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Production and Reproduction Performances of Livestock and their Implications on Livestock Water Productivity in Mixed Crop-Livestock Systems in the Highlands of Blue Nile basin: *A case study from Fogera, Diga and Jeldu districts (Ethiopia)*

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Abstract

Study about livestock production and reproduction performances and their implications on Livestock Water Productivity (LWP) in the rain-fed crop-livestock systems were conducted in the Blue Nile Basin (BNB). Seven farming systems (Rice-Pulse & Teff-Millet from Fogera), (Barley-Potato, Teff-Wheat & Sorghum farming systems from Jeldu) & (Teff-Millet & Sorghum farming systems from Diga districts) were selected & a total of 220 sample Household (HH) heads were involved. Lower milk yield & shorter lactation lengths, higher age at mating & calving, longer parturition intervals for female animals & higher age at first effective mating for breeding purposes by the bulls, jack & stallion were observed. Variability in performance within species observed between & among farming systems in this study are major indicators of potential to improve productivity & thereby LWP. Higher mortality & low off-take rates for different livestock species were observed. Mortality & morbidity affects LWP in two major ways: it reduces the efficiencies of the services & productivity of livestock. Secondly when animal dies water invested in feed for the animal will be lost. This is important in view of the increasingly scarce agricultural water. Values of LWP across the study systems were lower & the differences among systems were not as such apparent. More interesting is a huge gap between the minimum (0.001) & maximum values (0.627 USDm^{-3}) of LWP. In view of this it can be concluded that there is huge potential to improve LWP in mixed crop livestock systems of the BNB. Although understanding the determinants of these variability are important future research policy options that increase farmers access to key livelihood resources is important. Future crop livestock integration must consider not only a short term economic return but long term environmental sustainability. Improving the production and reproduction potentials of local breeds through the different livestock management practices & reducing feed scarcity through food-feed integration adjoined with improved livestock & feed management, better veterinary access & improved extension service could be possible suggestions to lift up the current low livestock productivity and Livestock Water Productivity.

Keywords: Livestock, Livestock water productivity (LWP), Reproduction, Production, Blue Nile Basin (BNB), Farming systems

Introduction

Production and reproduction performances of indigenous livestock are generally low and differences were observed both between and within the breeds themselves. This may be attributed to their poor genetic potential, inferior husbandry systems, lack of capital and inputs by the households.

Although indigenous livestock breeds are fairly well adapted to the tropical environments, the majority of animals are raised under an extensive husbandry. Mulugeta (2005) indicated that proper veterinary facilities are out of reach of most of the residents in highlands of Ethiopia. The mortality and poor productivity may be both attributed to preventable and non preventable causal factors. A sick animal is often a burden than an asset to small holders due to their inefficient usage of input invested in terms of attributes like water. For example lamb and kid mortality is the most important constraint limiting productivity of small ruminants in Blue Nile Basin (BNB).

Water, for agricultural activities besides consumption by human and animals is increasingly becomes a limiting factor. It is a scarce resource in most parts of Ethiopia including the BNB. Bekele (2008) and Mekonnen (2009) reported that this is especially crucial during the eight dry months, in most parts of the country, extending from October to May. The observation of Mekonnen (2009) further indicates that livestock play an important role in social food security issues of the inhabitants. However, they are often overlooked in planning research and interventions that involve livestock's efficient uses of the scarce water resources.

The study of Sileshi et al. (2003) reveals that on an average a TLU of livestock consumes about 25 liters of water on a daily basis. But this constitutes only small fraction of its daily water requirement. Peden et al. (2007); Haileslassie et al. (2009 a) and Van Breugel et al. (2010) suggested that the water consumed directly by livestock amounts to only 2% of the total water used to provide products and services under small-scale mixed farming systems. Studies by Peden et al. (2003) indicate that the prime user of water resources (for livestock production) is for the production of feed. On the other hand, the key constraint to livestock production in

Ethiopia is attributed to seasonal feed shortage, the production of which is often dependent on rainfall. Therefore, with increasing demand for livestock products it is anticipated that there will be increase of pressure on already scarce water resources.

