

Analysis of crop residue use in small holder mixed farms in Ethiopia

Ashraf Alkhtib*, Jane Wamatu, Girma T Kassie and Barbara Rischkowsky

International Center for Agricultural Research in the Dry Areas (ICARDA), P.O. Box 5689, Addis Ababa, Ethiopia

*Corresponding author: a.alkhtib@cgiar.org

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Abstract

Determinants of the use of cereal and pulse residue for livestock feeding and soil mulching among smallholder farmers in the mixed farming system were analyzed. Crop residue (CR) is dual purpose resources in the mixed crop–livestock systems of the Ethiopian highlands. They serve as livestock feed and inputs for soil and water conservation. They are generated predominantly from cereals and pulses. However, in view of the allocation of CR, soil conservation and livestock are two competing enterprises. Identifying the determinants of the intensity of use of cereal and pulse residue may help in designing strategies for more efficient CR utilization. Data on CR were generated and its utilization was collected in two highland regions in Ethiopia from 160 households using a structured questionnaire. The data were analyzed using the multivariate Tobit model. Results of the study showed that farmers prefer using CR from pulses over CR from cereals for livestock feeding purposes. The proportion of CR from pulses that was used as feed was positively affected by education level of the farmer, livestock extension service, number of small ruminants and CR production from the previous season. Distance of farm plots from residences of the farm households negatively affected the proportions of cereal and pulse residue used for feed. The use of pulse residue increased significantly when the women participated in decision making on CR utilization. The proportion of cereal and pulse residue used for soil mulch was positively affected by the education level of the farmer, the distance between the homestead and the cultivated land, extension service, awareness about soil mulch, the slope of cultivated land, participation in farmer-to-farmer extension and CR generated in the preceding season. In view that pulse CR have better nutritive value compared with cereal CR, better utilization of CR could be achieved by maximizing the use of pulse residue as livestock feed and optimizing the use of cereal residue as soil mulch. More livestock extension on the nutritive value of pulse residue should be provided to the farmers who cultivate sloppy plots. Encouraging the culture of labor exchange among the farmers could result in increased labor availability in the farms that would facilitate the transport and storage of pulse residue and increase its use as livestock feed. Increasing the awareness among farmers about the superiority of the pulse residue over cereal residue as feed and encouraging use of cereal residue as soil mulch could optimize the utilization of CR in the household.

Key words: cereals, pulses, residue, mixed crop–livestock farming system

Introduction

Crop–livestock mixed farming systems are the mainstay of smallholder livelihoods in the developing world (Herrero et al., 2010; Ryschawy et al., 2012). Population growth, increase in livestock population, increased income and rate of urbanization in the developing countries tend to increase the pressure on these systems (Herrero et al., 2010; Herrero et al., 2012). These challenges also tend to increase intensity of land use which leads to continuous cultivation of farmlands without fallowing (Collier and Dercon, 2009; Drechsel et al., 2001). Without adequate investment in agricultural land

management, this may contribute to land degradation and low agricultural productivity (Lal, 2009). Scientific reports on the use and importance of crop residue (CR) have shown that leaving 30% of the residue on crop farm plots reduces soil erosion by up to 80% (Rockström et al., 2009; Thornton and Herrero, 2015). In mixed crop–livestock farming systems, the use of CR for livestock feeding is becoming increasingly important due to the expansion of cropland and low productivity of natural pastures (Alkemake et al., 2012). The contribution of CR to the total dry matter intake of the livestock in Ethiopia ranges from 10 to 70% (Alemayehu, 2003; Zinash et al., 2001). The CR from cereals and pulses

has different nutritive values as livestock feed. According to Keftasa (1988), 1 kg of residue from cereal (pulse) contains on average 47 (69) g of crude protein (CP), 6.50 (6.95) MJ of metabolizable energy (ME) and 0.75 (0.55) g of phosphorus (P) and 2.5 (9.2) g of calcium (Ca), indicating that CR from pulses have better nutritive value compared with CR from cereals. Using pulse residue for soil mulching would therefore deprive livestock of valuable nutrients that could be used to improve dairy and meat production. Utilizing 1 kg of pulse residue as mulch would deprive the livestock of 22 g of CP, 0.4 MJ of ME, and 6.7 g of Ca. This is equivalent to a loss of 0.25 kg of cow milk of 4% fat [estimation from Kearn (1982)]. Under such situations, better utilization of CR could be achieved by maximizing the use of pulse CR for livestock feeding and optimizing the use of cereal CR for both mulching and livestock feeding. Studies on the utilization of CR are limited and have mainly focused on maize residue (Jaleta et al., 2013; Jaleta et al., 2015). Therefore, this study aimed at identifying the determinants of the utilization of cereal and pulse CR as livestock feed and soil mulch considering that CR from cereals and pulses is one of the major contributors to livestock feed and soil fertility in the highlands of Ethiopia.

