THE INTERDEPENDENCE OF CROP - LIVESTOCK PRODUCTION SECTORS: THE CASE OF SINANA DINSHO DISTRICT IN BALE HIGHLANDS OF ETHIOPIA

BOGALE S., SOLOMON MELAKU S., YAMI A.

Abstract

The study was conducted in Sinana Dinsho district of Bale highlands, southeast Ethiopia to assess the relationship between livestock and crop sectors in the farming systems. The integration of crop and livestock sectors was stronger in the Sinana sub district, whereby oxen holding had significant effect ($P < 0.05$) on crop production. The size of cultivated land increased ($P < 0.05$) with the number of oxen owned per household. In Dinsho sub district, cattle in general and oxen holding in particular did not significantly affect ($P > 0.05$) both cultivated land area and crop production suggesting relatively weak crop-livestock integration. In general, draught power and crop residues are the main linking elements in integrating crop livestock sectors, particularly in Sinana sub district of Bale highlands. Due to differences in climate and type of crops grown, mainly livestock production contributed to the livelihood of farmers in Dinsho sub district, whereas farmers in the Sinana sub district earned their livelihood mainly from crop cultivation.

Key words: Bale highlands, crop residues, draught power, mixed crop livestock system

INTRODUCTION

The highlands of Ethiopia are characterized by crop-livestock mixed farming systems. Nearly 90 percent of the total human and 70 percent of the livestock population of the country inhabit the highlands (Mohamed-Saleem and Abate Tedla, 1995). The crop-livestock mixed farming systems developed as a consequence of the beneficial effects resulting from inter-relationships and complementarities between crop and livestock production. Livestock production ensures the availability of food and income to the farming community throughout the year. Besides, livestock are sources of agricultural inputs such as draught power and organic fertilizer as a direct contribution to crop farming, while the contribution of the crop sector is through the supply of feed in the form of crop residues. Hence, the role of livestock is significant in this farming system (Powell and Williams, 1993; Peters, 1999; Agajie, 2002; Getachew, 2002).

The mixed crop-livestock farming systems in the highlands are characterized with a much higher degree of crop-livestock integration, grazing land being limited to areas not suitable for crop cultivation because of water logging or frost exposure, high cropping intensity and availability of a large amount of crop by-products as livestock feed (Jahnke, 1982; Gryseels, 1988). Crop and livestock can be competitive, supplementary or complementary with respect to production factors and the total output (Jahnke, 1982; McIntire and Gryseels, 1987; McIntire et al., 1992). According to Getachew et al. (1993), crop and livestock sub sectors in the highlands of Ethiopia are more of complementary to each other, and thus highly integrated.

However, the highlands are a complex zone with a wide diversity in agroclimatology where considerable differences in settlement and land use occur. Jahnke (1982) reported that some differences in land use also reflect the impact of a differential historical and cultural background. Knowledge of the interactions and the linking elements of the crop livestock sectors in the highlands are useful for planning sustainable agricultural development. The objectives of this study were, therefore, to assess the relationship between livestock and crop sectors in the mixed farming systems in Sinana Dinsho district of Bale highlands, Ethiopia.

MATERIALS AND METHODS

The study area

The study was conducted in Sinana Dinsho district of Bale highlands, Southeastern Ethiopia. Dinsho sub district has a mild sub-tropical highland climate with annual mean minimum and maximum temperature of 2°C and 20 °C, respectively (Williams, 2002). Temperature tends to be more severe with a high probability of frosts during the night time particularly at the higher altitudes of Dinsho. Temperature ranges between 9.4°C and 21.2°C in Sinana sub district and has a bimodal rainfall with the main rainy season from August – December and the short rainy season from March–July (SARC, 2001). The dry season in Sinana sub district is from December–March. The precipitation during the main rainy season ranges from 270–560 mm and that of the short rainy season is from 250–560 mm.

On the other hand, the rainfall pattern of Dinsho sub district is monomodal with the rainy season occurring from late March –October, with the greater bulk of the rain falling in April and then August–October (Williams, 2002). The rainy season in Dinsho sub district is followed by a four-month dry season – from

November to February. According to Williams (2002), the lower altitudes of the Dinsho sub district receive between 600–1 000 mm of rainfall annually, whereas the higher altitude areas receive up to 1 200 mm annually.