Thus, there is an urgent need to improve agricultural productivity and proper management of already scarce water resources for livestock production. Proper management of scarce resources is important to secure both the livelihood of smallholders and the sustainability of the environment as a whole (Molden et al., 2010).

Livestock water productivity (LWP) is defined as the ratio of livestock products and services (such as meat, milk, traction, hides, manure) expressed in monetary units to the water depleted in producing them (Haileslassie et al., 2009a; Amede et al., 2009; Peden et al., 2007)

LWP can be assessed at different scales including animal (Gebreselassie et al., 2009), household (Haileslassie et al., 2009b), farming system (Haileslassie et al., 2009a), and the catchment or basin scale (Cook et al., 2009).

Water productivity measures the ability of agricultural systems to convert water into food and feed; this can be defined as the ratio of agricultural outputs to the volume of water depleted for its production (Molden et al., 2010). There are two general driving factors of livestock water productivity: the impact of livestock on water resources depletion in the process of feed production and the efficiency with which the different livestock management practices help to convert this invested water, to produce feed, into useful products. The present research characterized the livestock production and reproduction performance under farmer's husbandry systems and its implications on the water productivity.

Objectives:

- To describe the current livestock production and productivity in different farming systems of the Blue Nile Basin;
- To analyze and contextualize implications of current livestock performance on livestock water productivity.

Materials and Methods

Location and biophysical characterization of the study sites

The highlands of BNB cover two major eco-physiographic regions, parts of the central highlands and the western highlands of Ethiopia. This research work was undertaken in Fogera; Jeldu and Diga of the Nile Basin under the auspices of Nile Basin Challenge (NBDC). These districts were initially selected by the NBDC prior to the commencement of this research and therefore this work adopted the same sites.

Fogera district is located in Amhara Regional State: North western parts of Ethiopia. It lies at 1774-2410 meter above sea level (m.a.s.l.) and has mean rainfall of 1200 mm and minimum and maximum temperature 11^{o}C and 27 ^{o}C, respectively. Jeldu district is located in Oromia Regional State: Western part of Ethiopia. It is situated between 1800-3000 m.a.s.l. and has average annual rainfall of 938mm. The mean minimum and maximum temperature in Jeldu is about 9 ^{o}C and 27 ^{o}C, respectively. Diga district is located in Oromia Regional State: Western Ethiopia. Its altitude ranges between 1338 and 2100 m.a.s.l. and has average annual rainfall of 1936 mm. The mean minimum and maximum temperature is 15^{o}C and 27^{o}C, respectively. Data from district Agricultural office suggests that in 2010, the livestock population in Fogera, Diga and Jeldu are about 120,367 TLU, 43,661 TLU and 122,181 TLU, respectively. Cropping systems are diverse. In Fogera district, rice-pulse and teff-millet farming are major farming systems while in Jeldu district, the farming system are barley-potato, teff-wheat and sorghum based. In Diga district Sorghum and Teff-millet based farming systems dominate (Haileslassie et al., 2011).

Household survey and data analysis

The household survey

In a single visit (ILCA, 1990) a multi stage stratified random sampling technique was employed to select farm households. First a watershed was selected within the three districts and stratified into different farming systems. Then households within kebeles[1] in each stratum were randomly selected.

Structured questionnaire covering data on farm household characteristics, resources ownership (land & livestock, feed), farming practices, livestock species composition, livestock management, productivity, off-take, mortality, feeding system, types of feed, marketing, and institutions, etc. were prepared, pretested and implemented.

Estimating Livestock Water Productivity

Livestock water productivity (LWP), as defined earlier is the ratio of livestock beneficial outputs and services to water depleted to produce livestock feed (Peden et al., 2007) as indicated in equation 1 below.