Materials and methods

Study sites and data

The study was carried out in cereal-based farming systems in two regions of Ethiopia, Oromia and Amhara where smallholder mixed crop–livestock systems prevail. These regions represent highlands, which have potential for both cereal and pulse production. The average minimum temperature ranges between 8 and 9°C and the average maximum temperature between 20 and 22°C. The mean annual rainfall ranges between 750 and 1200 mm (Table 1). There are two cropping seasons, between January and March and between June and September. Crop harvest takes place between June and July and between October and December. The dominant soil types are vertisols, nitisols and camisols. The source and provision mechanism of agricultural extension services are similar across districts varying only in the skills of the extension agents. Data were drawn across six districts. Two peasant associations (PA) were randomly selected within each district (Table 1). Farmers within each PA were selected using a proportionate to size sampling method. The total number of the farmers participated in the study was 160 farmers (Table 1). Data were collected using a structured questionnaire. The data collected included household characteristics, resource ownership by the households, and CR production and utilization. The CR production (ton per household) was estimated from the grain production of each crop using conversion factors (Table 2).

Calculations and statistical analysis

The extent of utilization of cereal and pulse residue per household was measured in terms of percentage. In this particular case, our formulation presumes that there will be limited farmers who do not account for any CR utilization. The implication is that our latent dependent variable (y^*), which denotes interest in a specific CR, is not observed until the interest in the CR utilization exceeds some known constant threshold (L); i.e., we observe y^* only when $y^* > L$. Using an ordinary least squares (OLS) method to regress the intensity of use on the explanatory variables will generate inconsistent estimates because the censored nature of the variable. Therefore, the Tobit model censored only from the left side ($L = 0$) was employed in this study. Our model is specified as an unobserved latent variable, y^* . The observed y was defined by the following measurement equation:

$$y = \begin{cases} y^* & \text{if } y^* > L \\ L & \text{if } y^* \leq L \end{cases} \quad (1)$$

Each type of residue is used as feed or mulch which leads to joint decision about the utilization of cereal and pulse residue. The allocation functions of CR are inter-related and hence our estimation needs to take simultaneity into account. There is also efficiency gain in estimating these equations simultaneously. This study therefore employs multivariate Tobit model (Lee, 1981; Cornick et al., 1994; Arias and Cox, 2001) as specified below. Following the discussion above, let Y_j^* be a ($G \times 1$) vector of latent allocation of the j th consumption of cereal (c) or pulse (l) residue for feed (f) or mulching (m) (this implies that ' j ' takes four values), related to a ($G \times K$) matrix of explanatory variables X_j by (suppressing observation indices):

$$Y_j^* = X_j \beta_j + \xi_j, \quad j = 1, \dots, N, \quad (2)$$

where ξ_j is an ($G \times 1$) vector of error terms and $\xi_j \sim N(0, \sigma_j^2)$, β is a ($K \times 1$) vector of estimated coefficients, K is the number of explanatory variables, G is the number of households, and N is the number of allocations ($N = 4$). The relationship between latent (Y_j^*) and observed (Y_j) allocation can be represented by:

$$Y_j = \text{Max}(f_j(X; \beta) + \xi_j, 0). \quad (3)$$

Since the four types of allocation of the CR are determined simultaneously, the error terms of the models are likely to be correlated. If that is the case, efficiency gains can be achieved by estimating the equations in Equation (3) as a system. Formally, the likelihood function of the system of equations for an observation in which the first m allocation equations are censored out of the four equations is given by:

$$L = \int_{-\infty}^{-X_1 \beta_1} \dots \int_{-\infty}^{-X_m \beta_m} f(\xi_1, \dots, \xi_4) d\xi_1, \dots, d\xi_m. \quad (4)$$

Here f is the multivariate normal probability density function. Since there are four kinds of allocations we are dealing with, we have to evaluate definite integrals in up

Table 1. General information about the studied areas ($N = 160$).

