A stall-feeding management for improved cattle in semiarid central Tanzania: factors influencing adoption

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Abstract

This study's objectives were to determine factors influencing smallholder farmers' adoption of a stall-feeding management system for improved dairy cattle in semiarid Tanzania and other related technology packages. Heckman's two-stage procedure was used to determine factors influencing participation in the project and the adoption of recommended management practices. Stall-feeding technology is particularly attractive to those households with fewer resources particularly those that are female headed. Wealthier farmers, as measured by area of land cultivated, are less likely to adopt the stall-feeding technology. Household labour is found to be important in determining the degree to which the technology and associated management practices were adopted. Age of the household head has a positive impact on the size of the intensive feed gardens. Different measures of extension-related contact are significant in influencing the potential for adopting stall-fed technology, the number of stall-fed cattle kept, the probability of growing water melons, and the size of intensive feed gardens. The implications are that research and extension messages with reference to the stall-feeding management system need to be targeted to specific types of households (e.g., female farmers, those with children to provide labor, and limited resource farms). This supports the notion that technology development and dissemination need to be sensitive not only to the characteristics of the biophysical environment but also to the socioeconomic environment, which is often neglected. The study also demonstrates that in the poorer parts of the world where land is very limited, a strategy for improving ecological sustainability can be linked closely to one for increasing agricultural productivity. © 1997 Elsevier Science B.V.

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1. Introduction

Central Tanzania comprises the Dodoma and Singida administrative regions, which are semiarid and situated in a zone of livestock/sorghum-millet farming systems. The growth of human and livestock populations and factors such as rainfall patterns, soil characteristics, and undulating topography, coupled with man-induced factors such as wild bush fires, deforestation, and other agricultural practices have precipitated the breakdown of the traditional bush fallow system that ensured sustainable yield and food supply. The results have been serious soil erosion and environmental degradation. Small-scale dairy farming, under the stall-feeding management system, is being developed currently in the area as a means of increasing farming system productivity, while at the same time ensuring environmental protection. The farming system research and extension (FSR/E) methodology (Norman et al., 1995) is used in the research and extension process.

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The project was concentrated initially in the Dodoma Region Soil Conservation Project (HADO). The HADO project was initiated in 1972 with major objectives of boosting crop yields and livestock production, while also conserving soil. The project was concerned initially with arresting the accelerating soil erosion and land degradation caused by human and livestock population pressure on land. The plan was to achieve this through physical and mechanical measures for soil conservation and tree planting.

A review of the project in 1978 showed that the physical and mechanical conservation measures were unsatisfactory because they were slow and costly, and soils were not fertile enough to allow rapid regeneration of vegetation. A decision was made in 1979 to close the most severely eroded areas to all ruminants to reduce the pressure on land. This area included the Irangi Highlands (1256 km^2), commonly called the Kondoa Eroded Area (KEA); Mvumi (713 km^2), a division in the Dodoma District; and some villages in Mpwapwa District. Animals were moved from these areas to others where livestock density was relatively low. A total of 46,370 cattle, 10,666 sheep, and 28,840 goats were removed from KEA, and 30,991 cattle, 8352 sheep, and 25,042 goats were removed from the Mvumi district (Anonymous, 1987). Boundaries were set by the government, and no ruminant was allowed to enter and graze or pass through the HADO-designated areas.

Diagnostic and follow-up surveys conducted in Berege village, KEA, and some villages in Mvumi Division under the HADO project (SAREC/HADO Project, 1988–1989) indicated that human nutritional problems resulted after livestock removal from these areas. This was due mainly to milk deprivation, especially for mothers and children. Crop yield also declined because of lack of manure. Also, poverty increased with the removal of animals, which were the major sources of income. Reintroduction of livestock in the HADO-designated areas was suggested as a way to address this problem.

Taking into account the problems facing the livestock subsector identified during the diagnostic surveys, the basic technical components suggested were: introduction of improved cattle under the stall-feeding management system for high milk production, establishment of pastures and fodder trees under intensive feed gardens for forage production, effi-

cient use of crop residues and utilisation of locally available non-conventional feed resources for dry-season feeding, effective routine disease control measures, good husbandry management practices, and the use of animal power for cultivation and transportation. It was also recommended that farmers continue the traditional practice of growing wild bitter water melon (*Citrullus vulgaris*) as a water substitute and protein supplement.

This study was designed to determine the factors that influence farmers' (farm households') participation in raising improved dairy cattle, use of the stall-feeding management system, and adoption of associated improved management practices.

2. Conceptualisation of adoption

Feder et al. (1985) define adoption as the degree to which a new technology is used in long-run equilibrium when farmers have complete information about the technology and its potential. Therefore, adoption at the farm level indicate farmers' decisions to use a new technology in the production process. On the other hand, aggregate adoption is defined as the process of diffusion of a new technology within the region.