[1] Kebele is the smallest administrative unit in Ethiopia

$$LWP = \frac{\sum_{j=1}^{n} OjPj}{\sum_{1=j}^{n} Kc*ETo(Gj)+\sum_{j=1}^{n} Kc*ETo\ (\beta j)}$$

In which *Kc*, is crop factor; *ETo* is reference evapotranspiration and *LWP* is livestock water productivity; *Oj* is the livestock beneficial output of type *j*; *Pj* is the price of output *j*; *Gj* and *βj* are grazing and arable land uses of type *j* from where the livestock feed is collected. The following subsections give details of steps and procedures that were used in estimating depleted water and livestock beneficial outputs given on equation 1 above (Haileslassie et al., 2009a).

Livestock water productivity was determined at the household level by taking into account all livestock products and services and unifying them based on their current market value.

Estimating depleted water

As the drinking water for livestock is not more than 2% of the total water for livestock production (Peden et al., 2007), only the amount of water used for feed production were accounted as depleted water. Depleted water was computed from the amount of water that was lost through evapotranspiration (ET). The results were analyzed using CROPWAT (FAO, 2003) software and FAO NewLockClim database was employed.

ETcrop = Kc x ETo

Where:

ETcrop: Crop water requirement in mm per unit of time
Kc : Crop coefficient (Crop factor)
ETo : Reference crop evapotranspiration in mm per unit time

To arrive at the total depleted water, the evapotranspiration for each crop grown and grazing pasture were estimated. The following data sources and steps were applied to work out.

1. Data on land use, crop group and type and the area covered by each crop type were collected from farmers' interview and the district agricultural and rural development office.
2. Harvest index value from literature was used to estimate the amount of crop residues from grain yield.
   2.1. Crop residues yield (kg) = Conversion factor * grain yield (kg/yr). Conversion factors established by FAO (FAO, 1987) and other sources from literature were used.
3. The amount of crop residue or grass that would be utilized by livestock was calculated by applying a use factor% developed by (Tolera and Said, 1994; FAO, 1987).
   3.1. Used for feed (kg) = Total residue or grass available(kg) * use factor%
4. Evapotranspiration and total water requirement

Using the Kc factors for the different crop types and reference evapotranspiration (ETo) ETcrop was calculated as follow:

   4.1. ETcrop = (ETo in farming system * Kc factors)
   4.2. Total water requirement
      4.2.1. GP = Growing Period for each crop and feed resource were obtained from literature and district agricultural office.
      4.2.2. Total Crop Water Requirement (CWR)/ m^3/ annum = (ETm * GP) * area (m^2)
      4.2.3. Residues CWR/ m^3/ annum = (Total CWR/ m^3/ annum * harvest index) * use factor%
      4.2.4. Grass CWR/ m^3/ annum = (Total CWR/ m^3/ annum * % total grass yield) * use factor%
5. The sum of residues and grass CWR/ m^3/ annum were considered as depleted water to calculate the livestock water productivity.

Estimating beneficial outputs

In the present study livestock products and services were estimated from primary and secondary data. Year 2010 market values for products and services in the study area were used to quantify the benefits and services in monetary terms.

Information regarding the livestock numbers and density were generated from the interviews with the farmers' and district Agricultural and rural development office. The total number of livestock was converted to Tropical Livestock Unit using TLU conversion factors for different livestock species: Total TLU = Livestock Nr * TLU factor and the Live Weight = TLU * 250 (ILCA, 1990; 1 TLU is equivalent to the weight of zebu cow of 250 kg), the TLU converter for each species of livestock.

1. Livestock Outputs
   1.1. Milk Yield

To calculate the total milk yield the following data were generated

      1.1.1. Total milk production = (total number of milking cows* (milk yield in liter per day*30)* length of lactation period))

1.1.2. Milk Value (ETB) = Total milk yield * price per liter (ETB)

1.2. Livestock off-take

To estimate the total off-take values of animals we used the number of sold, given to others and slaughtered animals per household in a year and the current market price in the study areas. For ruminants: market values from sale and estimated current price for gifted-out and for HH consumption. For equine: we used current market price for gifted-out and sold ones.