District	Village	Number of households interviewed	Altitude (m a.s.l.)	Average Temp. (°C)		Precipitation (mm)	Agroecology
				Min	Max		
Agafra	Illani	11	2606	8–9	21–22	750–1475	Highland
	Elabdu	12	2467	8–9	21–22	750–1475	Highland
Gasera	Ballo Amenga	12	2395	8–9	21–22	750–1475	Highland
	Nake Negaaso	12	2385	8–9	21–22	750–1475	Highland
Goba	Alloshe Tillo	14	2566	8–9	21–22	750–1475	Highland
	Sinja	10	2603	8–9	21–22	750–1475	Highland
Goro	Chefaa Mana	14	2038	8–9	21–22	750–1475	Highland
	Dayu	9	2150	8–9	21–22	750–1475	Highland
Sinana	Sanbitu	14	2454	8–9	21–22	750–1475	Highland
	Selka	12	2457	8–9	21–22	750–1475	Highland
Basona Worena	Goshe bado	20	2790	8–9	20–22	900–1200	Highland
	Godo Beret	20	3084	8–9	20–22	900–1200	Highland

Table 2. Multipliers used to estimation CR production.

Crop	Residue	Residue multiplier	Reference
Wheat	Straw	1.50	(Smil, 1983)
Barley	Straw	1.20	(Smil, 1983)
Sorghum	Straw	1.20	(Smil, 1983)
Corn	Stover	1.20	(Smil, 1983)
Lentil	Straw	2.40	(Tullu et al., 2001)
Faba bean	Straw	1.30	(Gebremeskel et al., 2011)
Field pea	Straw	5.10	(Keftasa, 1988)
Teff	Straw	2.30	(Gebretsadik et al., 2009)

to four dimensions to work out the likelihood function of the system. As Equation (4) does not have a closed form solution, we have to evaluate it numerically. Approximating the integral with a weighted sum of integrand values at a finite number of sample points in the interval integration, numerical quadrature serves as an alternative to calculating multi-dimensional integrals. Although quadrature works well for small-dimensional integrals, it is not as effective with higher dimensions (Train, 2003). Actually, if the dimension of integrals is greater than two, quadrature techniques cannot compute the integrals with sufficient speed and precision (Hajivassiliou and Ruud, 1994; Revelt and Train, 1998). As the integral to be calculated in this paper has a dimension of four, we employ the Geweke–Hajivassiliou–Keane (GHK) simulator in the estimation reported in the paper (Geweke, 1989; Keane, 1994; Hajivassiliou and McFadden, 1998). Suppose the value of the following integral with dimension N ($N = 4$ in our case) needs to be calculated by the GHK:

$$\Pr(a < \xi < b) = \int_a^b g(\xi) d\xi, \quad (5)$$

where ξ is a random vector with $\xi \sim N(0, \Sigma)$ and g is the density function of ξ . The idea of the GHK simulator is

to draw u from a univariate normal distribution and recursively compute multivariate probability values using Choleski factorization (Cappellari and Jenkins, 2006). Let L be the lower triangular Choleski factor of Σ satisfying $L'L = \Sigma$ and e is a vector of independent standard normal random draws, then:

$$\begin{aligned} \Pr(a < \xi < b) &= \Pr(a < Le < b) \\ &= \Pr(A_1) \Pr(A_2|A_1) \cdots \\ &\quad \Pr(A_N|A_1, \dots, A_{N-1}), \end{aligned} \quad (6)$$

where A_i represents the event in the right-hand side of Equation (5), $i = 1, 2, \dots, 4$.

$$\begin{aligned} A_1 &= \left(\frac{a_1}{l_{11}} < e_1 < \frac{b_1}{l_{11}} \right), \\ A_2 &= \left(\frac{a_2 - l_{12}e_1}{l_{22}} < e_2 < \frac{b_2 - l_{12}e_1}{l_{22}} \right), \\ &\dots \\ A_N &= \left(\frac{a_N - l_{1N}e_1 - \cdots - l_{N-1,N}e_{N-1}}{l_{NN}} < e_N \right. \\ &\quad \left. < \frac{b_N - l_{1N}e_1 - \cdots - l_{N-1,N}e_{N-1}}{l_{NN}} \right). \end{aligned} \quad (7)$$

By taking draws of e_i recursively and repeating the process for R times, we can get the simulated value of $\Pr(a < \xi < b)$ and then the likelihood function. The explanatory variables included in the model were household characters, farmland characters, extension and awareness, livestock wealth and CR stock from earlier harvests (Table 3).