Adoption at the farm level often is quantified using a binary variable (adoption of cattle stall-feeding = 1, non-adoption = 0). In the case of a divisible technology, a continuous variable describing the intensity of adoption (e.g., hectares devoted to a new technology or number of livestock under a new treatment) or extent of adoption (e.g., share of land or percentage of the livestock herd devoted to a new technology) often are used. Yaron et al. (1992) suggest other variables, including when the technology was first used by the farmer, how well the technology was adopted, the number of technical components from the recommended package adopted, and an index of innovativeness that aggregates the characteristics mentioned above.

Factors influencing adoption of new agricultural innovations sometimes are divided into three major categories: farm and farmers' associated attributes; technology attributes (Adesina and Zinnah, 1992; Misra et al., 1993); and the farming objective. In the first category, factors include human capital represented by the level of education of the farmer (Whar-

ton, 1963; Huffman, 1977; Rahm and Huffman, 1984); risk and risk management strategies (Feder, 1980; Saha et al., 1994); the institutional support system, such as marketing facilities, research and extension services, transportation (Feder, 1980); availability of production factors; factor endowment, such as farm size, number of livestock owned (Feder et al., 1985; Rahm and Huffman, 1984), and the level of off-farm income and income sources (Vankateswar and Fideis, 1988; Yaron et al., 1992; Heisey and Mwangi, 1993; Kimhi, 1994).

The second and third categories discussed above depend on the type of technology and are important when farmers have access to different types of technical innovation (e.g., different types of crop varieties) with differences in production characteristics and performance or when dealing with heterogeneous farmers with different farming objectives (e.g., small and larger farmers, subsistence versus market-oriented farmers). Therefore, the influence of each exogenous variable on adoption responses is unique and specific to the study area. These characteristics make adoption studies site-specific and often incomparable.

3. Empirical model development

Assuming that farmers participating in stall feeding have objectives other than profit maximisation, their choice to participate can be based on the random utility maximisation model as developed by McFadden (1981). We follow the implementation of the random utility maximisation model used by Misra et al. (1993) and Adesina and Zinnah (1992). This results in the estimation of the following model:

If $X_i \beta + \varepsilon_{ji} > h$, then $Y_i = 1$,

If $X_i \beta + \varepsilon_{ji} \leq h$, then $Y_i = 0$,

where Y_i is the probability of the adoption of some of the technical components contained in a recommended package in a zero one situation, and h is a threshold level that can take a value of zero. Alternatively, Y_i could be a censored variable representing the intensity of adoption of a particular technical package. The commonly used method to estimate asymptotically efficient parameters for the β vector

that maximises the log-likelihood function is either the probit (zero one) or tobit (censored) model (Feder et al., 1985; Shapiro, 1990).

However, most development projects recommend technical innovations in the form of a package. The choice to adopt one component entails adoption of some other basic management practices that complement each other. In such cases, two or more adoption equations are estimated, and the error term of these equations may be correlated. That is, correlation may exist along unobserved personal and farm attributes and across equations. In order to exploit all available information and to provide the most efficient estimator possible, the equations are estimated jointly to correct for correlation among the equation's error terms (Kimhi, 1994; Yaron et al., 1992).

Saha et al. (1994) and Smale et al. (1994) suggest the use of sample selection or Heckman's two-stage procedures which use non-random subsample respondents. In this framework, the individual's adoption intensity is conditional on the decision to adopt another technology and information as they learn by doing. Heckman's two-stage procedure is specified by:

$$Y_{1i} = X_1 \beta_1 + \varepsilon_1$$
$$Y_{1i} = 1 \qquad \text{if } X_i \beta_1 + \varepsilon_1 > h$$
$$\quad = 0 \qquad \text{if } X_1 \beta_1 + \varepsilon_1 \leq h$$
$$Y_{2i} = X_2 \beta_2 + \varepsilon_2 \quad \text{if } Y_{1i} = 1$$
$$\text{Var}(\varepsilon_1) = 1 \qquad \text{Var}(\varepsilon_2) = \sigma^2$$
$$\text{Corr}(\varepsilon_1, \varepsilon_2) = \rho$$

where Y_{2i} in the second equation is observed when Y_{1i} is equal to one. Therefore, the second-stage equation utilises the subsample of farmers that use the stall-feeding system. The second-stage equation in our study is an OLS equation to model the number of improved cattle which are stall-fed. The second-stage equation is also reestimated where Y_{2i} is the adoption of and the size of an intensive feed garden. The intensive feed garden is a censored variable and will be estimated using tobit. The number of stall-fed cattle could be modelled using a standard tobit model. However, the intensive feed garden is a nonlinear model. Hall (1994) notes that the sample selection procedure that attempts to solve the two equations simultaneously does not guarantee convergence, es-

pecially when the system of equations has the same matrix formulation or when the second-stage equation is nonlinear. For those cases, Heckman's two-stage procedure is suggested, which allows for a probit equation to be estimated using information from the whole sample (participants and nonparticipants) and the inverse mills (@MILLS) ratio computed from fitted values. In the second stage, equations are estimated with the calculated inverse mills ratio function from the probit residuals as an exogenous variable. This procedure not only guarantees convergence, but the inverse mills ratio is a proxy for omitted nonlinear functions of the right-hand side variables. When the second-stage equation is linear, the estimated standard errors of the coefficients are not consistent estimates (Greene, 1993, p. 709). This problem is avoided by computing heteroskedastic-consistent standard errors (Hall, 1994).