1.3. Total Manure

The quantity of total manure produced per year per household was calculated based on the number of TLU and quantity of manure produced daily from each TLU on dry matter basis. We used literature values for dry weight daily dung production of 3.3 kg day^{-1} TLU^{-1} for cattle and 2.4 kg day^{-1} for equines and sheep and goats to estimate total dung produced in different farming systems. The nutrient content of dung (e.g. Nitrogen, Phosphorus and Potassium) was estimated based on average chemical composition for Ethiopia of 18.3 g N kg^{-1}, 4.5 g P kg^{-1} and 21.3 g K kg^{-1} on a dry weight basis (Haileslassie et al., 2006) . This was converted to fertilizer equivalent monetary values using the current local price of fertilizer. To estimate the value obtained from manure the current fertilizer market price was used.

1.3.1. Total Manure = TLU * (kg manure per day/ TLU * 365.25 days)

1.3.2. Manure Value (ETB) = Total Manure (kg) * price/kg (ETB).

1.4. Traction (threshing, ploughing and transportation) services

The time utilized for different services of animals such as threshing, ploughing and transportation and the local price of the different classes of livestock for the respective services were considered to estimate the value of such services.

1.4.1. Traction animal Nr * Traction Values (ETB)

2. Finally the total value of beneficial outputs was derived from the values of products and services calculated from the above procedures.

2.1. Beneficial Outputs (USD) = Value for products + Values for services

Statistical analysis

Both descriptive and inferential procedures were used to analyze the data collected from the survey work. The descriptive part included mainly percentage values summarized in the form of tables and figures as appropriate. The software Statistical Package for Social Sciences ((SPSS) version 16.0, 2007)) and Excel for windows 2003 were used to enter and analyze the data. ANOVA tests were done using GLM procedures of SAS (Statistical Analysis Systems version 9.0) to assess the effects of farming systems on most response variables. Effects of wealth class on beneficial output and livestock water productivity was also accessed separately using the GLM procedures of SAS.

An index was calculated to provide rankings wherever necessary. Differences between group means were expressed as least Squares Means (LSM) $\pm$ SE. Significant differences were compared using Duncan's Multiple range Test (Duncan, 1997).

Model 1: $Yijk = \mu + Fi + \varepsilon i$. Where,

Yijk = Dependant variable

(Milk yield, lactation length, LWP,…)

μ = The overall mean

Fi = Effect of i^{th} Farming system (*1-7: =Rice-Pulse & Teff-Millet from Fogera. Barley-Potato, Teff-Wheat & Sorghum from Jeldu. Teff-Millet & Sorghum from Diga districts)*.

εi = Random error term

Results and Discussion

Productive performances of livestock

Daily milk yield

Table 1 indicated that the estimated mean daily milk yield significantly differ ($p<0.05$) among the study farming systems. Highest and lowest milk yield was recorded from the Rice-Pulse Fogera and in Teff-Millet farming systems of Diga, respectively. The overall average yield was about 1.57 liters/day. These values were higher than reported by Tassew (2007) from *Bahir Dar Zuria* and *Mecha* districts but similar with the national average of 1.50 liters/day described by (CSA, 2011). Observations during the study made at Alember (Fogera) showed the potential to improve milk yield up to 8 liters per day from Fogera X Fresian crosses. It is clear that higher milk yield needs more feed. But Haileslassie et al. (2011a) from their work in India reported that the milk produced outweighs the water cost in feed production and thus improves LWP.

The present study also indicated a broad range between the lowest and highest milk yield (Table 1). The study also indicates that the difference between the minimum and the maximum exceeds 3 liters; however this may be is attributed to both genetics and non-genetic factors (feeding, health care and management).

There is a significant relationship between season and milk yield of cattle. This can be attributed to feed availability and environmental stresses. The availability of fodder is usually scanty during the dry season whereas there are plenty of grasses in the wet season. Proper management and storage of excess fodder in the form of silage or hay can help reduce the feed gap during the dry months and thereby ensure adequate nutritional requirements throughout the year.

