF) Adoption

Variables	ME[b](1) Full	ME(2) Seasonal	Count(3) Seasons of SF	IRR[c](4) Seasons of SF
Closed Area To Households Ratio(Hec)	0.133***	0.152***	0.256***	1.291***
	(0.0383)	(0.0443)	(0.0593)	(0.0765)
Farm Size To Village Farm Size ratio (Hectare)	0.278	-0.857	-0.336	-0.336
	(6.195)	(8.124)	(6.782)	(6.782)
Grazing Area To Household Ratio(Km2)	-32.22**	-90.73***	-98.66***	1.42e-4***
	(12.85)	(14.64)	(21.78)	(3.09e-4)
Average Community Farm Size (Hectare)	-8.70e-05**	5.18e-06	-0.000205***	0.9997***
	(4.23e-05)	(4.33e-05)	(6.13e-05)	(0.0000)
Cash Assistance From Relatives/Friends (Etb)	4.38e-06	1.44e-05*	1.18e-05*	1.0000*
	(7.13e-06)	(8.71e-06)	(6.11e-06)	(6.11e-06)
Information(Access To Tv, Radio &Mobile=1)	0.181***	0.197***	0.333***	1.3947***
	(0.0649)	(0.0580)	(0.0790)	(0.1101)
Total Number Of Milking Cows	-0.0108	0.0400*	0.0372	1.0379
	(0.0196)	(0.0219)	(0.0256)	(0.0266)
Distance To Animal Water Site (Minutes)	-0.00537***	-0.00391***	-0.00922***	0.9908***
	(0.00138)	(0.00137)	(0.00206)	(0.0020)
Improved Cows (Breed=1)	0.661***	0.323***	0.700***	2.0133***
	(0.0636)	(0.0660)	(0.136)	(2.748)
Exposure To Sf (Years)	0.0595***	0.0927***	0.0746***	1.0774***
	(0.0188)	(0.0241)	(0.0251)	(0.0270)
Labour For Rearing Cattle/Farm Size(Hr/Ha)	0.000111***	7.00e-05*	0.000147***	1.0001***
	(3.26e-05)	(3.57e-05)	(4.18e-05)	(0.0000)
Family Size (Number)	0.0238**	0.0208*	0.0397**	1.0405**
	(0.0112)	(0.0122)	(0.0163)	(0.0169)
Household Head Age(Years)	-0.00117	-0.00362*	-0.00555**	0.9944**
	(0.00182)	(0.00208)	(0.00253)	(0.0025)
HH Head Sex (Male=1)	0.139**	0.105	0.194*	1.2135*
	(0.0595)	(0.0784)	(0.101)	(0.1227)
HH Head Education (Literate=1)	-0.0117	0.130**	0.126*	1.1341*
	(0.0515)	(0.0556)	(0.0721)	(0.0817)
Access To Formal Credit (Yes=1)	0.0176	0.109*	0.143*	1.1538*
	(0.0555)	(0.0589)	(0.0773)	(0.0891)
Log Transfer Income(ETB)	-0.0607*	-0.133***	-0.148***	0.8628***
	(0.0321)	(0.0368)	(0.0455)	(0.0392)
Ratio Of Herd Size To Farm Size(Tlu/Ha)	-0.0111**	-0.00863***	-0.0163***	0.9838***
	(0.00440)	(0.00329)	(0.00524)	(0.0051)
Feed Transport Time (Minutes)	-8.89e-05**	-0.000139***	-0.000203***	0.9997***
	(4.25e-05)	(5.07e-05)	(6.08e-05)	(0.0001)
Feed Demand Per Year(Donkey Load)	-0.000242	-0.00123**	-0.000913	0.9990
	(0.000543)	(0.000600)	(0.000790)	(0.0007)
Distance To Grazing Land(Walking Minute)	0.000738	0.00432***	0.00239***	1.0023***
	(0.000577)	(0.000889)	(0.000716)	(0.0007)
Animal Shock(Shock=1)	0.155**	0.129**	0.239***	1.2702***
	(0.0623)	(0.0615)	(0.0784)	(0.0995)
Mean Village Wage(Etb)	-0.000985***	-0.000866**	-0.00315***	0.9968***
	(0.000379)	(0.000388)	(0.000627)	(0.0006)
Milk Price/Village Wage(Ratio)	0.150***	0.829***	0.440***	1.5529***
	(0.0497)	(0.132)	(0.0722)	(0.1120)
Distance To Road(Walking Minutes)	-2.30e-05	-0.000564	-0.000575	0.9994
	(0.000807)	(0.000904)	(0.00125)	(0.0012)
Constant			1.869***	1.869***
			(0.447)	(0.447)
Predicted Probability	79.92%	82.82%		
Observed Probability	.361	.556		
P-Values For The Joint LR- Test For Hh Chrematistics	0.0000	0.0000		
P-Values For The Joint LR- Test For Market Factors	0.0000	0.0000		
P-Values For The Joint LR- Test For Farm Capital	0.0000	0.0000		
Observations	518	518	518	518

Source: own compilation, 2016: Standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1 indicate level of significance at 1%.5% &10% respectively: [b] marginal effects for the full year and seasonal adoption, and [c] incident rate of ratio from the Poisson regression

The findings support the **Boserup's (1965)** hypothesis that population pressure motivates farmers to adopt more intensive cattle farming practices, and are consistent with the findings of **Kruseman et al.,(2006)** and **Benin (2006)**. Besides, the ratio of the exclosure to the total users appear to be positive factors, causing FSF and SSF adoption to increase by about 15 % and adopting seasons by 29 %. While the ratio of individual farm size to village farm size did not affect the decision to us SF, the average village farm again supports the result of **Benin (2006)** who found that households that own less land are more likely to apply modern agricultural inputs and use more labour and oxen. Results from Column (1-4) of Table 2 showed that results in the SSF indicated that possession of milking cow contributes positively to the use of SSF. However, the number of improved cows had a positive significant relationship with the use of SF practice in both FSF and SSF. This implies that the likelihood to use FSF increases by about 66% as they acquire one more improved cows which are in line with the findings of **Kaaya *et al.* (2005)** and **Benin (2006)** who found a positive relationship between a number of breed cattle and adoption of SF.

Household size significantly increased FSF or SSF adoption as well as SF adopting seasons. Male farmers were more likely to participate; the probability of male farmers adopting was 14% higher than the probability for female farmers in FSF adoption. The result agreed with the work of (**Beshir, 2014; Gunte, 2015)** who found a direct relation between male farmers and forage adoption in Ethiopia. The results of the study conform to the expectations that age is negatively associated with the probability of SSF adoption indicating that younger farmers are more likely to use SF. **Shiferaw and Holden (1998)** found that there was an inverse relationship between age and soil conservation practice adoption in Ethiopia. This is probably because older farmers are less energetic to manage the activities of SF practice as compared to the more energetic young farmers. Earlier work by **Fufa and Hassan (2006)** found that age of a farmer reduces the probability of using agricultural technologies.

Education is a significant factor to induce and realize the benefits of a new technology through the ability to acquire information (**Musaba, 2010**). As anticipated, literacy had a positive significant effect on adoption of SF, implying that educated farmers are about 13% to use SSF and increase adopting seasons by about 13% than their illiterate counterpart in line with **Gunte (2015)** who found out that literacy had a positive and significant influence on the adoption of forage technology. Results further showed that access to credit had a positive impact on the use of SF, increasing SSF adoption by 11% and SF adopting seasons by 15%. Similar signs are found in the works of (**Mugisha *et al*., 2004; Beshir, 2014**) which can be attributed to the fact that some of the investments of inputs need more money.