4. Models estimated

Adoption and intensity of adoption are the endogenous variables in the empirical models. Farmers' and farm-specific characteristics are the exogenous variables. Farmers in the study area have limited choices on how to manage improved cattle and are assumed to be relatively homogeneous across clusters. Factors influencing both participation and adoption of the management practices are analysed at the farm household level.

Four models are estimated using the endogenous variables defined in Table 1. Two models estimated the probabilities of adopting cattle stall-feeding (which is reserved for improved cattle) and growing bitter water melon for cattle feeding. Two second-stage models measure the intensity of adoption: the number of livestock units owned by the farmer under the stall-feeding management system and acres of

intensive feed garden owned by the farmer. Heckman's two-stage procedure was used to estimate both adoption and intensity of adoption. Probit models were used to estimate the equations reflecting the probabilities of adopting the stall-feeding technology and growing bitter water melon. The inverse mills ratio function for estimation of the probability of adopting stall-feeding was computed and used as a regressor for the models involving the number of cattle under stall-feeding and the size of the intensive feed gardens. Only those farmers who use the stall-feeding technology have observations on the number of cattle under stall feeding and the size of the intensive feed garden. The second-stage models are conditional on the adoption of the stall-fed technology and include the inverse mills ratio calculated from the probit model explaining the adoption of the stall-feeding technology. Exogenous variables used to explain adoption, together with the rationale for their inclusion, are in Table 2 The variables can be placed in three groups, namely those relating to the characteristics of the household head, those reflecting the resources available to the household, and those that are determined externally.

The models involving the probabilities of adopting the stall-feeding technology and growing bitter water melon use all the sample households (i.e., 234), whereas the models involving the number of cattle under stall feeding and the size of the intensive feed gardens use the subsample of farmers utilising the cattle stall-feeding technology (i.e., 78). The farmers' decision to participate in the project and number of cattle to keep under such a system and/or size of intensive feed garden to establish are discrete decisions but are correlated to each other. That is, farmers make the decision to participate in the stall-feeding project and later make decisions on the number of cattle or the size of the feed garden. These

Table 1
Definition of exogenous variables used in the regression models

Endogenous variable	Measurement
Probability of adoption of cattle stall feeding	1 = Adoption; 0 = Non-adoption
Probability of growing bitter water melon for cattle feeding	1 = Adoption; 0 = Non-adoption
Improved cattle under stall-feeding management system correlated with the adoption of cattle stall feeding	Number
Intensive-feed gardens (censored variable at zero) correlated with the adoption of cattle stall feeding	Acres

Table 2
Rationalisation of the exogenous variables in the regression models

Independent variable	Measurement	Ho sign	Justification
Household head characteristics			
Sex[a]	1 = Male	+	Female farmers, who are usually poor,
	2 = Female		more willing to participate in the project
			to increase their income.
Age	Yrs	−	Within age range of sample, older farmers
			are more resistant to change.
Education	1 = Illiterate	+	Education increases adoption by giving
	2 = Informal		the farmer more ability to evaluate
	3 = Formal		alternatives.
Household resources			
Labour:			
Adult		±	Custom dictates how farming activities are
Male	Number		divided by age and gender. Thus
Female	Number		influence will vary according to activity
Children (10–17 yrs)			required to adopt technology
Male	Number		
Female	Number		
Other		−	Variables represent proxies for wealth.
Land	Acres		activity required to adopt technology.
Indigenous cattle	Number		decrease interest in technologies being
			offered
External influences			
Extension contact		+	Extension contact with improved
Frequency	1 = None		information has positive impact on
	2 = Sometimes		adoption.
	3 = Frequently		
Field day attendance	Number		
Seminar attendance	Number		
Geographical location[b,c]	1 = Yes	±	The signs depend on the interaction of
Dodoma	0 = No		farm characteristics, institutional support,
Mpwapwa			and the environment.
Kondoa			

[a] The binary variables of 1 and 2 were used instead of 1 and 0 as suggested by Greene (1993). When creating binary regressor variables, Greene suggests that they should not be identical, or nearly so, to the dependent variable.
[b] Singida was omitted to avoid perfect collinearity.
[c] The four districts also reflect differences in ethnic origin.