Sampling techniques

A stratified multistage sampling technique was employed to select the sampling unit. Sinana Dinsho district was first stratified in to two 'recommendation domains' based on the rainfall pattern and cropping system (ICRA, 2001). A total of 195 households were randomly selected based on the proportion of the number of households owning livestock and the size of the stratified areas. Hence, 131 and 64 households were considered for the study in Sinana and Dinsho sub districts, respectively.

Household characteristics and livestock survey

Informal interviews were conducted in the district involving representatives from the different segments of the community and agricultural extension agents. Then, a semi-structured questionnaire was developed and pre-tested with few farmers to collect information on household size, farm size, cultivated land, grain production and land-use patterns. Information was also collected on herd size, livestock species composition and purpose of livestock production. Livestock population was converted into Tropical Livestock Units (TLU) using conversion factors (Gryseels, 1988).

Statistical analysis

Descriptive statistics was employed to describe various variables in the farming system. Correlation analysis was run to test the relationships between household size, land (cultivated and grazing land) holding, crop produced and herd size. Step-wise linear regression analysis was also run for factors affecting herd size, cultivated area and grain production.

Normality and homogeneity test procedures were performed prior to analysis to examine the frequency distributions of the data, which showed some skewness regarding herd size and crop production. Therefore, square root and log transformations were made for herd size and crop production, respectively. Test of significance was performed on the transformed data and means were re-transformed back. The data were analyzed statistically using the General Linear Model (GLM) procedures in Minitab Software, Version 12.0 (Minitab, 1998). The means which showed significant differences at the probability level of $P < 0.05$ were compared with each other using the Tukey pair-wise comparison procedures. Data collected in the study were analyzed using the following statistical models.

a) $Y_{ijk} = \mu + F_i + C_j + G_k + e_{ijk}$

where: Y_{ijk} = herd size per household, μ = overall mean, F_i = the effect of i^{th} household size, Cj = the effect of j^{th} cultivated area, G_k= the effect of k^{th} grazing area,e_{ijk}= random error

b) $Y_{ijkl} = \mu + F_i + M_j + C_k + S_l + e_{ijkl}$

where: Y_{ijkl} = cultivated area per household, μ = overall mean, F_i = the effect of i^{th} household size, M_j = the effect of j^{th} farm size, C_k = the effect of k^{th} cattle holding, S_l = the effect of l^{th} small ruminant holding, e_{ijkl} = random error

c) $Y_{ijkl} = \mu + F_i + C_j + O_k + Z_l + e_{ijkl}$

where: Y_{ijkl} = total crop production per household, μ= overall mean, F_i = the effect of i^{th} household size, C_j = the effect of j^{th} cultivated area, O_k = the effect of k^{th} oxen holding, Z_l = the effect of l^{th} fertilizer amount, E_{ijkl} = random error

RESULTS

The effect of household size, area of cultivated and grazing land on herd size

Area of cultivated land had significant effect ($P < 0.001$) on herd size and households with more than four hectares of cultivated land area had significantly larger ($P < 0.05$) herd size in Sinana (Table 1) sub district. Herd size reared in Sinana was not significantly affected ($P > 0.05$) either by family size or by area of pastureland, although there was a tendency of increase in herd size with increase in household size and area of private grazing land. Herd size was positively correlated with area of cultivated land ($P < 0.001$, $r = 0.57$), household size ($P < 0.001$, $r = 0.33$) and area of private grazing land ($P < 0.001$, $r = 38$) in Sinana sub district (Table 4). In the regression analysis, the contribution of cultivated land to r^2 (coefficient of determination) was observed to be 32 %, while that of area of private pastureland and family size were very small. This shows the greater variation in herd size was due to the area of cultivated land.

Household size significantly affected ($P < 0.05$) herd size in Dinsho sub district and the correlation between herd size and household size was significant ($P < 0.05$, $r = 0.43$) (Table 5). However, herd size was not significantly correlated ($P > 0.05$) with both area of cultivated and private grazing land. In the regression analysis, the contribution of household size to r^2 (coefficient of determination) was significant ($P < 0.001$) with r^2 value of more than 17%.