Results

Descriptive analysis

The summary of the descriptive statistics of the variables used in the regression model is presented in Table 4. The

Table 3. Brief description of the explanatory variables used in the Tobit model.

Explanatory variables	Description
Household characters	
Age of the head	Continues, years
Sex of the head	Dummy, takes the value of 1 if female and 0 otherwise
Education of the head	Continues, years
Size	Continues, persons
Decision maker on CR	
Male	Dummy, takes the value of 1 if male and 0 otherwise
Female	Dummy, takes the value of 1 if female and 0 otherwise
Joint	Dummy, takes the value of 1 if joint and 0 otherwise
Cultivated land	
Area	Continues, ha household ⁻¹
Slop	
Flat	Dummy, takes the value of 1 if flat and 0 otherwise
Mild	Dummy, takes the value of 1 if mild and 0 otherwise
Steep	Dummy, takes the value of 1 if steep and 0 otherwise
Distance from the homestead	Continues, hours
Extension and perception	
Farmer-to-farmer	Dummy, takes the value of 1 if there is and 0 otherwise
Extension	Dummy, takes the value of 1 if there is and 0 otherwise
Perception about crop residue mulching	Dummy, takes the value of 1 if there is and 0 otherwise
Livestock kept by the household	
Livestock units density	Continues, tropical livestock units ha ⁻¹ of cultivated land
Small ruminants	Continues, head ha ⁻¹ of the cultivated land
Large ruminants	Continues, head ha ⁻¹ of the cultivated land
CR stock from earlier harvests	Continues, ton ⁻¹ household

result showed that 14.5% of the sample households were female headed. The average age (years) and the education level (years in school) of sample household heads were 45.1 and 4.48, respectively. The average family size was six persons. The average farmland size was 3.68 ha. The walking distance between the cropping land and the homestead was 0.93 h. It was observed that 52.2, 40.25 and 7.55% of the households cultivated flat, mild slope and steep slope plots, respectively. Manure was the main input used for land fertilization by the sample households. The studied households kept 2.09 tropical livestock units (TLU) ha⁻¹ of cultivated land. The households kept on average 5.26 heads of small ruminants, 7.64 heads of large ruminants and 7.64 TLU. On the decision to undertake CR utilization, the men made the decision in 35.85% of the interviewed households, the women made the decision in 9.43% of the households, and men and women made the decision jointly in 54.7% of the cases. It was observed that 89.3% of the interviewed farmers were aware of the role of mulching CR in improving the quality of the soil. It was also observed that 35.2 and 89.9% of the household heads respectively got farmer-to-farmer and state extension on mulching. The total CR production per household was 14.2 t yr⁻¹, and of which 76.1% were cereal residue and 23.9% were pulse residue. Considering only the cereal residue, 98.1% of the households used it for livestock feeding whereas 88.8% of the households used it for mulching. For pulse

residue, 98.7% of the interviewed households were using it as feed and 71.8% of the interviewed households were using it as soil mulch. However, 3–4% of the farmers reported CR sales and burning *in situ*. The biomass of cereal and pulse residue utilized as feed was 84.6 and 89.6%, respectively, and 15.4 and 10.4% as soil mulch, respectively. The results of *t*-test presented in Table 5 show that the proportion of the pulse residue used as feed was significantly higher than the proportion of cereal residue used as feed ($P < 0.01$). Contrary to that, the proportion of CR used for soil mulch was significantly higher in cereal residue compared with pulse residue ($P < 0.01$).

Regression analysis

Household characters. Female headed households allocated significantly larger proportion of pulse residue as feed compared to the male headed households ($P < 0.01$). The higher the literacy level of the household head, the larger the proportion of pulse and cereal residue used as soil mulch ($P < 0.01$). The bigger the household size, the higher the proportion of pulse residue used as feed and the lesser proportion of pulse residue used as soil mulch ($P < 0.01$). No significant effect of household size on the utilization of cereal residue was detected ($P > 0.1$). It was observed that when the female joined in making the decision on CR utilization, more proportions of pulse residue were used as

Table 4. Descriptive statistics of variables used in the empirical analysis.