decisions are made after acquiring additional information and gaining experience with the stall-feeding technology. Farmers who decide not to participate may lack the additional information and experience about the technology. Most of the information from research and extension is directed towards participating farmers. The inclusion of nonparticipating farmers in the second-stage equations would incorrectly assume that both decisions (i.e., participation and number of cattle and size of intensive feed garden to

establish) are made simultaneously and both groups of farmers have equal knowledge about the technology. Therefore, the second-stage equation of the sample selection procedure for the number of cattle under stall feeding and the size of the intensive-feed gardens covers participating farmers only. Although ordinary least squares was used to estimate the number of cattle under the stall-feeding model, the tobit model was used to estimate the size of intensive-feed gardens because all participating farmers had im-

Table 3
Sample households' characteristics in Central Tanzania, July 1993[a]

Variables		Sample	Dodoma	Mpwapwa	Kondoa	Singida
Endogenous variables						
Growing bitter water melon (%)						
Yes		35.90	43.33	37.93	3.45	60.71
No		64.10	56.67	62.07	96.55	39.29
Improved cattle (number)[b]		2.26 (1.24)	2.50 (0.76)	3.40 (1.54)	2.16 (0.90)	1.37 (0.60)
Intensive feed garden (acres)[b]		0.48 (0.56)	0.39 (0.50)	0.93 (0.65)	0.20 (0.21)	0.41 (0.51)
Household head characteristics						
Sex (%)	Male	91.88	81.67	93.33	93.10	94.46
	Female	8.12	18.33	6.67	6.90	5.54
Age (yrs)		47.47 (14.16)	53.95 (10.00)	44.85 (15.90)	50.29 (14.51)	40.43 (11.86)
Education (%)	Illiterate	21.37	38.33	21.67	17.24	7.14
	Informal	18.38	30.00	15.00	18.97	8.93
	Formal	60.25	31.67	63.33	63.79	83.93
Household resources						
Labour (number)						
Adults	Male	1.58 (1.01)	1.58 (1.22)	1.75 (1.08)	1.53 (0.90)	1.43 (0.76)
	Female	1.76 (1.44)	2.22 (1.91)	1.95 (1.79)	1.38 (0.59)	1.45 (0.74)
Children	Male	0.84 (0.97)	0.80 (0.67)	1.03 (1.23)	0.91 (1.01)	0.59 (0.83)
	Female	0.82 (1.07)	1.02 (0.98)	0.97 (1.40)	0.60 (0.79)	0.69 (0.97)
Other	Cultivated land (acres)	9.16 (6.28)	6.90 (3.38)	15.72 (7.96)	6.99 (3.35)	6.82 (3.45)
	Indigenous cattle (number)	5.99 (12.52)	1.42 (4.94)	12.48 (21.26)	2.74 (3.45)	7.30 (7.74)
External influences						
Extension contact						
Frequency (%)						
	None	11.11	11.67	11.67	5.17	16.07
	Sometimes	47.01	47.67	56.67	44.83	39.29
	Frequent	41.88	40.66	31.66	50.00	44.64
Field day attendance (number)		0.55 (0.82)	0.23 (0.49)	0.75 (0.95)	0.53 (0.80)	0.66 (0.90)
Seminar attendance (number)		0.44 (0.72)	0.65 (0.92)	0.38 (0.64)	0.28 (0.56)	0.43 (0.66)
Sample size (number)						
Adopters		78	20	20	19	19
Nonadopters		156	40	40	38	38

[a]Figures in brackets are standard deviations.
[b]Average for only farmers participating in the stall-feeding technology.

proved animals but not all participating farmers had intensive-feed gardens.

5. Data

Data for this study were obtained through a formal survey conducted by the primary author in four clusters in Central Tanzania during 1993. The clusters reflect the four basic agroclimatic conditions of the area and each cluster was ethnically homogeneous. First, a village that participated in the improved cattle stall-feeding project before 1990 was identified and acted as a nucleus for the survey. Then, two other nearby villages were identified, and the three villages formed a cluster. A total of 240 farmers (i.e., heads of farming households) was interviewed using a structured questionnaire; the sample from each cluster consisted of 20 farmers practising stall feeding, and 40 farmers who had not adopted the practice. Farmers were selected randomly, and the respondent was the household head. Six responses were not used in the analysis because of inconsistent responses.

The means for the sample households are summarised in Table 3. Participating farmers had on average 2.3 improved cattle under stall-feeding management, and intensive feed gardens were limited to about half an acre. Major differences occurred across districts in the percentage of households growing bitter water melon, with relatively little emphasis on this in Kondoa. Female-headed households were relatively more common in Dodoma, and the percentage of household heads who were educated formally were relatively high in Singida. In terms of household resources, little difference occurred in the availability of household labour, but major differences occurred in the areas cultivated and numbers of indigenous (zebu type) cattle, with households in Mpwapwa having higher levels of both compared to the other districts. Although about 11% of all household heads had no contact with the extension service, in aggregate, major differences did not occur across areas. However, some differences existed between the areas in specific extension initiatives (e.g., attendance at fields in Dodoma was relatively low, as was seminar attendance in Kondoa).