Transfer income negatively influenced the decision to use FSF and SSF as well as adopting seasons. The possible justification for this result is that transfer income might be used to utilize other inputs such as fertilizer, breed cow, and labour. This is contrary to the findings by **Gebremedhin *et al.* (2003)** but consistent with the findings of **Beshir (2014)**, who found that off-farm income negatively affected forage technology adoption. Access to information did have a positive significant effect on the use of SF (18%) and adopting seasons (40%). This is possible where the information is relevant to livestock production in line with the proposition of **Feder and Slade (1984)** and **Gunte (2015)** who stated that adopters of improved forages had higher access to a mobile telephone.

Endowments of livestock as an asset may influence the decision to use SF practice through two mechanisms. Ownership of more livestock may discourage SF adoption by increasing the cost of management but at the same time encourage farmers to adopt SF by making cash available from an animal sale to finance this cost. It was expected that herd size relative to farm size has an inverse relationship with adoption, and the result confirms herd size influenced negatively the use of FSF or SSF adoption. This is possible in the study area where farmers with more herd size cannot afford to stall-fed them on the limited homestead grazing land particularly when feed is available on communal lands. Each additional animal is associated with an estimated 1.1% decrease in the use of FSF or SSF and 1.6% decrease in adopting seasons in contrast to the result of **Beshir (2014)** who found a positive relation between forage adoption and herd size.

Farmers with higher labour supply relative to farm size were more likely to allocate more cattle to SF, suggesting that SF use imposes an additional labour on farmers. A one hour increase in labour supply increased the adoption of FSF and SSF by 0.01%. The positive relationship agrees with **Beshir (2014)** and **Gunte (2015)**. As a noticeable finding, results further indicated that social network had the expected positive and significant effect on the probability of SF adoption, showing that farmers with more peers are willing to adopt the practice in favour the results of **Hogset (2005)** in that transfer income was positively related to adoption in Kenya. This is attributed to the fact that access to informal credit minimizes the problem of liquidity constraint for investments.

The negative and significant relation between feed need and use of SF seem to agree with the expectation, suggesting for every additional donkey load feed demand, the probability of using SSF reduces by 0.1%. This implies that crop residues plays a complementary role for SF and used to fill feed gaps during periods of inadequate crop residues (**McIntire and Debrah, 1987**) and SF improve the utilization of crop residues and straw even in the presence of abundant crop residues. The negative effect of distance to an animal water source and crop residue on the use of SF supported the hypothesis that long distance and the high cost of transport are negatively associated with the use of SF practice and adopting seasons. The estimated coefficients for distance to an animal water source and transport indicated that the probability of SF adoption is reduced by 0.05% and 0.01% when traveling time gets longer.

It was also observed that longer distance to free grazing lands positively influenced the likelihood of SSF adoption by 0.4 % and a number of adopting seasons by 0.23%. The proximity of farmers to roads is essential for

timely input delivery and output disposal resulting in less transport cost. Contrary to the study of **Gebremedhin *et al.* (2003)**, the coefficient of distance to roads had the expected negative sign but insignificant. The milk price relative to the labour wage rate was positive and significant. The probability of using SF and number of SF adopting seasons also seem to decrease with the village labour wage rate, thus underscoring the crucial role played by market incentives in SF decisions. Among the formal information diffusion variables, exposure to SF seems to be the most important determinant in decisions regarding SF. Farmers who were exposed to SF earlier are more likely to manage their cattle under SF in a full year. Similarly, farmers who experienced an animal shock in the last four years were found to support SF practice in conformity with the hypothesis and to the result **Bezabih and Sarr (2010)** who indicated that shocks from rainfall variability positively affected the level of crop diversity.

The hypothesized relationships embodied in the decision-making model developed in section 3 were tested jointly, using a likelihood ratio test for both estimations. The probability values showing the level of significance are presented in Table 2. It was initially sought to test whether market imperfections are important in SF decisions with the null hypothesis that consumption and production decisions are separable. A non-separability may result from output and factor market imperfections. A familiar approach used to test for market failures is that of testing the joint significance of household characteristics (age, gender, education, household size) for both estimations.

The joint significance test of consumption and production decisions does not support the hypothesis of separability for both estimations. However, the rejection of the null hypothesis does not clearly indicate which market imperfections are important. These results may imply imperfections in the output market or the labour market. The joint significance test of farm capital reveals the importance of household endowments, highlighting the importance of missing markets for inputs used in SF decisions. As **Pender and Kerr (1996)** demonstrate, factor endowments will have no effect on production decisions when perfect markets exist, Statistical tests suggested that farm capital is more important in explaining variations in SF. Market factors are also highly significant and relevant in explaining variations in farmer decisions of using SF practices.

Extent of Use Stall Feeding Adoption

The second aspect of the use decision for a technology is the extent of use, share to which the practices are applied, and was estimated using Heckman model to account for the selection bias associated with missing observations for a given sub-sample due to the truncated nature of the dependent variable. The motivation underlying the use of Heckman regression model was dependent on a statistical rejection of the null hypothesis of sample selection bias. The results for the second stage estimation are summarized in Table 3.

The coefficient of lambda is significant and negative, which suggests that the error terms in the selection and outcome equations are negatively correlated indicating that unobserved factors that make adoption more likely tend to be associated with the lower extent of SF.As shown in Table 3, grazing area ratio and distance, total family and herd size significantly negatively influence farmers' extent of SF adoption but labour supply, distance to the animal water source and farm size ratio positively affect the extent of SF adoption. The ratio of individual farm size to village farm size has opposite signs in the selection and outcome equations. A positive effect is observed for the share of animal kept under SF contrasted by a negative and insignificant effect on the use of SF. This is expected since large farm size produces more crop residue and SF is mainly dependent on this feed. Similar results are found in the study of **Beshir (2014).** We also found that farmers with less grazing land allocate more cattle to SF, again consistent with the hypothesis of **Boserup (1965)** and her followers (**Benin, 2006**).

The ratio of herd size to farm size has negative effects in both equations consistent with the idea that more herd size discourages SF use and its intensity. In line with the hypothesis made earlier, the ratio of labour time to farm size positively affected the extent of using SF, indicating that each additional labour spent on animal rearing results in more extent of the practice. Household size negatively influenced the intensity of using SF, showing that more family members may engage in crop production (**Beshir, 2014**). Sex of the farm household head was negatively related to the intensity of use of FSF or SSF implying that that male farmers allocate less share of cattle under SF as compared to their female counterparts. The justification for this is that female farmers might have more chance to stay at home than their male counterparts. **Beshir (2014)** found opposite signs for other forage technology adoption in Ethiopia.

The literacy rate of household head is positive but not important in the extent of use of SF. Farmers with the longer distance to the nearest road allocate a larger share of their cattle to SF. Age of the farm household head was positively related to the extent of SF use, except in full year. The justification for this is that older farmers might have gained knowledge and could be explained by the fact that the practices of SF require investment on information to break the information barrier that impedes them from using the practice. These findings are consistent with the findings of **Kaliba et al., (1997)**, whose results indicate that older farmers were more likely to adopt SF and have larger intensive feed gardens in Tanzania.

The lack of statistical importance of distance to crop residue and animal water site in decisions regarding the extent of use of SF implies that the observed partial use of this practice can be explained by factors other than these variables. Although statistical significance is lacking, estimation results also show that farmers with animal shock also use SF practice more extensively than those that are shock free. The length of time that farmers have travelled to free grazing lands had a negative and significant impact on cattle under SF. The possible explanation for this could be as the number of traveling minutes to FG increases, it is not economical to allocate more animal to SF and few to FG especially in seasons where free grazing is ubiquitous, as farmers respond to labour savings.