Tab. 1: Least- square means of factors affecting herd size in Sinana Dinsho district

Variance	Sinana Di			nsho		
	N LSM		SE	N	LSM	SE
Overall 13	1	7.73	0.18	64	8.31	0.31
Household size (N)		ns			*	
≤ 5	25 6.	75^{a} 0.	008	11	4.17^{c} 0.	03
6–10 8	1	7.61^{a}	0.003	29	8.61^{ab} 0.	01
> 10	25	8.29^{a} 0.	008	24	12.08^{a} 0.	01
Cultivated area (ha)		***			NS	
< 2.01	16	6.03^{b} 0.	01	35	7.68^{a} 0.	01
2.01–4 5	8	7.08^{b} 0.	004	22	8.43^{a} 0.	02
> 4	57	9.91^{a}	0.004	7	8.91^{a} 0.	05
Grazing area (ha)		ns			ns	
None 72		6.84^{a} 0.	003	23	7.78^{a} 0.	02
0.01 - 0.51	46	7.42^{a} 0.	004	21	8.76^{a} 0.	02
> 0.51	13	8.39^{a} 0.	01	20	8.94^{a} 0.	02

^{abc} means with different superscripts (a, b, c) within a column are significantly different (P < 0.05); LSM = re-transformed least square means; N = number of respondents; SE = standard error; NS = not significant; * = P < 0.05; ** = P < 0.01; *** = P < 0.001

The effect of household resources area of cultivated land

Size of land holding significantly influenced (P < 0.01) cultivated area in Sin ana and Dinsho su b districts (Table 2). C ultivated area per hou sehold significantly increased (P < 0.05) as farm size changed from two and half to five hectares. Herd size of cattle reared in Sinana had also exerted a si gnificant effect (P < 0.05) on area of cultivated land, wh ere hou seholds p ossessing more than ten TLU cu ltivated more land. Area of cultivated land was positively correlated with farm size (P < 0.001, r = 0.96), household size (P < 0.001. r = 0.25), livestock herd si ze (P < 0.001, r = 0.57) a nd sm all rum inant holding (P < 0.001, r = 0.23) in Sinana sub district. The regression analysis for fact ors affecting cul tivated land in Si nana sub di strict pe r household sh owed t hat l and holding was the m ost important factor accounting for the variation in the area of cu ltivated land with r^2 value of more than 92%.

Tab. 2: Least-square means of factors affecting cultivated area in Sinana Dinsho district

Variation	Sinana Di			nsho		
	N LSM		SE N		LSM	SE
Overall 13	1	3.82	1.22	64	2.16	0.78
Household size (N)		ns			ns	
≤ 5	25	3.86^{a} 0.	05	11	1.98^{a} 0.	08
6– 10	81	3.8^{a} 0.	04	29	2.41^{a} 0.	03
> 10	25	3.8^{a} 0.	05	24	2.09^{a} 0.	04
Land holding (ha)		***			***	
< 2.51	19	1.94^{c}	0.07 27		1.10^{c} 0.	03
2.51– 5	60	3.45^{b} 0.	03	24 1.	99^{b} 0.	04
> 5	52	6.08^{a} 0.	03	13	3.40^{a} 0.	07
Cattle holding (TLU)		*			ns	
< 5.01	39	3.39^{b} 0.	04	25	1.96^{a} 0.	03
5.01–10	71	3.68^{ab} 0.	02	24	2.47^{a} 0.	04
> 10	21	4.41^{a} 0.	07	15	2.06^{a} 0.	06
Small ruminant holding (TLU)		ns			ns	
< 0.51	80	3.77^{a} 0.	02	15	1.88^{a} 0.	04
0.51–1	32	3.87^{a} 0.	04	18	2.47^{a} 0.	04
> 1	19	3.84^{a} 0.	07	31	2.14^{a} 0.	04

^{ab} means with different superscript (a, b, c) within a column are significantly different (P < 0.05); N = number of respondents; LSM = least square means; SE = standard error; NS = not significant; * = P < 0.05; ** = P < 0.01; *** = P < 0.001

Land holding significantly influenced ($P < 0.05$) area of cultivated land in Dinsho sub district (Table 2), and the latter was positively correlated with land holding (P $P < 0.001$, $r = 0.82$) but the relationship was weak with herd size ($P > 0.05$, $r = 0.05$) and small ruminant holding ($P > 0.05$, $r = 0.1$). Regression analysis showed that size of land holding in Dinsho sub district was the most important factor contributing about 66% of the variation in cultivated area per household.