6. Results and discussion

6.1. Participation in stall-feeding projects for improved cattle

The results from the probit model explaining the adoption of stall-feeding technologies for improved cattle correctly predicted 84.2% of the responses (Table 4) . The χ^2 for the log likelihood test of the hypothesis that the regressors included in the model have zero influence on farmers' participation (i.e., $\beta_i = 0$) was significant at the 0.01 probability level. Thus, the hypothesis that the variables have no explanatory power was rejected.

The results suggest that variables relating to household head characteristics, resources possessed by household, and external influences all significantly influence participation in stall-feeding for improved cattle (Table 4).

As anticipated, female-headed households were more likely to participate; the probability of female farmers participating was 27.5% higher than the probability for male farmers. In terms of household resources, an additional male child in the household increased the probability of participation by 5.2%. Female-headed households usually tend to be poor, and the availability of projects supporting the adoption of the stall-feeding technology gives them an opportunity to acquire assets and earn income. Male children are important in routine activities of feed collection, harvesting, transportation, and crop residue storage. Availability of male children helps ensure that the household has enough labour not only to feed stall-fed cattle, but also to facilitate the traditional, free-range, grazing system for zebu cattle. The children provide a major supervisory function by ensuring the herd gets enough feed and water. As anticipated, households cultivating larger acreages were less likely to participate in cattle stall feeding, because they had less need to look for alternative sources of income. An increase in one acre of land reduced the probability of participation by 1.7%.

Turning to external influences, the extension service had a significant impact on the probability of adopting the stall-feeding technology. Increasing the frequency and number of extension service seminars attended by the household head increased the probability of participation by 14.6% and 22.1%, respec-

Table 4
Estimated probit model for participation in cattle stall feeding

Variable			Estimated coefficient	Asymptotic standard errors	$\partial P(.)/\partial X^{a}$
Intercept			−4.317	0.927	−0.997
Household head characteristics					
Sex			1.190	0.464**	0.275
Age			0.012	0.010	0.003
Education			0.136	0.157	0.031
Household resources					
Labour	Adult	Male	0.046	0.136	0.011
		Female	0.021	0.115	0.005
	Children	Male	0.227	0.124*	0.052
		Female	−0.011	0.031	−0.003
Other	Land cultivated		−0.071	0.031***	−0.017
	Indigenous cattle		0.008	0.001	0.002
External influences					
Extension contact					
Frequency			0.632	0.196***	0.146
Field day attendance			−0.116	0.139	−0.027
Seminar attendance			0.957	0.196**	0.221
Geographical location					
Dodoma			−0.454	0.365	−0.105
Mpwapwa			0.724	0.378**	0.167
Kondoa			0.050	0.312	0.012
Log of likelihood function			−95.685		
Restricted log likelihood function			−148.518		
Percent correct prediction			84.188		
Number of positive observations			78		
χ^2 (slopes = 0)			106.518***		

* Significant at 0.10 probability level, ** Significant at 0.05 level, *** Significant at 0.01 level. ^{a} The partial derivatives are in probability units.

tively, for one unit changes. Geographical location also is significant. Specifically, Mpwapwa farmers were more likely to participate in cattle stall feeding than Singida farmers; the probability was higher by 16.7%. Farmers in the Mpwapwa district have had greater exposure to, and experience with, cattle stall feeding than farmers in the other areas. The Livestock Production Research Institute (LPRI), located in Mpwapwa, supervises most of the seminars and farmer field days in the district. No differences occurred among the other three areas in terms of the probability of participating in the stall-feeding technology.

6.2. Adoption of bitter water melon for cattle feeding

The results for the probit model on the adoption of bitter water melon for cattle feeding are in Table 5. The χ^2 for the likelihood ratio test was signifi-

cant at the 0.01 probability level. The model correctly predicted 81.2% of the farmers' adoption of the bitter water melon technology. The Mpwapwa binary variable was dropped from the model because all Mpwapwa farmers grow bitter water melon.

Once again, female-headed households (which tend to be poorer) had more limited access to alternative sources of feed and were therefore more likely to grow bitter water melon. The probability of growing bitter water melon was 25.0% higher for female farmers than for male farmers. An additional male child increases the probability of growing bitter water melon by 6.2% because they are the principle sources of labour for harvesting and transporting bitter water melon.

In terms of other variables reflecting household resources, both area of land cultivated and number of indigenous cattle owned were statistically significant.