Table 3. Heckman Second Stage Estimation of full (FSFR) and seasonal (SSFR) Stall Feeding Intensity

Variables	(Full - intensity) Share of cattle under SF	(Seasonal - Intensity) Share of cattle under SF
Closed area to households ratio(hec)	-0.0581	0.00674
	(0.0411)	(0.0365)
HH farm size relative to village farm size(hectare)	5.212*	6.046*
	(3.137)	(3.639)
Grazing area to household ratio(Km2)	-29.60**	-35.07**
	(15.05)	(15.62)
Network- assistance from relatives/friends (ETB)	-7.41e-07	-7.07e-07
	(3.28e-06)	(3.54e-06)
information(access to Tv, radio &mobile=1)	-0.132**	-0.0441
	(0.0518)	(0.0438)
Total number of milking cows	-0.0393**	-0.0562***
	0.00204	-0.000579
Distance to animal water site (minutes)	0.00204	-0.000579
	(0.00148)	(0.000963)
Improved cows (breed=1)	0.00377	0.137*
	(0.0960)	(0.0703)
Exposure to SF in years	-0.0117	0.0146
	(0.0193)	(0.0142)
Labour for rearing cattle per week/farm size(hr/ha)	5.62e-05**	8.49e-05***
	(2.42e-05)	(2.59e-05)
Family size (number)	-0.0235**	-0.0172**
	(0.00927)	(0.00831)
Household head age(years)	0.00192	0.00277**
	(0.00124)	(0.00126)
HH head sex (male=1)	-0.0936*	-0.0762
	(0.0560)	(0.0488)
HH head Education (literate=1)	0.0255	0.0306
	(0.0360)	(0.0361)
Access to formal credit (Yes=1)	0.0151	-0.0164
	(0.0383)	(0.0396)
Log transfer income(ETB)	0.0414	0.0227
	(0.0269)	(0.0243)
Ratio of total herd size to farm size(TLU/ha)	-0.0199**	-0.00374**
	(0.00944)	(0.00190)
Feed transport time (minutes)	-1.14e-05	1.02e-05
	(3.04e-05)	(3.02e-05)
feed demand per year(donkey load)	-0.000106	-0.000259
	(0.000405)	(0.000392)
Distance to grazing land(walking minute)	-0.00163***	-0.00139***
	(0.000407)	(0.000418)
Animal shock(shock=1)	0.0163	0.0289
	(0.0474)	(0.0414)
Milk price/ village wage (ratio)	0.0712	0.0672
	(0.0568)	(0.0554)
Distance to road(walking minutes)	0.00140**	0.000856
	(0.000705)	(0.000629)
Mill's Ratio	-0.195**	-0.175***
	(0.0823)	(0.0503)
Constant	0.839***	0.570***
	(0.241)	(0.199)
Observations	187	288

Source: own compilation, 2016: Standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1 indicate level of significance at 1%.5% &10% respectively.

Animal and Seasonal Choices

In order to reinforce our results from the above estimation, we estimated a multinomial logit model to directly understand the choice of animal or season in the study area. Referring to Table 1, dependent variables in the multinomial empirical estimation are the choices of animals and seasons to feed under SF where one choice is considered as base category or a choice of seasons (for the purposes of estimation one choice is again used as the base category). The choice of animals allocated to SF include cow (40%), ox (31%) and other animals (29%) of the given sample indicating feeding cow under SF takes the largest share. Similarly, the choice for season were, 65% full year, 29 % wet (summer and autumn) and 6% dry (winter and spring). This would again imply that more than half of the sample farmers practice SF the year round. Econometric results from the marginal effect of multinomial logit model are presented in Table 4. We compare results from the multinomial logit model in order to further understand the choice of animal and season among SF adopting farmers.

Table 4. Multinomial Logit Estimation for Animal and Seasonal Choice

	(Animal Choice)		(Seasonal Choice)	
Variables	cow	ox	dry	year
Formal credit(Yes=1)	-0.640*	-0.630	-2.054**	-0.311
	(0.372)	(0.400)	(0.965)	(0.515)
Location(highland >2500mas=1)	2.001*	1.934	-21.01	1.873*
	(1.174)	(1.182)	(3,184)	(0.979)
Information(access to TV, Radio & mobile=1)	0.577*	0.191	0.677	0.902*
	(0.346)	(0.360)	(0.769)	(0.495)
Fodder shed(Yes=1)	12.74	15.00	2.465	19.69
	(417.2)	(417.2)	(22,216)	(13,379)
Farm cart(Yes=1)	1.481**	1.580**	-18.45	0.144
	(0.646)	(0.674)	(6,342)	(0.789)
Network(got gift/support=1)	0.257	0.330	0.755	22.24
	(0.509)	(0.498)	(0.810)	(6,163)
Animal shock of last 4 years (Yes=1)	0.773*	0.474	1.493*	1.986***
	(0.419)	(0.435)	(0.834)	(0.704)
Land holding(number of plots)	-0.140*	-0.0621	0.115	0.213*
	(0.0831)	(0.0870)	(0.188)	(0.120)
Total cows(number)	0.0914	0.00689	-1.369**	0.574**
	(0.187)	(0.191)	(0.552)	(0.251)
Owning breed cow(yes=1)	2.040*	1.925*	6.472***	1.456
	(1.126)	(1.165)	(2.346)	(1.267)
Village Exposure of SF(years)	0.294**	0.199	-0.604	-0.352*
	(0.133)	(0.137)	(0.422)	(0.200)
Labour(hour)	1.14e-05	-0.00141*	-0.00365	0.00402***
	(0.00069)	(0.0008)	(0.00317)	(0.00115)
Water well(Access =1)	0.719	1.493	-15.69	2.217
	(1.338)	(1.278)	(14,541)	(1.536)
Household head age(year)	-0.000814	0.0116	0.0503*	0.0318**
	(0.0115)	(0.0120)	(0.0302)	(0.0152)
Gender of household head(male=1)	-0.823**	0.0403	0.0712	-0.811
	(0.378)	(0.420)	(0.955)	(0.537)
Education of household head(literate=1)	-0.0132	-0.527	0.128	-0.632
	(0.346)	(0.372)	(0.818)	(0.448)
Herd size(TLU)	-0.187**	-0.0852	0.298	-0.300**
	(0.0911)	(0.0889)	(0.186)	(0.118)
Own produced feed(donkey load)	0.00808*	0.00165	0.00710	-0.00102
	(0.00479)	(0.00511)	(0.0101)	(0.00607)
Feed transporting time(minute)	1.30e-05	1.71e-05	4.98e-06	7.86e-06
	(3.83e-05)	(3.73e-05)	(2.94e-05)	(3.73e-05)
Distance to grazing land(minute)	-0.00167	0.00421	-0.00527	-0.0179***
	(0.00437)	(0.00308)	(0.0107)	(0.00637)
Constant	1.388	1.482	-3.486	-24.84
	(1.362)	(1.361)	(2.975)	(6,163)
Observations	288	288	288	288

NB: Standard errors in parentheses & *** p<0.01, ** p<0.05, * p<0.1 indicate significance level at 1%, 5% & 10% respectively

Table 4 suggests that household who have access to credit had a lower probability of choosing a cow and dry season as compared to choosing other animal and wet season but had no significant effect on choosing ox and year. In a related study, **Beshir (2014)** found a positive significant effect of credit. Location of household is significant for those farmers deciding on choosing cows and year round practice. Highland location increased the probability that the farmer will allocate a cow to SF by 2% and to practice the full year by 1.9% compared to choosing other animal and wet season. This shows that highland increases the likelihood of SF adoption and cow selection because rural farmers living there do not have enough grazing lands due to population pleasure. This is a new result but agree with the findings of **Bishu (2014**) and **Gebreyohannes and Hailemariam (2011)** who found that SF is more practical in the high land parts of the country.