The effect of household resources on crop production

Both area of cultivated land and oxen holding significantly affected ($P < 0.01$) grain yield in Sinana sub district (Table 3).

Grain yield was significantly higher ($P < 0.05$) for households possessing more than four hectares of cultivated land and two pairs of oxen. As expected, the regression analyses for factors affecting grain production showed that the difference in cultivated area is the most useful factor in explaining the variation in crop production in Sinana sub district. Hence, the contribution of area of cultivated land to the total r^2 was about 45%. But, household size and amount of fertilizer applied did not increase grain production significantly ($P > 0.05$). Grain production per household in Dinsho sub district was independent of household size, area of cultivated land, oxen holding and amount of fertilizer applied (Table 3). However, in regression analysis the variation in crop production per household due to cultivated land was significant ($P < 0.05$), but the contribution of area of cultivated land to r^2 was very small with value of 9%.

Tab. 3: Least- square means of factors affecting grain production in Sinana Dinsho district

Variance	Sinana			Dinsho		
	N	LSM	SE	N	LSM	SE
Overall	131	57.31	0.24	64	22.81	0.49
Household size (N)		ns			ns	
≤ 5	25	56.65ᵃ	0.01	11	20.29ᵃ	0.09
6–10	81	56.89ᵃ	0.003	29	23.75ᵃ	0.04
> 10	25	58.40ᵃ	0.01	24	24.41ᵃ	0.05
Cultivated area (ha)		***			NS	
< 2.01	16	41.28ᶜ	0.01	35	21.58ᵃ	0.03
2.01–4	58	60.09ᵇ	0.005	22	22.88ᵃ	0.04
> 4	57	81.25ᵃ	0.01	7	23.98ᵃ	0.20
Oxen holding (N)		**			ns	
< 2.1	48	41.22ᵇ	0.006	56	20.48ᵃ	0.03
2.1–4	63	50.19ᵇ	0.004	6	24.76ᵃ	0.11
> 4	20	80.66ᵃ	0.01	2	23.19ᵃ	0.29
Fertilizer amount (q)		ns			ns	
< 1.01	59	52.70ᵃ	0.005	54	22.71ᵃ	0.03
> 1.01	72	61.81ᵃ	0.004	10	22.89ᵃ	0.08

[abc] means with different superscript (a, b, c) within a column are significantly different ($P < 0.05$); LSM = Least square means are re-transformed; N = number of respondents; SE = standard error; NS = not significant; * = $P < 0.05$; ** = $P < 0.01$; *** = $P < 0.001$

Relationships between various household resources

Household size was positively correlated with oxen holding ($P < 0.05$, $r = 21$), flock size of small ruminants reared ($P < 0.05$, $r = 0.21$, and equine holding ($P < 0.01$, $r = 0.30$) in Sinana sub district. However, area of privately owned pastureland was not significantly related ($P > 0.05$) with family size in the same area. In Dinsho sub district, the same holds true but the involvement of households on livestock production was higher than that in Sinana sub district. Hence, family size was not significantly correlated with area of private grazing land ($P > 0.05$, $r = 0.24$) in Dinsho sub district, while it was positively correlated with oxen holding ($P < 0.001$, $r = 47$), flock size of small ruminants reared ($P < 0.05$, $r = 0.31$) and equine holding ($P < 0.01$, $r = 0.38$).