Variables	Unit	Statistic	
		Mean (s.d.)	%
Household characteristics			
Household head age	Years	45.1 (13.3)	—
Household head sex (male)	%	—	14.5
Household head education	Years in school	4.84 (3.55)	—
Size	Number	6.05 (2.83)	—
Cultivated land			
Size	ha	3.68 (2.47)	—
Slop			
Flat	%	—	52.2
Mild	%	—	40.3
Steep	%	—	7.55
Distance from the farmland	Hours	0.93 (0.76)	—
Livestock kept			
Small ruminants	Head ha ^{−1}	2.31 (3.78)	—
Large ruminants kept in the household	Head ha ^{−1}	2.51 (1.57)	—
Livestock kept in the household	TLUs	2.09 (1.31)	—
CR stock from earlier harvests			
Cop residue biomass	<i>t</i>	14.2 (13.2)	—
Pulse residue	<i>t</i>	10.8 (10)	—
Cereal residue	<i>t</i>	3.40 (5.97)	—
Decision-making about CR			
Male	%	—	35.9
Female	%	—	9.43
Joint	%	—	54.7
Perception about mulching CR	%	—	89.3
Extension on mulching			
Farmer-to-farmer	%	—	24.5
State extension	%	—	54.7
Extension on livestock			
Farmer-to-farmer	%	—	35.2
State extension	%	—	89.9

TLU, tropical livestock units adopted from (Jahnke, 1982); s.d., standard deviation.

Table 5. Utilization of cereal and pulse residue by the interviewed households.

Utilization	Cereal	Pulse	<i>P</i>
Livestock feed (%)	84.6 (13.7)	89.6 (15.1)	<0.001
Soil mulch (%)	15.4 (13.7)	10.4 (15.1)	<0.001
Percentage of the households used the CR as			
	Cereal	Pulse	
Livestock feed	98.1	98.7	
Soil mulch	88.8	71.8	

Values between parentheses are noted for the standard deviation.

livestock feed and lesser proportions of pulse residue were used as soil mulch ($P < 0.01$). However, the decision maker did not significantly affect the utilization of cereal residue ($P > 0.1$).

Cultivated land. The households who cultivated steep and mild slope plots used higher proportion of both cereal and pulse residue as soil mulch compared with

the households which cultivated flat plots. The distance between the cultivated land and the homestead decreased significantly the proportion of both cereal and pulse residue used as livestock feed and increased significantly the proportions used as soil mulch.

Extension and perception. Household heads who got farmer-to-farmer extension and state extension on

Table 6. Multivariate Tobit estimation results on the CR uses as feed and soil mulch.

Explanatory variables	Cereal		Pulse	
	Mulch Estimate	Feed Estimate	Mulch Estimate	Feed Estimate
Household characters				
Age of the head (years)	0.07 (0.07)	−0.04 (0.07)	0.02 (0.06)	0.02 (0.08)
Sex of the head (female)	5.81 (3.83)	−3.38 (3.67)	−11.6 (2.69)***	14.6 (2.33)***
Education of the head (years)	0.62 (0.26)**	−0.51 (0.25)**	−0.27 (0.17)	0.41 (0.1)***
Size (persons)	0.43 (0.42)	−0.18 (0.42)	−1.51 (0.52)***	1.12 (0.44)***
Cultivated land				
Area (ha)	0.12 (0.12)	—	0.19 (0.16)	—
Slop				
Flat				
Mild	1.51 (0.87)*	—	1.98 (1.17)*	—
Steep	1.62 (0.89)*	—	2.17 (1.19)*	—
Distance from the homestead (h)	2.41 (1.29)*	−2.5 (1.26)**	2.171 (1.44)*	−2.37 (1.32)**
Extension and perception				
Farmer-to-farmer extension on soil mulch	3.87 (0.7)***		5.46 (0.89)***	
Farmer-to-farmer extension on livestock production		−0.140 (0.35)		0.26 (0.45)
Extension on mulching	5.68 (0.71)***	—	7.85 (0.92)***	—
Extension on livestock	—	−4.84 (0.5)***	—	5.96 (0.64)***
Perception about crop residue mulching	2.3 (0.67)***	—	2.53 (0.92)***	—
Decision maker on CR				
Female	3.64 (4.78)	−4.13 (4.52)	−18.8 (3.87)***	17.6 (3.25)***
Joint	1.36 (4.52)	−1.71 (4.31)	−13.5 (3.6)***	13.5 (3.02)***
Livestock kept by the household				
Livestock units density (TLU ha ^{−1})	0.00 (0.43)	—	0.01 (0.57)	—
Small ruminants (head ha ^{−1})	—	0.36 (0.07)***	—	0.48 (0.09)***
Large ruminants (head ha ^{−1})	—	0.78 (0.29)***	—	0.99 (0.39)**
CR stock from earlier harvests (ton)	0.01 (0.01)	−0.02 (0.000)***	−0.02 (0.02)	0.02 (0.000)**
Sigma	10.2 (0.38)***	9.99 (0.38)***	13.9 (0.58)***	13.5 (0.56)***