Access to information was a positive significant for cow and year choices. Among the farm tool while fodder shed was insignificant, Availability of cart positively influenced the probability of a farmer choosing the cow and ox with SF practice relative to the choice of other animal. Social network was positive but insignificant for all choices. However, the marginal effect of animal shock indicates that, an additional animal shock exposure will increase the probability of choosing a cow and the full year with SF by 0.77 and 1.98% respectively compared to that of the others and wet season, conforming to earlier findings of **Bezabih *et al.* (2012).**This indicates the vital role played by shock exposure in the adoption decision of agricultural practices. An extra plot had a positive effect on the probability of practicing SF in a year base relative to season base but found insignificant on the choice of animals. The number of cows owned by the farmer had no significant effect on the choices of animal but had a positive significant effect on the probability of choice of the year relative to the choice of single season. This result is expected considering that cow owning farmers adopt SF in year base relative other animal type.

Similarly, number of breed cows had a significant positive effect on the probability of choice of cow, ox and season. This means that the farmer's decision to feed cow, ox and to practice in dry season will increase as the farmer own breed cows. Village SF exposure had a positive significant effect on the probability of choosing cow but negative significant effect on that of choosing a year for SF. Age of household head had a significant positive effect on the probability of practicing SF in dry and full year period against wet period. The higher the age of the farmer, the greater the chance of the farmer choosing the dry and full year season to wet season. Gender is only significant on the choice of cow, indicating that female headed farmers show higher chance of feeding cow under SF than other animal type .This result is in line with earlier researcher, **De Cao *et al.* (2013**) who found a positive relation between female headship and adoption of zero grazing and cross breed cow technology in Ethiopia. The study indicated that adoption of zero grazing was more likely when female farmer owned cross breed cows and these are more likely to be fertilized using Artificial insemination and zero grazing breeds. As expected, owning large herd size decreased the probability that the household will choose cow and practice yearly SF by 0.19 % and 0.30% compared to feeding others and wet season. However, own produced feed increased the probability of putting a cow in SF. The finding concurs with findings **of De Cao *et al.* (2013**); **Gebremdhin *et al.* (2003)** which have shown that the access to own cattle feed significantly increases the adoption of high yielding farming varieties.

SUMMARY AND CONCLUSIONS

Farmers' adoption of SF and number of SF adopting seasons were assessed in northern Ethiopia in 2015 using a household survey sponsored by NORHED-CLISNARP using 518 randomly selected sample farmers. The Heckman model of SF was used to estimate both discrete data and the continuous stage to account for the extent of adoption. Moreover, a Poisson regression model was applied to explain the variation in the number of SF adopting seasons. We further estimated a multinomial logit model in order to reinforce understanding of the choices. While SF has been assumed feasible and applicable in the region, its adoption rate has remained below its expectation. A research on this area is relevant to the literature. The aim of this study was to understand the driving factors of a full year and seasonal SF adoption and its intensity as well as the choice of animal and season by developing a model of technology adoption within the framework of a utility maximizing agricultural household model.

The study results indicate that the choice of and demand for SF depend on a host of factors identified from the theoretical model. All factors were statistically significant in either the use of or extent of SF practices, or both, implying that the model appropriately explains the nature of SF process in Ethiopia. The rejection of the null hypothesis of separable production and consumption decisions support the use of the non-separable household model to analyse the production decisions of SF. The evidence showed that population pressure seems to be a driving force for intensifying SF in all seasons, supporting Boserup's(1965) hypothesis in that less grazing land increased use of SF and adopting seasons. Adoption of SF was also stimulated by the ratio of the closed area probably by shrinking free grazing land and giving extra by-product for animal feed.

The study also shows that SF appears to be attractive to farmers with more milking cows, particularly those that are with improved cows. Wealthier farmers, as measured by the number of herd size, were less likely to adopt and intensify this practice as feeding a large number of cattle increases the cost of its management. The availability of labour is found to be important in determining the use and extent of the practice. While the distance to the animal water site and crop residue reduce the probability to use SF, distance to grazing land, social network and early exposure to SF greatly increased the likelihood of using SF. The significance of education and information confirmed that the awareness level of a farmer influence adoption of SF, suggesting that addressing illiteracy promote adoption. Male farmers were found to practice SF.

Log of transfer income has a negative impact on the use of the practice, as does the total feed demand. Animal shock is significant in influencing the potential for adopting SF. The analysis also reveals that transfer from social networks positively influences decisions regarding the use of SSF. Market-related factors were found to be the most important factors in explaining variations in the use of SF and its extent. While the coefficient of milk price ratio was positive in both the probability and the extent of use of SF, average village wage rate seems to be in the opposite direction causing the probability of SF use to fall during wage rise. While total labour time ratio, farm size ratio and breed cow ownership positively affect the extent of SF adoption, livestock pressure, distance to grazing land and grazing land ratio negatively influences farmers' extent of SF adoption.

Using extra information from the multinomial logit result, the following points are worth mentioning. Farmers in the highland location and with high shock exposure were found to be pro SF adoption and full year application mainly for cow compared to their counterparts. In Ethiopia, the highland location is better in terms of weather condition and infrastructure compared to lowland areas but worse in terms of grazing lands. Farmers' access to information and farm cart influenced the level of the choice of cow and full year positively. Ownership of breed cow is positively associated to choosing cow, ox in dry season. Households who have exposure to SF were in favour of cow and rejected full year practice as households with high herd size. Male headed households negatively and significantly influenced the choice cow but possession of high bi-product fed positively support the choice of cow even if its effect is weaker. This implies that female headed households are interested to stall fed cow compared to male headed households; probably female may stay longer at home compared to male.

The results of the study have at least three important implications. The first is that cattle SF practice appears to be attractive to the more literate but male households. Thus, policies targeting efficient promotion of the practice are recommended to invest in training and substitute the high quantity herd size with less number of improved cattle. The major implication arising from this study is that efforts to encourage the adoption of SF should be directed towards credit provision, water and road service expansion, for those that have adequate family labour. Information diffusion using demonstration center appear to be justifiable to stimulate and nurture the adoption process. Moreover, better coordination is needed to facilitate the production of complementary feeds and the dissemination of information regarding the market price of an animal product.

REFERENCES

AHMED, M. A., EHUI, S., & ASSEFA, Y. (2004). Dairy development in Ethiopia. IFPRI.

ALKEMADE, R., REID, R., VAN DEN BERG, M., DE LEEUW, J., AND JEUKEN, M. (2012). Assessing the impacts of livestock production on biodiversity in rangeland ecosystems. Proceedings of the National Academy of Sciences of the United States of America 110:20900–20905. DOI: doi.org/10.1073/pnas.1011013108

AMUDAVI, D.M., KHAN, Z.R., WANYAMA, J.M., MIDEGA, C. A. O., PITTCHAR, J., HASSANALI, A. AND PICKETT, J.A. (2009). Evaluation of farmers' field days as a dissemination tool for Push–Pull technology in Western Kenya. Crop Protection 28:987–996. DOI: doi.org/10.1016/j.cropro.2009.04.010

BABULO, B., MUYS, B., FREDU, N., TOLLENS, E., NYSSEN, J., DECKERS, J., MATHIJS, E. (2009). The economic contribution of forest resource uses to rural livelihoods in Tigray, Northern Ethiopia. *Forest Policy and Economics* 11:109–117. DOI: doi.org/10.1016/j.forpol.2008.10.007

BALTENWECK, I., MUBIRU, S., NANYEENYA, W., NJOROGE, L.; HALBERG, N., ROMNEY, D. AND STAAL, S. (2007). Dairy Farming in Uganda: Production Efficiency and Soil Management Strategies under Different Farming Systems. ILRI Research Report 1. International Livestock Research Institute, Nairobi, Kenya.