Lactation length

Table 1 indicates that the overall average lactation length of the native cows was 8.62 months. This value is higher than the national average (CSA, 2011). The present results are in agreement with the reports of Anteneh (2006). Differences (*p<0.05*) in lactation lengths were observed among the farming systems. Accordingly, differences of ± 2 months were observed between the study areas of Fogera and Diga districts. The difference in lactation length between Jeldu and Fogera was observed to be ± 1.34 month. The differences in lactation length across farming system can be accounted for by both to feed, management and genotype related factors. Hence, yield can be attributed to both genetics and managerial factors as indicated before.

Table 1: Least squares means ± standard errors of milk yield in Liters and Lactation length in months.

Districts	Farming system	Milk yield of local cows				Lactation Length of local cows	
		N	*LSM ± SE*	*Min.*	*Max.*	*N*	*LSM ± SE*
Fogera	Rice-Pulse	28	1.90 ± 0.13^{a}	0.75	3.50	28	9.82 ± 0.45^{a}
	Teff-Millet	32	1.59 ± 0.11^{ab}	0.63	3.00	32	9.77 ± 0.62^{a}
Jeldu	Barley-Potato	26	1.86 ± 0.14^{ab}	0.63	3.00	28	8.18 ± 0.45^{b}
	Teff-Wheat	29	1.65 ± 0.11^{ab}	0.63	4.00	29	8.79 ± 0.48^{ab}
	Sorghum	30	1.55 ± 0.06^{b}	0.75	3.00	30	8.37 ± 0.46^{ab}
Diga	Teff-Millet	35	1.08 ± 0.08^{c}	0.34	2.50	35	7.73 ± 0.34^{b}
	Sorghum-Maize	29	1.53 ± 0.12^{b}	0.63	3.50	30	7.80 ± 0.51^{b}
Overall		**209**	**1.57±0.04**	**0.34**	**4.00**	**212**	**8.62±0.19**

Means with different superscripts within the same column (for all farming systems) are statistically different (p< 0.05).

Age of Livestock to fit service and Slaughter

Age at which livestock start providing services and also production determines the life time productivity and thus LWP values (Haileslassie et al., 2010). Table 2 indicated that the average marketing age of cattle in the study areas was 3.49±0.10 years while the average age of bull to commence traction services was estimated to be 3.88±0.05 years. Differences among the study areas were also observed. For example in the Sorghum farming system of Jeldu, cattle reach marketable age earlier (*p<0.05*) than those in the farming systems under Fogera and Diga districts. In the Diga district cattle are slow growers compared to those reared in Fogera and Jeldu districts. This is in contrast to the relatively good feed availability in Diga. Probably infestation of tsetse fly in Diga can explain the differences. Generally they reach market age at the age of 6 to 12 months later than in Fogera and Jeldu districts respectively.

Even though overall average age of slaughter in this study was comparable to the results obtained by Menbere (2005) for the *Yerer* watershed; it was also noticed that the average slaughter age of cattle at sorghum farming system of Jeldu was lower than the results reported by the same author. Similarly this study revealed a significant (*p<0.05*) difference among farming system in the age at which the bulls reach and fit for plowing. Example could be between the Sorghum and Teff-Millet farming systems of Diga.

Table 2: Least squares means ± standard errors of slaughter age and age bulls fit for service in years

Districts	Farming system	Slaughter age for cattle		Age of bulls fit service (plowing)	
		N	LSM ±SE	N	LSM ±SE
Fogera	Rice-Pulse	26	3.37 ± 0.28^{b}	26	3.90 ± 0.17^{bc}
	Teff-Millet	32	3.61 ± 0.24^{ab}	31	4.26 ± 0.12^{ab}
Jeldu	Barley-Potato	30	3.30 ± 0.24^{bc}	30	3.57 ± 0.13^{dc}
	Teff-Wheat	29	3.28 ± 0.25^{bc}	30	3.57 ± 0.10^{dc}
	Sorghum	30	2.60 ± 0.12^{c}	29	3.45 ± 0.11^{d}
Diga	Teff-Millet	35	4.20 ± 0.23^{a}	34	4.35 ± 0.12^{a}
	Sorghum	29	3.97 ± 0.34^{ab}	28	3.95 ± 0.16^{bc}
Overall		**211**	**3.49±0.10**	**208**	**3.88±0.05**

Means with different superscripts across column for all farming systems are statistically different (p< 0.05).