Both overall farm size and area of cultivated land were directly and significantly correlated with overall herd size as well as with oxen, small ruminants and equines possessed by households in Sinana sub district. Equines holding was positively correlated with land holding ($P < 0.001$, $r = 0.47$), area of cultivated land ($P < 0.001$, $r = 0.046$), area of grazing land ($P < 0.001$), herd size ($P < 0.001$, $r = 0.68$) oxen holding (*$P < 0.001$, $r = 0.54$*) and small ruminant reared ($P < 0.001$, $r = 0.39$) in Sinana sub district. However, equine holding was not significantly correlated ($P > 0.05$) with farm size ($r = 0.22$), area of cultivated land ($r = 0.14$) and private pastureland ($r = 0.11$) in Dinsho sub district. Number of equines reared by the households in Dinsho was highly positively correlated with herd size ($P < 0.001$, $r = 0.87$) oxen holding ($P < 0.001$, $r = 0.73$) and small ruminants reared ($P < 0.001$, $r = 0.67$) as compared to that of Sinana sub district. Oxen and small ruminants holding was not significantly correlated ($P > 0.05$) with farm size in Dinsho sub district, while it was positively correlated ($P < 0.001$) in Sinana sub district. In general, the relationship between farm size and livestock holding was weak in Dinsho sub district.

Tab. 4: Correlation between various household resources in Sinana sub district of Bale highlands

	Family size	Land holding (ha)	Cultivated land (ha)	Grazing land (ha)	Herd size (TLU)	Oxen (TLU)	Small ruminants (TLU)
Family size	1.00						
Land holding (ha)	0.27**	1.00					
Cultivated land (ha)	0.25***	0.96***	1.00				
Grazing land (ha)	0.09	0.48***	0.33***	1.00			
Herd size (TLU)	0.33***	0.57***	0.57***	0.38***	1.00		
Oxen (TLU)	0.21*	0.51***	0.53***	0.21*	0.79***	1.00	
Small ruminants (TLU)	0.21*	0.25**	0.23**	0.11	0.46***	0.45***	1.00
Equines (TLU)	0.30**	0.47***	0.46***	0.32***	0.68***	0.54***	0.39***

TLU = tropical livestock unit; ha = hectare; * = $P < 0.05$; ** = $P < 0.01$; *** = $P < 0.001$

DISCUSSION

Herd size

The increase in herd size with the area of cultivated land in Sinana sub district suggests that households with more area of cultivated land could produce more crop residues for livestock feeding. Positive correlation between herd size and cultivated land in Sinana sub district also indicates that livestock in turn contribute to increased cultivated area through provision of draught power and supply of agricultural inputs through purchase of agricultural inputs probably from cash generated through the sales of livestock and/or their products. This finding is in agreement with Abdinasir Ibrahim (2000), who observed significant effect of cultivated area on herd size in the highlands of Arsi, Central Ethiopia.

Non significant effect ($P > 0.05$) of family size and area of grazing land on herd size in Sinana sub district may be due to the hiring of labour for livestock herding and cooperative livestock herding systems practiced (Solomon, 2004). However, positive correlation of herd size with family size and area of grazing land indicates that with the availability of family labor and grazing land, there is a tendency to increase livestock size. Herd size was observed to increase as household size rises that reflects family labor is essential for livestock management in Dinsho sub district (Solomon, 2004). The result of the study is similar to the reports of Niftalem and Peters (1999), who observed household size as the most important factor that affected herd size in the Deneba – Inwari areas, Central Highlands of Ethiopia. The non-significant effect of cultivated area on herd size in Dinsho sub district showed the interdependence between crop and livestock sub- sector to be weak.

In the study area, size of livestock herd kept by the farmers was independent of area of private grazing land. In contrast, herd size tended to increase with the availability of grazing area in Arsi (Abdinasir, 2000) and other parts of the Central Highlands of Ethiopia (Gryseels, 1988; Niftalem and Peters, 1999). The reason for such differences with the other studies could be attributed to the communal ownership of a large proportion of the grazing areas in Bale highlands that minimized the contribution of area of private grazing land to feed resource base (Solomon, 2004).