BENIN, S. (2006). Policies and programs affecting land management practices, input use, and productivity in the highlands of Amhara region Ethiopia, In: Pender, J., Place, F., Ehui, S. (Eds.), Strategies for Sustainable Land Management in the East African Highlands. International Food Policy Research Institute, Washington, DC, pp. 217–256.

BESHIR, H. (2014). Factors affecting the adoption and intensity of use of improved forages in North East Highlands of Ethiopia. *American Journal of Experimental Agriculture*, 4(1), 12-27. DOI: doi.org/10.9734/AJEA/2014/5481

BEZABIH, M., & SARR, M. (2012). Risk preferences and environmental uncertainty: Implications for crop diversification decisions in Ethiopia. *Environmental and Resource Economics*, 53(4), 483-505. DOI: doi.org/10.1007/s10640-012-9573-3

BISHU, K. G. 2014. Risk management and the potential of cattl insurance in Tigray, Northern Ethiopia. PhD Thesis, University College Cork.

BoARD (2012). Effect of Free Grazing on Natural Resource Management, in Tigray Region. Bureau of agriculture Natural resource development protection and utilization core process, Mekelle, Ethiopia.

BOSERUP, E. (1965). Conditions of Agricultural Growth. Aldine Publications, Chicago.

FDRE (2011). Ethiopia's Climate-Resilient Green Economy, Green Economy Strategy. Addis Ababa: CRGE

CONLEY, T. G., AND C. R. UDRY (2010). Learning about a New Technology: Pineapple in Ghana. *American Economic Review*, 100 (1): 35-69. DOI: doi.org/10.1257/aer.100.1.35

DE CAO, E., VAN DEN BERG, M. M., TILE, C. Y., & WONDWOSEN, T. (2013). The effects of zero grazing in Ethiopia. In Proceedings of the CSAE Conference 2013: Economic Development in Africa (pp. 1-15).

DE JANVRY, A., M. FAFCHAMPS AND E. SADOULET (1991). Peasant Household Behaviour with Missing Markets: Some Paradoxes Explained. *The Economic Journal*, 101(409): 1400-1417. DOI: doi.org/10.2307/2234892

DE GRAAFF, J., KESSLER, A., OLSEN, P. (2010). Farm-level adoption of soil and water conservation measures and policy implications in Europe. *Land Use Policy* 27, 1–3. DOI: doi.org/10.1016/j.landusepol.2008.08.008

DIAO, X. AND NIN-PRATT, A. (2007). Growth options and poverty reduction in Ethiopia —an economy-wide model analysis. *Food Policy* 32 (2):205–228. DOI: doi.org/10.1016/j.foodpol.2006.05.005

EDMEADES, S. (2003). Variety Choice and Attribute Trade-Offs Within the Framework of Agricultural Household Models: The Case of Bananas in Uganda. A Ph.D. Dissertation, North Carolina State University.

FAO (Food and Agriculture Organization of the United Nations) (2009). Production yearbook. FAO, Rome, Italy http://faostat.fao.org/default.aspx.

FEDER, G., AND R. SLADE (1984). The Acquisition of Information and the Adoption of New Technology *American Journal of Agricultural Economics*, 66 (3): 312-320

FEDER, G., JUST, R. AND ZILBERMAN, D. (1985). Adoption of agricultural innovations in developing countries: a survey, *Economic Development and Cultural Change*, vol. 33, pp. 255–298. DOI: doi.org/10.1086/451461

FEDER, G. AND D. UMALI (1993). The Adoption of Agricultural Innovations: A Review. *Technological Forecasting and Social Change*, 43: 215-239. DOI: doi.org/10.1016/0040-1625(93)90053-A

FUFA, B. & HASSAN, R.M. (2006). Determinants of fertilizer use on maize in Eastern Ethiopia: A weighted Endogenous sampling analysis of the extent and intensity of adoption. *Agrekon*, 45 (1), 38-49. DOI: doi.org/10.1016/S0169-5150 (99)00028-6.

FOLTZ, J. & LANG, G. (2003). The adoption and impact of management-intensive rotational grazing (MIRG) on Connecticut dairy farms. *Renewable agriculture and food Systems*, 20 (4), 261–266. DOI: doi.org/10.1079/RAF2005127

FUENTE, S., NEGESSE, T. & LEGESSE, G. (2009). Feed Resources and Their Management Systems in Ethiopian Highlands: The Case of Umbulo Whaco Watershed In Southern Ethiopia. Tropical and subtropical agroecosystems, 12(1), 47-56.

GASS, G. M. AND SUMBERG, J.E. (1993). Intensification of livestock production in Africa: Experience and issues. Draft. Norwich: University of East Anglia.

GARCIA, O., BALIKOWA, D., KICONCO, D., NDAMBI, A. AND HEMME, T. (2008). Milk Production in Uganda: Dairy Farming Economics and Development Policy Impacts. IGAD LPI, Working Paper No. 09 – 08.

GEBREMEDHIN, B., AHMED, M. M., & EHUI, S. K. (2003). Determinants of adoption of improved forage technologies in Crop-livestock mixed systems: Evidence from the highlands of Ethiopia.

GEBREMEDHIN, B. & SWINTON, S. M. (2003). Investment in soil conservation in northern Ethiopia: the role of land tenure security and public programs. *Agricultural economics*, *29*(1), 69-84. DOI: doi.org/10.1111/j.1574-0862.2003.tb00148.x

GEBREMEDHIN, B., HIRPA, A., & BERHE, K. (2009). Feed marketing in Ethiopia: Results of rapid market appraisal (No. 15). Full text by ILRI.

GEBREYOHANNES, G. AND HAILEMARIAM, G. (2011) Challenges, opportunities and available good practices related to zero grazing in Tigray and Hararghe, Ethiopia. Drylands Coordination Group (DCG) Report No. 66.

GREENE, W.H. (2003) Econometric analysis, 4th ed. Prentice Hall, Upper Saddle River, New Jersey, USA.

GREENE, W.H. (2008). Econometric Analysis, 6th ed. New Jersey: Prentice Hall.

GUNTE, K. E. (2015). Understanding factors affecting technology adoption in smallholder livestock production systems in Ethiopia: the role of farm resources and the enabling environment (Doctoral dissertation, Wageningen: Wageningen University).

HALL, B.H. (1994). Time Series Processor Version 4.3 Reference Manual. TSP International, Palo Alto, CA.

HERRERO, M., THORNTON, P., NOTENBAERT, A., WOOD, S., MSANGI, S., FREEMAN, H., BOSSIO, D., DIXON, J., PETERS, M., VAN DE STEEG, J., LYNAM, J., RAO, P., MACMILLAN, S., GERARD, B., MCDERMOTT, J., SERE, C., AND ROSEGRANT, M. (2010). Smart investments in sustainable food production: Revisiting mixed crop–livestock systems. *Science* 327:822–825. DOI: doi.org/10.1126/science.1183725

HOGSET, H. (2005). Social Networks and Technology Adoption. Selected Paper, AAEA Annual Meetings, July 2005 Providence, RI.

HOLDEN, S., & SHIFERAW, B. (2004). Land degradation, drought and food security in a less-favored area in the Ethiopian highlands: a bioeconomic model with market imperfections. *Agricultural Economics*, 30(1), 31-49. DOI: doi.org/10.1111/j.1574-0862.2004.tb00174.x

HOLTLAND, G. (2007). The uneasy relationship between science and development, (May).

HUFFMAN, W.E. (1991). Agricultural Household Models: Survey and Critique, in Multiple Job- Holding among Farm Families in North America. Milton Hallberg, et al., ed., Iowa State University Press, pp. 79-111.