Table 5
Estimated probit model for growing water melon for cattle feeding

Variable			Estimated coefficient	Asymptotic standard errors	$\partial P(.)/\partial X$[a]
Intercept			− 0.691	0.929	− 0.163
Household head characteristics					
Sex			1.062	0.470[**]	0.250
Age			0.002	0.010	0.000
Education			− 0.176	0.158	− 0.041
Household resources					
Labour	Adult	Male	− 0.121	0.143	− 0.028
		Female	0.141	0.108	0.033
	Children	Male	0.263	0.143[*]	0.062
		Female	− 0.065	0.109	− 0.015
Other	Land cultivated		− 0.089	0.025[***]	− 0.021
	Indigenous cattle		0.017	0.001[***]	0.004
External influences					
Extension contact					
Frequency			0.154	0.182	0.036
Field day attendance			0.125	0.142	0.029
Seminar attendance			0.884	0.204[***]	0.208
Geographical location					
Dodoma			− 0.904	0.316[***]	− 0.213
Mpwapwa			na	na	na
Kondoa			− 2.321	0.392[***]	− 0.546
Log of likelihood function			− 97.235		
Restricted log likelihood function			− 152.761		
Percent correct prediction			81.19		
Number of positive observations			84		
χ^2 (slopes = 0)			111.052[***]		

[*] Significant at 0.10 probability level, [**] Significant at 0.05 level, [***] Significant at 0.01 level.
[a] The partial derivatives are in probability units.

As the acres of cultivated land increased by one, the probability of growing water melon decreased by 2.1%. Wealthier farmers had other means of accessing water and alternative sources of protein, so the importance of bitter water melon decreased. Ownership of indigenous cattle significantly increased the probability of growing bitter water melon by 0.4% per head of cattle increase. Bitter water melon serve as a source of water for calves and sick animals that can't travel long distances and have to be nursed near the homestead, especially during the dry season.

With reference to extension, only household head attendance at seminars was statistically significant; an addition of one seminar increased the probability of growing bitter water melon by 20.8%. Most farmers' seminars conducted by the LPRI focus on the advantages and disadvantages of non-conventional animal feeds and bitter water melon as an alternative

source of water and protein. Therefore, seminars are good sources of information on bitter water melon production.

In terms of geographical location, the results indicated that farmers in Dodoma and Kondoa were less likely to grow water melon than those in Singida district; the probabilities were lower by 21.3% and 54.6%, respectively. In these two areas, water availability is not a problem and land is more limiting compared to the Mpwapwa and Singida districts. As indicated above, all farmers in Mpwapwa grew bitter water melon.

6.3. Number of improved cattle raised under the stall-feeding system

The results for second stage estimation for the number of improved cattle under stall-feeding management are summarised in Table 6. The R^2 for the

Table 6
Estimated Heckman two-stage model for the number of stall-fed cattle

Variables			Estimated coefficients	Standard errors[a]	Elasticity[b]
Constant			3.850	0.784	—
Household head characteristics					
Sex			−0.654	0.211***	—
Age			0.010	0.011	0.216
Education			−0.153	0.131	—
Household resources					
Labour	Adult	Male	−0.361	0.114***	−0.252
		Female	0.322	0.124***	0.251
	Children	Male	0.078	0.109	0.029
		Female	−0.179	0.083**	−0.065
Other		Land cultivated	−0.037	0.028	−0.150
		Indigenous cattle	0.012	0.109	0.035
External influences					
Extension contact					
Frequency			−0.311	0.243	—
Field day attendance			0.409	0.163*	0.100
Seminar attendance			−0.077	0.126	−0.015
Geographical location					
Dodoma			0.432	0.254*	—
Mpwapwa			1.313	0.421***	—
Kondoa			0.527	0.283**	—
Intensive feed garden			0.075	0.224	0.016
@Mills			−0.239	0.178	—
$R^2 = 59.7$			F (slopes $= 0) = 5.23$		

* Significant at 0.10 probability level, ** Significant at 0.05 level, *** Significant at 0.01 level.
[a] Standard errors shown are heteroskedastic-consistent estimates.
[b] Calculated by the following formula: $\frac{\partial Y}{\partial_k} \times \frac{\bar{X}}{\bar{Y}} = \beta_k \times \frac{\bar{X}}{\bar{Y}}$.

regression indicates that 59.7% of the variation is explained by the regression equation. The F-statistic that tests the hypothesis that the variables included in the model have no influence on the number of improved cattle managed was rejected at the 0.01 probability level. The inverse mills ratio was not statistically significant, indicating that no significant nonlinear variables were omitted from the model.