Area of cultivated land

The increase in farm size positively influenced size of cultivated area, whereby land put under cultivation increased progressively as farm size increased from two and half to five hectares. This trend is in line with the reports of Niftalem and Peters (1999), and Abdinasir (2000), who found significant effect of farm size on area of cultivated land. The relationship between land holding and area of cultivated land may imply that the size of land holding per household is not beyond the cultivation needs of the household, where farmers with larger farm size have an opportunity to cultivate more land.

Herd size of cattle reared and area of cultivated land in Sinana sub district were positively correlated, probably this is associated with the better integration of crop - livestock production in the area, whereby income from crop production may have been invested on livestock production, which in turn can lead to the increase in area of cultivated land. Non-significant effect ($P > 0.05$) of household size on area of cultivated land per household in Sinana sub district may be due to the fact that land is allocated to household units rather than to household members.

Overall land holding determined area of cultivated land per household in Dinsho sub district. This reflects the fact that households with extra plot of land can put more land under cultivation. However, independent effect of family size, cattle and small ruminant holding on area of cultivated land in Dinsho sub district is probably due to less investment on cultivation. In other words, income generated from livestock sector may go to the purchase of grains rather than to invest directly on cultivation of crops.

Crop production

Both sizes of cultivated area and oxen holding increased grain yield in Sinana sub district. This is logical since the increase in area of cultivated land leads to concomitant increase in grain production. A significant effect of oxen holding on area of cultivated land shows the contribution of oxen through supply of draught power to crop production in Sinana sub district. This result is agrees with that of Abdinasir (2000), who found increased crop production in response to size of oxen holding in the Arsi highlands, Central Ethiopia. Household size and grain production were independent of each other in Sinana sub district due to the availability and use of improved agricultural technologies such as herbicides and combine harvesters that substitute manual labour. Similarly, rate of fertilizer applied had no significant effect ($P > 0.05$) on grain production, probably because crop cultivation is a relatively recent farming activity in the area and the soil may not have lost its inherent fertility compared to elsewhere in the Ethiopian highlands (Bekele et al., 1998; ICRA, 2001). According to Solomon (2004), farmers in the highlands of Bale applied fertilizer mostly on a less fertile soil, and thus blanket application of fertilizers on all cultivated land was not practiced. Grain production per household was independent of family size in Dinsho sub district indicating that the involvement of family labor on crop production was not important. Similarly, oxen holding were observed to have non significant effect ($P > 0.05$) on the amount of grain produced, showing that crop cultivation is not as important as livestock production. Grain produced per household was also unaffected by the amount of fertilizer applied, probably due to the practice of fallow, which is a common in Dinsho sub district (Bekele et al., 1998). The higher livestock herd size per household in Dinsho compared to Sinana sub district proves the importance of livestock rearing as a major source of livelihoods in the former sub district, whereas in the latter sub district, crop cultivation is a major source of livelihoods for the farmers (Solomon, 2004).The tendency towards specialization in livestock or crop production in the two sub districts could be attributed to variations in the climatic and topography, which are relatively unfavorable for crop production in Dinsho sub district.

CONCLUSIONS

The integration of crop and livestock sector was stronger in Sinana sub district, whereby the oxen holding had significant effect on crop production via the supply of draught power to the production system. Households that owned more than two pairs of oxen cultivated more area of land. In Dinsho sub district, however, the integration of crop and livestock production was relatively weak due to less dependence on crop production for their livelihood as a result of limitations imposed by climate to cultivate a diversity of crops. Draught power and crop residues are the main linking elements between livestock and crop production, particularly in Sinana sub district of Bale highlands.

Acknowledgments

The first author is grateful to the financial support given him by Ethiopian Institute of Agricultural Research to conduct the project and the second author is grateful to Haramaya Unversity for granting leave of absence and the German Academic Exchange Service for financial support while preparing the manuscript.

REFERENCES

ABDINASIR I. (2000): Smallholder Dairy Production and Dairy Technology Adoption in the Mixed Farming System in Arsi Highland, Ethiopia. Ph.D. Thesis, Humboldt University, Berlin, Germany.

AGAJIE T., CHILOT Y, MENGISTU A., ELIAS Z., YOHANNES A. (2002): Smallholder livestock production systems and constraints in the highlands of North and West Shewa zones. In: Proceedings of the 9th Annual Conference of the Ethiopian Society of Animal Production (ESAP) held in Addis Ababa, Ethiopia, August 30–31, 2001, pp. 49–72.