IFAD (2007). Livestock and range lands; livestock feeding [www page]. URL http://www.ifad.org/lrkm/theme/production/feeding.htm .

ILRI (International Livestock Research Institute) (2000). Policy for Sustainable Land Management in the Highlands of Ethiopia. May 22-23, 2000. Addis Ababa, Ethiopia. 20p.

ISHAM, J. T. (2000): A model of Technology Adoption with Social Capital. A Ph.D. Dissertation, University of Maryland.

KAAYA, H., BASHAASHA, B., AND MUTETIKKA, D. (2005). Determinants of utilization of artificial insemination (AI) services among Ugandan dairy farmers. African crop science conference proceedings, 7. Pp.561-567.

KALIBA, A. R., FEATHERSTONE, A. M., & NORMAN, D. W. (1997). A stall-feeding management for improved cattle in semi-arid central Tanzania: factors influencing adoption. *Agricultural Economics*, 17(2), 133-146. DOI: https://doi.org/10.1016/S0169-5150(97)00028-5

KASSAM, A., KUENEMAN, E., KEBE, B.,

OUEDRAOGO, S. and YOUDEOWEI, A. (2010). Enhancing Crop–Livestock Systems in Conservation Agriculture for Sustainable Production Intensification: A Farmer Discovery Process Going to Scale in Burkina Faso, Integrated Crop Management, vol. 7-2009, FAO, Rome

KIRUI, O. K., & MIRZABAEV, A. (2014). *Economics of land degradation in Eastern Africa* (No. 128). ZEF Working Paper Series.

KLITZING, A., DAS, A., BONZI, M., BARRO A., LANGKAMP, U., DEREJE, K., PALE, S., NAYAK, S., AND GUPTA, A. (2014). Promoting Best Practice in Agriculture: Examples from Burkina Faso, Ethiopia, India and Europe, Deutsche Welthungerhilfe e.V., Friedrich-Ebert-Straße 1, 53173 Bonn.

KRUSEMAN, G., RUBEN, R. and TESFAY, G. (2006). Village stratification for policy analysis: multiple development domains in the Ethiopian highlands of Tigray. In: Pender, J., Place, F., Ehui, S. (Eds.), Strategies for Sustainable Land Management in the East African Highlands. International Food Policy Research Institute, Washington, DC, pp. 81–106.

JALETA, M., KASSIE, M., AND SHIFERAW, B. (2013). Tradeoffs in crop residue utilization in mixed crop–livestock systems and implications for conservation agriculture. *Agricultural Systems* 121:96–105. DOI: doi.org/10.1016/j.agsy.2013.05.006

LAL, R., & STEWART, B. A. (2010). Food security and soil quality. Advances in soil science.

LENAERTS, L. (2013). Insights into Agency and Social Interactions in Natural Resource Management (Doctoral Dissertation, Wageningen University).

LONG & FREESE (2003). Regression Models for Categorical Dependent Variables Using Stata, Revised Edition,

MARRA, M., D.J. PANNELL, AND A. ABADI GHADIM (2003). The economics of risk, uncertainty, and learning in the adoption of new agricultural technologies: Where are we on the learning curve? *Agricultural Systems* 75(2- 3):215-234. DOI: doi.org/10.1016/S0308-521X(02)00066-5

MCFADDEN, D. (1981). Econometric models of probabilistic choice. In: Minsk, C.F., McFadden, D. (Eds.), Structural Analysis of Discrete Data with Econometric Applications. MIT Press, Cambridge, MA, pp. 198-272.

MCINTIRE, J. AND DEBRAH, S. (1987). Forage research in smallholder and pastoral production systems. In: Little, D.A., and Said, A.N. (eds) Proceedings of a workshop held at Ryall's Hotel, Blantyre, Malawi in September 1986. pp. 118–126. [International Livestock Centre for Africa (ILCA): Addis Ababa, Ethiopia].

MEKURIA, W., VELDKAMP, E., TILAHUN, M., & OLSCHEWSKI, R. (2011). Economic valuation of land restoration: The case of exclosures established on communal grazing lands in Tigray, Ethiopia. *Land Degradation & Development*, 22(3), 334-344. DOI: doi.org/10.1002/ldr.1001

MISRA, S.K., CARLEY, D.H. and FLETCHER, S.M. (1993). Factors influencing southern dairy farmer's choice of milk handlers. *J. Agric Appl. Econ.* 25 (July), 197-207. DOI: doi.org/10.1017/S1074070800018757

MUGISHA, J. AND D. NGAMBEKI (1994). Marketing System of the Uganda Banana Industry. *African Crop Science Conference Proceedings*, 1: 384-387.

MUYANGA, M. & JAYNE, T. S. (2014). Effects of rising rural population density on smallholder agriculture in Kenya. *Food Policy*, 48(0), 98-113. DOI: doi.org/10.1016/j.foodpol.2014.03.001

MUSABA, E. C. (2010). Analysis of factors influencing adoption of cattle management technologies by communal farmers in Northern Namibia. *Livestock Research for Rural Development*. Volume 22, Article #104. Retrieved December 12, 2015, from DOI: http://www.lrrd.org/lrrd22/6/musa22104.htm

NALUNKUUMA, J., AFFOGNON, H., KINGORI, S., SALIFU, D. & NJONGE, F. (2013). Adoption of zero grazing and impact on livestock keepers' knowledge of cattle reproductive parameters in Western Kenya. In *African Crop Science Conference Proceedings* (Vol. 11, pp. 599-604).

NEGASSA A., RASHID S., GEBREMEDHIN, B. AND KENNEDY, A. (2012). Chap. 6 "Livestock Production and Marketing" in Food and Agriculture in Ethiopia. Progress and Policy Challenges. Paul Dorosh and Shahidur Rashid Editors. PENN Press.

NYSSEN, J., DESCHEEMAEKER, K., NIGUSSIE HAREGEWEYN, M. H., DECKERS, J., & POESEN, J. (2007). Lessons learned from 10 years research on soil erosion and soil and water conservation in Tigray. Tigray Livelihood Papers No. 7, Mekelle: Zala-Date Project, Mekelle University, KU Leuven, Relief Society of Tigrai, Africa museum and Tigrai Bureau of Agriculture and Rural Development, 53 p. ISBN 978-90-8826-027-8.

PENDER, J. AND KERR, J. (1996). Determinants of farmer's indigenous soil and water conservation investments in India's semi-arid tropics. EPTD Discussion Paper No. 17. International Food Policy Research Institute, Washington Dc.

PENDER, J., PLACE, F. and EHUI, S. (2006). Strategies for Sustainable Land Management in the East African Highlands. International Food Policy Research Institute, Washington, DC.

ODAME, H., KIMENYE, L., KABUTHA, C., ALEMU, D. AND ODUORI, L.H. (2013). Why the low adoption of agricultural technologies in Eastern and Central Africa? ASARECA (Association for Strengthening Agricultural Research in Eastern and Central Africa), Entebbe.

OMAMO, S.W., DIAO, X., WOOD, S., CHAMBERLIN, J., YOU, L., BENIN, S., WOOD-SICHRA U. AND TATWANGIRE, A. (2006). Strategic Priorities for Agricultural Development in East and Central Africa," Research Report 150. Washington, DC: International Food Policy Research Institute (IFPRI).

RYSCHAWY, J., CHOISIS, N., CHOISIS, J., JOANNON, A. AND GIBON, A. (2012). Mixed crop–livestock systems: An economic and environmental-friendly way of farming? *Animal* 6:1722–1730. DOI: doi.org/10.1017/S1751731112000675

SADOULET, E. AND DEJANVRY A. (1995). Quantitative Development Policy Analysis. The John Hopkins University Press Baltimore and London.