The results indicated that female headed households are likely to manage fewer cattle under the stall-feeding system, presumably because of their relative poverty and the substantial investments required in expanding such an enterprise. As far as labour available to the households is concerned, an increase in female adults by one increased the number of cattle raised under the stall-feeding system by 25.1%. Female adults play an important role in implementing the stall-feeding technology because

they have major responsibility for the milking, feeding, and watering of animals, stall cleaning, and sometimes feed collection. Thus, female adult labour is important in determining the number of improved cattle that can be managed under the stall-feeding system. In contrast, an increase in male adults and female children in the household by one reduced the number of improved cattle kept by 25.3% and 6.5%, respectively. Given that male adult labour is likely to be devoted to pursuits other than stall feeding of cattle, an increase in availability of such labour is likely to reduce the need or incentives for adopting such a labour-intensive technology. However, the negative relationship between female children and the number of improved cattle is difficult to rationalise.

In terms of external influences, extension input expressed as the number of farmer field days at-

tended by a household head had a positive impact on the number of improved cattle kept. Interaction with other farmers at farmer field days may improve the familiarity and confidence with the stall-feeding technology, thus helping stimulate the farmers' to move from the tentative adoption stage to more enthusiastic adoption by increasing the number of improved cattle that are stall fed.

As far as geographical location, the results show that farmers in Dodoma, Mpwapwa, and Kondoa are more likely to keep more cattle than Singida farmers. This can be attributed to the relative lack of experience of farmers in the Singida area and differences in the availability of extension services. The stall-feeding technology was introduced initially in the Mpwapwa region and then later into the Dodoma and Kondoa areas. Farmers in these three areas have been exposed to the stall-feeding technology for longer periods than those in the Singida area. Also, the information flows have greater deficiencies in the Singida area, where the linkage between research and extension is particularly weak.

6.4. Size of intensive feed gardens

The results for the size of intensive feed gardens for participating farmers are summarised in Table 7. The χ^2 for the log of the likelihood ratio test was significant at the 0.01 probability level. With reference to the characteristics of the household head, the only statistically significant variable was age. The results indicate that older farmers are more likely to adopt and have larger intensive feed gardens. An increase in age by 1 yr increased the probability of adopting the intensive feed garden technology by 0.7% or of an adopter expanding an existing one by 0.013 acres. These intensive feed gardens usually are grown near the homestead and are intended for dry-season feeding. Older farmers are likely to have limited labour supplies of male children for feed collection from other sources because the male children of older farmers are likely to be adults with their own families, thus precluding them from engaging in activities on their fathers' farms. Intensive feed gardens help ensure feed supply for older farmers' animals, especially during the dry season.

Although average land cultivated had a negative impact on the probability of participating in cattle stall feeding (Table 4), it had a positive influence on the size of the intensive feed gardens. An increase in land cultivated by a participating farmer by 1 acre increased the total effect of growing an intensive feed garden by 0.025 acre and expanding an existing one by 0.029 acre. For farmers practising stall feeding but without an intensive feed garden, an increase of land cultivated by 1 acre increased the probability of establishing one by 1.5%. Competition for land between intensive feed gardens and other food crops is less on large farms, and, consequently, some land is allocated to the former.

In terms of geographical location, the results indicate that households in Singida are more likely to grow intensive-feed gardens than in the other areas. As indicated earlier, intensive feed gardens are for dry-season feeding. This food source is supplemented by crop residues. In Singida, competition for crop residues exists between improved stall-fed and indigenous zebu cattle. In addition, zebu cattle are kept fairly close to the villages, thus limiting the availability of crop residues for stall-fed cattle. Consequently, Singida farmers are likely to place relatively greater emphasis on intensive feed gardens for dry-season feeding than farmers in the other areas where sizes of farms were larger and/or the number of indigenous cattle raised was lower.

Somewhat surprisingly perhaps, an increase in the intensity of extension service use reduced the total effect of participating farmers to grow intensive feed gardens by 0.122 acres and reduced the size of those in existence by 0.143 acres. An increase in the intensity of extension service use also reduced the probability of farmers establishing an intensive feed garden by 7.4%. This indicates a possible conflict in the messages conveyed to farmers by research and extension personnel. Most extension messages or impact points that are used in the current extension system focus on harvesting and storing crop residues for dry season feeding. The research messages (i.e., by LPRI) focus on intensive feed gardens to improve the quality of feed during the dry season. Both messages are important and necessary for improving the quantity and quality of feed available to the animals during the dry season. However, because extension personnel are often in closer contact with farmers, the LPRI messages may be overshadowed by the extension messages.