BEKELE H., WORKU J., FEYISA T., MULUGETA A., MENGISTU Y., ARFASA KIROS (1998): The Dinsho mixed farming systems of Bale highlands. In: Chilot Y., Fekadu A. and Woldeyesus S. (eds.): Barley Based Farming Systems in the Highlands of Ethiopia. Addis Ababa, Ethiopia. pp. 101–106.

GETACHEW A., ZERBINI E., ABATE TEDLA (1993): Crop-livestock interaction and implications for animal traction research in the Ethiopian highlands. In: Proceedings of the 4th National Livestock Improvement Conference (NLIC) Held in Addis Ababa, Ethiopia, 13–15 November 1991, pp. 29–36.

GETACHEW E. (2002): An Assessment of Feed Resources, Their Management and Impact on Livestock Productivity in the Ginchi Watershed Area. M. Sc. Thesis, Alemaya University of agriculture, Alemaya.

GRYSEELS G. (1988): Role of Livestock on a Mixed Smallholder Farms in the Woredas near Debre

Berhan. Ph.D. Thesis, Agricultural University, Wageningen, Netherlands.

ICRA (International Center for Development Oriented Research in Agriculture) (2001). The shift to Cereal Mono-cropping, a Threat or a Blessing? Toward Sustainable Agricultural Production in the Wheat-barley Farming System in the Highlands of Southeast Oromia, Ethiopia. ICRA–2001 Ethiopian Team, Working Document Series 92, Ethiopia.

JAHNKE H.E. (1982): Livestock Productions and Livestock Development in Tropical Africa. Kieler Wissenschafts Verlag Vauk, Kiel, West Germany

MCINTIRE J., BOUZART D., PINGALI P. (1992): Crop-livestock Interaction in sub-Saharan Africa. World Bank, Washington, D.C., USA.

MCINTIRE J., GRYSEELS G. (1987): Crop-livestock interaction in sub-Saharan Africa and their implication for farming research. Experimental Agric., 23: 235–243.

Minitab (1998). Minitab User's Guide: Data Analysis and Quality Tools, Release 12 for Windows, Windows 95 and Windows NT. USA.

MOHAMED-SALEEM M.A., ABATE TEDLA (1995): Feed improvement to support intensification of ruminant production systems in the Ethiopian highlands. In: Proceedings of the 3rd Annual Conference of the Ethiopian Society of Animal Production (ESAP) Held in Addis Ababa, Ethiopia, 27–29 April 1995; pp. 296–306.

NIFTALEM DIBBISA, PETERS K.J. (1999): Livestock species composition and herd size in relation to household farm resources in mixed farming systems in the Ethiopian highlands. Outlook on Agriculture, 28: 51–54.

PETERS K.J. (1999): Livestock production and food security: consequences for the environment? Agriculture and Rural Development, 6: 43–47.

POWELL J.M., WILLIAMS T.O. (1993): An overview of mixed farming in sub-Saharan Africa. In: Livestock and Sustainable Nutrient Cycling in Mixed Farming Systems of Sub-Saharan Africa. Volume II. Technical Papers. Proceedings of an international conference held in Addis Ababa, Ethiopia, 22–26 November 1993. ILCA Addis Ababa, Ethiopia.

SARC (Sinana Agricultural Research Center). 2001. Profile of Sinana Agricultural Research Center. Oromia Agricultural Research Institute. Bulletin No. 1, November.

SOLOMON BOGALE (2004): Assessment of Livestock Production System and Feed Resource Base in Sinana Dinsho District of Bale Highlands, Southeast Oromia. M. Sc. Thesis, Alemaya University, Alemaya.

WILLIAMS S. (2002): Bale Mountains: a guidebook. EWCP, Addis Ababa.

Received for publication on February 2, 2007
Accepted for publication on February 4, 2009

Corresponding author:

Solomon Bogale
Sinana Agricultural Research Center,
PO Box 208
Bale Robe
Ethiopia
e-mail: solmelay@yahoo.com