SHAPIRO, D. (1990). Farm size, household size and composition and women contribution in agriculture:

evidence from Zaire. *J.Dev. Studies* 27 (October), 1-21. DOI: doi.org/10.1080/00220389008422179

SHIFERAW, B. AND HOLDEN, S. (1998). Resource Degradation and Adoption of Land Conservation Technologies in the Ethiopian Highlands: A case Study in Andit Tid, North Shewa. *Agricultural Economics*, 18: 233-247. DOI: https://doi.org/10.1016/S0169-5150(98)00036-X

SINGH, I., SQUIRE, L. AND STRAUSS, J. (1986). Agricultural Household Models. Extension, Applications and Policy. The Johns Hopkins University Press Baltimore, Maryland 21211, USA.

SMALE, M AND HEISEY, P. W. (1993). Simultaneous Estimation of Seed and Fertilizer Adoption Decisions: An Application to Hybrid Maize in Malawi. Technological Forecasting and Social Change, 43: 35-368. DOI: doi.org/10.1016/0040-1625(93)90061-B

SMALE, M., JUST, R.E. and LEATHERS, H.D. (1994). Land allocation in HYV adoption models: an investigation of alternative explanations. *Am. J. Agric. Econ.* 76 (August), 535-547. DOI: doi.org/10.2307/1243664

STAAL, S.J., WAITHAKA, M., NJOROGE, L., MWANGI, D.M., NJUBI, D. AND WOKABI, A. (2003). Costs of milk production in Kenya: Estimates from Kiambu, Nakuru and Nyandarua districts. SDP Research and Development, Report No.1 Smallholder Dairy (R& D) Project.

TSE, Y. K. (1987). A diagnostic test for the multinomial logit model. *Journal of Business & Economic Statistics*, 5(2), 283-286.

TURINAWE, A., MUGISHA, J., & KABIRIZIBI, J. (2011). Socio-Economic Evaluation of Improved Forage Technologies in Smallholder Dairy Cattle Farming Systems in Uganda. *Journal of Agricultural Science*, 4(3), 163–174. DOI: doi.org/10.5539/jas.v4n3p163

USAID (2013). Climate change and natural resource management. Addis Ababa: USAID. Retrieved from http://www.usaid.gov/ethiopia/environment

WINSTON, J. R., PARSONS, R. L. & G.D. HANSON (2000). A profitability analysis of dairy feeding systems in the Northeast. *Agricultural and resource economics review*, 29, 220–228. DOI: doi.org/10.1017/S1068280500005359

WÜNSCHER, T., SCHULTZE-KRAFT, R., PETERS, M. & RIVAS, L. (2004). Early adoption of the tropical forage legume Arachis Pintoi in Huetar Norte, Costa Rica. *Experimental agriculture*, 40, 257–268. DOI: doi.org/10.1017/S0014479703001583

YESUF, M., DI FALCO, S., DERESSA, T., RINGLER, C., & KOHLIN, G. (2008). The impact of climate change and adaptation on food production in low-income countries: evidence from the Nile Basin, Ethiopia. Free downloads from IFPRI.

YILMA, Z., GUERNEBLEICH, E., SEBSIBE, A., & FOMBAD, R. (2011). A review of the Ethiopian dairy sector. Addis Ababa, Ethiopia: FAO Sub-Regional Office for Eastern Africa (FAO/SFE)

APPENDIX

Essentially, farmers face different constraints and so choose among technologies in order to maximize their profit. For simplicity, there are two types of farmers in the model, traditional farmers who use a traditional technology such as free grazing or local cow, and those with an improved technology such as access to stall feeding or breed cow. The use of the improved technology requires extra variable cost for feed including transports $(P + s_s)$ and fixed cost (D) which enhances the productivity of modern farming. By making technology choices, farmers switch from traditional to more modern farming if the payoffs from switching exceed the costs of adopting the new technology. Assuming there is one period with two stages, each farmer independently decides whether to pay the costs and adopt the technology, or remain with the traditional technology. Then in the second stage each farmer determines how much to produce and how much of this output to sell in a market (or to consume domestically).

For simplicity, the household is assumed to derive utility from the consumption of animal products (x^m) such as milk and milk product, meat, manure and drought power; other purchased goods(x^o), and home time(h). Household utility is affected by a vector of exogenous household characteristics (Λ_h), such as human capital, age, and household size and village characteristics (Λ_v) including rainfall and agro ecology location that condition household consumption decisions (Eq.8).

$$\max_{\psi} U[x^m, x^o, h; \Lambda_h, \Lambda_v] \qquad (8)$$

Where Λ_h include factors that influence the marginal utilities of the consumption items to reflect his consumption preferences. Maximization of this equation subject to cash income, time and technology constraint gives demand equations for the improved feeding (F)or breed cow and share allocation to these technologies. Households in LDC mainly engages in animal production for home consumption but a surplus may be sold on the market. Variable inputs used in the production of animal (q^m) are mainly labour(L), crop residue from straw and green grass from free grazing (R) and improved feed (F) on the number of animals $(\bar{C})$ for given farm (Λ_f), household (Λ_h), and village (Λ_v) characteristic. The production output is assumed to be strictly increasing in variable inputs but at a decreasing rate for a given number of animals $(\bar{C})$, farm characteristics (Λ_f).However, farmers may produce this output under two alternative practices: Modern farming (f^m) and traditional farming (f^t).

Modern farming (f^m)

f^m utilizes labour (L), crop residue $R(S)$ and improved feed (F) such as mixed fodder, residual brew, salt and, bi-products given the number of animals (C^m)allocated to this farm production. The population pressure (S) reduces the availability of R in the farm production by reducing crop and grazing lands (**Muyanga & Jayne, 2014**) so that the population pressure (S) should be incorporated into the production technology implicitly, not as a shifter of the

production function. Feed production R and its use is driven by rise in population and income, which increase demand for animal product and thus the demand for feeds. f^m is assumed to be superior to that of f^t, however, requires additional resources such as cash income to hire labour or buy and transport the extra feed and construct shelter which causes the farmer to incur some variable and fixed costs (in terms of time or money). Farm output under (f^m) may be defined as Eq.9.

$$q^m = f^m\left(C^m, L, R(S), F; \Lambda_f, \Lambda_h, \Lambda_v\right) \quad (9)$$

Traditional farming (f^t)

Unlike the modern farming, the traditional farmer under f^tuses only labour(L) , crop residue R(S) given the number of animals (C^t) allocated to this farm production but does not depend on the improved feed (F). Its equation looks like:

$$q^t = f^t\left(C^t, L, R(S); \Lambda_f, \Lambda_h, \Lambda_v\right) \quad (10)$$

Total Farming

The household can choose to manage its production farming with (f^m) or with (f^t)since the two technologies compete for the same number of animals ($C^m + C^t = \bar{C}$) or the farmer has an option to allocate some number of animals to $f^m$and the remainder of them to f^t. For simplicity, if the share of animals the farmer allocates to the f^m is represented by (δ) and ranges from 0 to 1,then it can be equal to 0 when no animal is reared under f^m (i.e., $C^m = 0$) and equals 1 when all animals are reared under f^m(i.e.$C^m = \bar{C}$). Given a binding number of animals constraint ($\bar{C}$), the total farm output produced by the farmer is given by Eq. 11.

$$Q^A = f^m\left(\delta, L, R(S), F; \Lambda_f, \Lambda_h, \Lambda_v\right) + f^t\left(1 - \delta, L, R(S); \Lambda_f, \Lambda_h, \Lambda_v\right) + \varepsilon_i \quad (11)$$