Value between parentheses is noted to the standard error of the estimate.

TLU, tropical livestock unit.

***, ** and *, significant at 0.01, 0.05 and 0.1, respectively.

mulching using CR allocated larger proportions of cereal and pulse residue for soil mulching ($P < 0.01$). The extension services on livestock production increased the proportion of pulse residue used as livestock feed ($P < 0.01$) and decreased the proportion of cereal residue used as livestock feed ($P < 0.01$). The household heads who were aware of the importance of soil mulching used greater proportions of cereal and pulse residue as soil mulch.

Livestock kept by the household. The livestock herd size (TLU ha^{−1}) of the household did not decrease the proportions of CR used for mulching. As the number of small ruminants increased, the use of both cereal and pulse residue as feed significantly increased ($P < 0.01$). Significant and positive correlation between the number of large ruminants and the use of cereal and pulse residue as feed was detected ($P < 0.01$).

CR stock from earlier harvests. The availability of CR stock from previous harvests within the household negatively affected ($P < 0.01$) the proportion of cereal residue allocated as feed, while it positively affected ($P < 0.01$) the proportion of pulse residue allocated as feed (Table 6).

Discussion

Descriptive analysis

There was high awareness among the farmers about the importance of mulching CR to improve the soil quality. However, the average proportion of CR allotted for soil mulching only met 50% of the recommendation for mulching. Farmers in the studied areas tried to maximize the utilization of CR by using as much of the proportion of pulse residue as they could for livestock feeding and to minimize the use of pulse residue as mulch. Introducing new feed resource such as forages and grass, aiming to increase the biomass production of feed in the household, would allow the farmers to increase the use of CR as soil mulch. According to FAO (2015) and Kearn (1982), one TLU needs 239 g CP, 28.7 MJ ME and 7.5 kg dry matter day^{−1} for the maintenance propose. Thus, the livestock kept in the households need an average of 20.91 ton of dry matter, 666.48 kg of CP and 80,033 MJ of ME. In the current situation, the CR per household could provide

11.19 ton of dry matter, 503.55 kg of CP and 75,420 MJ of ME. Therefore, the cereal and pulse residue could cover only 53.51, 75.55 and 94.24% of the maintenance requirement of the household's livestock from dry matter, CP and ME, respectively. Although pulse residue has better feeding value compared with cereal residue, 10.43% of it is still lost as it was used as soil mulch. Calculation shows that using 100% of pulse residue as feed can provide the livestock with additional 1128 kg of pulse residue biomass, which can be converted into 282 kg of 4% fat cattle milk annually. According to Thornton and Herrero (2015) and Rockström et al. (2009), 30% of CR production should be retained in the plot to reduce soil runoff by 80%. Compared with the previous recommendation, the proportion of straw left in the plot covers around 50% of the recommendation for soil mulch. However, to optimize the livestock productivity in the household and to enable more use of CR as mulch, introducing new feed resources at household level is required. Using pulse residue exclusively to feed the livestock could provide them with more nutrients and therefore increase their production levels.