Table 7
Estimated Heckman two-stage model for the size of intensive feed gardens

Variable			Estimated coefficients	Standard errors	Total effect ($\partial EY_{ji}/\partial X_i$)	Adopters ($\partial EY_{1i}/\partial X_i$)	Non-adopters ($\partial F(z)/\partial X_i$)
Constant			−0.272	0.830	−0.132	−0.155	−0.080
Household head characteristics							
Sex			−0.204	0.264	−0.099	−0.116	−0.060
Age			0.023	0.089**	0.011	0.013	0.007
Education			−0.073	0.108	−0.035	−0.042	−0.021
Household resources							
Labour	Adult	Male	0.014	0.106	0.007	0.008	0.004
		Female	0.039	0.111	0.019	0.022	0.011
	Children	Male	−0.047	0.095	−0.023	−0.027	−0.037
		Female	−0.022	0.088	−0.016	−0.013	−0.065
Other	Land cultivated		0.051	0.024**	0.025	0.029	0.015
	Indigenous cattle		0.035	0.012	0.017	0.020	0.010
External influences							
Extension contact							
Frequency			−0.251	0.161*	−0.122	−0.143	−0.074
Field day attendance			0.311	0.125**	0.151	0.177	0.092
Seminar attendance			0.144	0.127	0.070	0.082	0.042
Geographical location							
Dodoma			−0.550	0.264**	−0.266	−0.313	−0.162
Mpwapwa			−0.470	0.360	−0.227	−0.267	−0.138
Kondoa			−0.688	0.296**	−0.333	−0.391	−0.203
Improved cattle			0.026	0.097	0.0127	0.015	0.008
@Mills			−0.052	0.213	−0.025	−0.030	−0.015
Sigma			0.612	0.067***			
X^2 (slopes = 0)			43.203***	LLF =	−63.476	RLL =	−84.555
Positive observations			47	F(z) =	0.603	z =	1.260
Sample size			78			f(z) =	1.180

* Significant at 0.10 probability level, ** Significant at 0.05 level, *** Significant at 0.01 level.

7. Summary and recommendations

In summary, this study shows that the stall-feeding technology appears to be particularly attractive to households with fewer resources, particularly those that are female-headed. Wealthier farmers, as measured by area of land cultivated, were less likely to adopt this technology. However, availability of household labour is found to be important in determining the degree to which the technology and associated management practices were adopted. Households with more male children are likely to adopt the stall-feeding technology and also grow bitter water melon. At the same time, a significant positive relationship occurred between the number of female adults and the number of stall-fed cattle. Because of the availability of other income-earning opportunities, increased availability of male adults has a negative impact on the number of stall-fed cattle. Age of the household head has a positive impact on the size of the intensive feed gardens, as does the area of land cultivated by the household.

Different measures of extension-related contact are significant in influencing the potential for adopting stall-feeding technology, the number of stall-fed cattle raised, the probability of growing water melon, and the size of intensive feed gardens. With the exception of the effect of frequency of extension contact on the size of the intensive feed gardens, the relationships are positive.

In terms of geographical location, all the models showing the popularity of the stall-feeding technology and its associated practices indicated that the Mpwapwa area was either the same or more inclined to their adoption than the other three areas. This is perhaps not surprising, given the proximity of LPRI and the fact that the technology was introduced first in that area.

The results of the study have at least three interesting and important implications. The first is that the cattle stall-feeding technology appears to be particularly attractive to the more disadvantaged households, thus helping to positively address inequitability issues including those relating to gender. The other two go beyond the scope of this paper, but the results indirectly imply that the stall-feeding technology is likely to have positive impacts. The first relates to a potential improvement in the nutritional status of disadvantaged households adopting the stall-feeding technology. Circumstantial evidence presented elsewhere provides some support for this assertion (Kaliba, 1995). The second relates to the ecological sustainability issue. Poverty commonly has been shown to contribute to ecological degeneration in areas where the population densities are higher than the carrying capacity of land (World Bank, 1992). In helping the disadvantaged, the stall-feeding technology is providing a means for improving the productivity and hence welfare of such households while at the same time potentially helping to ensure ecological sustainability. Identifying such strategies is critically important in many ecologically fragile areas (Norman and Douglas, 1994). The degree to which the stall-feeding technology can become such a strategy is not known, but the signs are promising.

The major implication arising from the results of this study is that efforts to encourage the adoption of the labour-intensive technology of cattle stall-feeding should be directed towards the more disadvantaged households in the study area, namely those that are female headed, that have small areas of cultivated land, and that have adequate household labour in the form of male children and female adults. Varied extension approaches, including farmer–farmer contact via farmer field days, appear to be justified to stimulate and nurture the adoption process. However, better coordination between research and extension seems to be needed to facilitate the development of relevant technology and the dissemination of consistent extension messages.

The potential of the stall-feeding technology to increase agricultural productivity, while simultaneously ensuring ecological sustainability, needs to be verified and encouraged through research and extension activities that seek to better integrate crop and livestock production in the area. In addition, few data are currently available on the input–output components and relationships in the stall-feeding technology. Analysis of detailed records of feeding rations, milk production, and other factors could be very useful for improving the efficiency of the stall-feeding technology, in identifying priorities for further research, and in fine-tuning extension recommendations. Such types of records also could help verify the nutritional benefits households derive from

adopting the stall-feeding technology and provide insights into designing relevant strategies for sustainable livestock development in Central Tanzania.

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