The inclusion of the random variable,$\varepsilon_i$captures the idea that farm production is subject to exogenous risk factors associated with the uncertainty of weather conditions but farmers are assumed to be risk-neutral with respect to the new technology. Therefore the choice of the farming technology is based on expected output. In LDC, households face a bundle of constraints: in the presence of incomplete markets. Farmers may have an exogenous income (E) obtained from networked relatives or safety net which enables them to overcome the cash constraints that impede the new technology adoption. Thus, the full income constraint to the household is expressed as the market value of the marketed surplus $P^m(Q^m - x^m)$ including the exogenous income E but excluding off farm wage because its value is insignificant. Then, this income is spent on purchasing other goods (x^o) consumed by the household at market prices(P^o), inputs (F) at a price of P_s with transport cost s ($P_s + s$)and input (R) at a price of P_r(P_r) including fixed cost of shelter construction and other farm tools(D) as well as labour wage (W) (Eq.12).

$$P^m(Q^A - x^m) + E - P^o x^o - WL - P_r R - (P_s + s)F - D = 0 \quad (12)$$

The difference between the modern and traditional farming lies on the value of, $(P_s + s)F + D$ term which is the value of extra feed and fixed cost incurred by the modern farmer. Each household has an initial endowment of time allocated between farm production (L) and leisure(h) that is $T = L+h$. Then, the objective of the farm household is to maximize utility from the consumption of goods and leisure subject to the farm production, income, and time constraint, given η, λ and μ as the Lagrange multipliers of the income, production and the time constraints (Eq.13).

$$\max_{\psi} E[x^m, x^o, h; \Lambda_h, \Lambda_v] \quad (13)$$

Where:

$\psi = (x^m, x^o, h, L, R, \mathrm{F}, \delta)$

subject to

Full income constraint: $P^m(Q^A - x^m) + E - P^o x^o - WL - P_r R - (P_s + s)\mathrm{F} - D = 0$

Production technology:

$\mathrm{G}\left[f^m\left(\delta, L, R(S), F; \Lambda_f, \Lambda_h, \Lambda_v\right) + f^t\left(1 - \delta, \mathrm{L}, R(S); \Lambda_f\ , \Lambda_h, \Lambda_v\right) + \varepsilon_i\right]$

Time constraint: $\mathrm{T} = \mathrm{L}+h$

Non-negativity restriction: $\mathrm{F}, R, \delta, \mathrm{L} \geq 0$

An interior solution is expected on the consumption side. However, the utility derived from the use of the farming technology may vary among households and the corner solution is possible for some households indicating that the first-order necessary conditions are derived based on the assumption that an interior solution will hold for some choices but not for others. For instance, it is assumed that every household will consume animal output, other goods and leisure time. Using Kuhn-Tucker conditions, the derivatives of optimal choices of farming technology are derived as Eq.13.1-13.10.

First-order condition

$$x^m: \frac{\partial U(.)}{\partial x^m} - \eta P^m = 0 \quad (13.1)$$

$$x^o: \frac{\partial U(.)}{\partial x^o} - \eta P^o = 0 \quad (13.2)$$

$$h: \frac{\partial U(.)}{\partial h} - \mu = 0 \quad (13.3)$$

$$L: \lambda \frac{\partial G(.)}{\partial L} - \eta W - \mu = 0 \quad (13.4)$$

$$R: \lambda\left(\frac{\partial G(.)}{\partial R} * \frac{\partial R}{\partial S}\right) - \eta P_r = 0 \quad (13.5)$$

$$F: \lambda\left(\frac{\partial G(.)}{\partial f^m}\frac{\partial f^m}{\partial F}\right) - \eta(P_s + s) \leq 0; F \geq 0 \quad (13.6)$$

$$\delta: \lambda\left(\frac{\partial G(.)}{\partial f^m}\frac{\partial f^m}{\partial \delta} - \frac{\partial G(.)}{\partial f^t}\frac{\partial f^t}{\partial \delta}\right) \leq 0; \quad \delta \geq 0 \quad (13.7)$$

$$\eta: P^m(Q^A - x^m) + E - P^o x^o - WL - P_r R - (P_s + s)F - D = 0 \quad (13.8)$$

$$\lambda: G\left[f^m\left(\delta, L, R(S), F; \Lambda_f, \Lambda_h, \Lambda_v\right) + f^t\left(1 - \delta, L, R(S); \Lambda_f, \Lambda_h, \Lambda_v\right)\right] \quad (13.9)$$

$$\mu: T - L - h = 0 \quad (13.10)$$

Dividing Equations 13.4 by 13.3 gives the marginal rate of substitution between work and leisure which shows a possible solution regarding the choice of labour allocation by the household:

$$MRS_{L,h} = \frac{\partial G(.)}{\partial L} / \frac{\partial U(.)}{\partial h} = \frac{\eta W + \mu}{\mu\lambda} = \mathrm{w}^* \quad (14)$$

By equating the rate of technical substitution of labour used in farm production for leisure to the marginal valuation of labour, ($\eta W + \mu / \mu\lambda$) gives the price ($w^*$) of labour where W is off farm wage within the village. However, looking into equations (13.6) and (13.7), the solution of the optimization problem consists of two related decisions: the decision regarding whether or not to adopt new technology and the decision regarding the extent of animals treated under this technology, given that the optimal solution in equation (13.6) holds with equality. Thus, the modern input (F) will be used and the household will equate the marginal valuation of this input to production to its price plus transport cost. But, if the cost of input (F) is greater than its marginal valuation, the household will be unwilling to adopt the input (F) so that the observed demand of the input (F) will be censored at zero and this happens when the optimal solution in (13.6) holds with inequality, and its first order condition can also be defined by Eq. 15.

$$\frac{\partial G(.)}{\partial f^m}\frac{\partial f^m}{\partial F} < \frac{\eta(P_s + s)}{\lambda} = M^*; \; F = 0 \quad (15)$$

The two sequential decisions whether to use input (F) or not and allocate some animals to f^m reveal that the optimal solution in equation (13.7) is conditional on the optimal solution in equation (13.6). This implies that the optimal solution in (13.7) holds with inequality when the optimal solution in equation (13.6) also holds with inequality, thereby no animal will not be allocated to the modern technology, indicating that the expected gain from the traditional farming f^t exceeds the expected gain derived from the modern technology f^m (Eq. 16).

$$E(P^m f^t) > E(P^m f^m + P^m f^t) - M^* F - D \quad (16)$$

This assumes that price of output (P^m) and price of input F (P_s) may be exogenous for households who participate in the local market. Thus, the optimal share allocated to (f^m)is determined by equating the marginal net benefit in both farming technologies. Depending on the first-order conditions, demand equations for the modern feed (F) and share allocation (δ) to the modern farming (Eq. 17).

$$F^* = F\left(P^m, P_s, P_r, W, S, D, \Lambda_f, \Lambda_h, \Lambda_v\right)$$
$$\delta^* | F > 0 = \delta\left(P^m, P_s, P_r, W, S, D, \Lambda_f, \Lambda_h, \Lambda_v\right) \quad (17)$$

From this, we expect that adoption of modern feeding and breed cow is discouraged when the cost of adoption $\left((P_s + s)F + D\right)$ increases that is, $\frac{\partial f^m}{\partial F} < 0$ *and* $\frac{\partial f^m}{\partial \delta} = 0$, thereby reducing farm output, $\frac{\partial G(.)}{\partial f^m} < 0$ so that farmers will remain with the traditional free grazing or local cow. We also predict that population pressure leads to adoption of modern feeding and breed when the effect on the crop residue and grazing land is negative that is, $\frac{\partial f^m}{\partial S} > 0$ when $\frac{\partial R}{\partial S} < 0$