Regression analysis

Household characters. Female headed households allocated more proportion of pulse residue as feed compared with the male headed household ($P < 0.01$). Meaning that when farmers notice the differences in livestock intake and preference between the cereal and pulse straw, they increase the use of pulse residue as feed. This signifies the importance of on-farm trials to demonstrate the difference in the nutritive value between cereal and pulse residue. Jaleta et al. (2013) stated that labor is important to increase the CR collection and transportation from the field to the homestead. The results of this study showed a positive effect of household size on the use of pulse residue as feed, while it did not affect the use of cereal residue as feed. This implies that when active labor is available within the household, the household head prefers to use them to transport and store pulse residue rather than cereal residue. When women joined the decision-making process on CR utilization, they used more proportion of pulse residue as livestock feed and less proportion of pulse residue as soil mulch. However, there was no significant effect of decision maker on the utilization of cereal residue. This means that the farmers who were in constant contact with the livestock could perceive more about the differences in palatability between cereal and pulse residues.

Cultivated land. The farmers who cultivated steep and mild slope plots used higher proportion of both cereal and pulse residue as mulch compared with the farmers that cultivated flat sloped plots. This result agrees with what Jaleta et al. (2013) reported. As the slope of the plot increased, the use of the residue for mulching increases. That means that farmers who cultivate sloppy

plots are aware of the soil erosion more than the farmers who cultivated flat plots. The distance between the cultivated plots and the homestead is correlated positively with allocating more CR as mulch which agrees with the results of Jaleta et al. (2013). This result implies the importance of the need of labor for collecting and transporting the CR to the homestead to use it as livestock feed.

Extension and perception. The household heads who got farmer-to-farmer extension allocated higher proportion of cereal and pulse residue for mulching. The state extension service increased the utilization of the CR as mulch which agrees with Jaleta et al. (2015) and Jaleta et al. (2013). The result of the study also showed an important role of extension service on increasing the use of pulse residue as feed. However, the same extension negatively affects the utilization of cereal residue as feed. The overall results showed the significant role of the extension service in maximizing the utilization of CR through increasing the use of pulse residue as feed and the use of cereal residue mainly as soil mulch. Extension services on livestock and soil mulch, in addition to informal social networks, could effectively enhance of the utilization of CR.

Livestock kept by the household. When the number of the small ruminants in the household increases, the use of both cereal and pulse residue as feed increases. This demonstrates clear pressure the livestock has on cereal and pulse residue. Such result was obtained by Jaleta et al. (2013) on maize stover. The result shows the importance of the CR as a crucial feed resource in the mixed farming system of Ethiopia highlands.

CR stock from earlier harvests. The stock of CR negatively affected the proportion of cereal residue allocated as feed while it positively affected the use of pulse residue as feed. This reflects the preference of the farmers towards using pulse residue as feed compared with cereal residue. CR is the sole in-house feed resource for the livestock. When the production of CR increases, the household start to show clear preference towards using pulse residue (which has better feeding value compared with cereal residue) as feed over cereal residue. That means the increase in the biomass availability, by introducing new feed resource like grasses and introducing food-feed varieties, which have high grain and CR yields, could increase the efficiency of CR utilization in the mixed farming system.

Conclusions

CR is an important source of feed and soil mulch in the mixed cropping–livestock systems of Ethiopia highlands. Pulse residue has better nutritive value and palatability as livestock feed compared with cereal residue (Keftasa, 1988). Under limited resources in the households, better utilization of CR could be achieved by maximizing the

use of pulse residue as feed and optimizing the use of cereal residue as soil mulch. Institutional factors like extension services on mulching and livestock as well as access to information about the importance of CR mulching may lead to better utilization of CR. Providing extension and training services on the importance of the use of CR as mulch may help to improve the awareness among farmers and lead to enhance their use of CR as soil mulch. Better utilization could also be promoted by the extension service through bringing out the difference in nutritive value between the cereal and pulse residue. On-farm trials could play an important role by showing the farmers the superiority of pulse residue over cereal residue as livestock feed. Policy interventions should encourage informal social networks that stimulate group discussion and better information flow to enhance better utilization of CR. Special attention of the livestock extension should be given to the sloppy areas to maximize the farmers' utilization of pulse residue as feed. Increasing the feed availability in the household could be by introducing new varieties of cereal and pulse crops with superior food-feed traits and alternative feed resources, such as grasses, at household level could decrease the pressure on the use of CR as feed. Generally, interventions introducing conservative agriculture should account for tradeoffs related to alternative and competing uses of CR. However, better utilization of CR could be achieved by using pulse residue exclusively for livestock feeding and cereal residue exclusively for soil mulching.

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