Table 3 indicates that the overall average marketable age for sheep and goat was 9.2 and 9.5 months, respectively. However, the values obtained in the present study was lower than those reported by Getachew (2008) for Menz sheep where the average market ages of rams and ewes were 11.3 and 11.9 months, respectively. The age of slaughter for sheep from the present study is higher than the values reported by Menbere (2005) in *Yerer* Watershed. However, differences were also observed among the study farming systems. The study also indicated that small ruminants in the Sorghum and Teff-Millet farming systems of Diga district have a higher slaughter age than the other farming systems under study. Surprisingly, small ruminants reared at Sorghum farming systems of Diga reached their market and slaughter age earlier ($p<0.05$) than those reared at Teff-Millet farming system of Diga district. On the average the slaughter age for small ruminants in the Diga district was at yearling age while in the other farming systems the small ruminants are marketed at an earlier age.

Table 3: Least squares means ± standard errors of slaughter age of Sheep and goats in months in the study farming systems.

Districts	Farming system	Slaughter age for Sheep		Slaughter age for Goats	
		N	LSM ± SE	N	LSM ± SE
Fogera	Rice-Pulse	11	7.73 ± 0.92^{b}	9	6.78 ± 0.83^{bcd}
	Teff-Millet	6	7.67 ± 0.99^{b}	20	8.80 ± 0.64^{bc}
Jeldu	Barley-Potato	27	7.11 ± 0.63^{b}	5	5.40 ± 0.75^{cd}
	Teff-Wheat	27	7.52 ± 0.76^{b}	11	5.0 ± 0.86^{d}
	Sorghum	21	7.95 ± 0.74^{b}	4	7.82 ± 0.71^{bcd}
Diga	Teff-Millet	27	13.81 ± 0.94^{a}	20	14.40 ± 1.01^{a}
	Sorghum	20	10.30 ± 1.00^{b}	10	9.50 ± 1.09^{b}
Overall		**139**	**9.15±0.39**	**79**	**9.53±0.50**

Means with different superscripts across column for all farming systems are statistically different ($p< 0.05$).
As indicated in table 4 donkeys and horses reach service at 2 and 3 years, respectively.

Table 4: Least squares means ± standard errors of age at which equines reach and fit for services (years).

Districts	Farming system	Age donkeys fit services		Age horses fit services	
		N	LSM ±SE	N	LSM ±SE
Fogera	Rice-Pulse	17	1.67 ± 0.20^{b}	-	-
	Teff-Millet	21	1.83 ± 0.27^{b}		-
Jeldu	Barley-Potato	6	2.25 ± 0.48^{ab}	22	2.86 ± 0.16^{a}
	Teff-Wheat	14	2.36 ± 0.23^{ab}	17	2.99 ± 0.25^{a}
	Sorghum	15	2.75 ± 0.18^{a}	26	3.04 ± 0.17^{a}
Diga	Teff-Millet	27	2.22 ± 0.26^{ab}	-	-
	Sorghum	19	1.95 ± 0.20^{ab}	-	-
Overall		**119**	**2.12±0.10**	**65**	**2.95±0.12**

Means with different superscripts within the same column (for all farming systems) are statistically different ($p< 0.05$).

Reproductive Performance of Livestock in the Study Areas

Age at first mating and calving for cattle

Table 5 indicate that the overall estimated average age at first service of the heifers was 45.5 months while the age at first calving was estimated to be 55.5 months. The study also indicated that the results differed ($p<0.05$) considerably among the study farming systems.

The average estimated ages at first mating of the heifers and subsequent age at first calving was shortest at the Sorghum farming system of Jeldu followed by those reared in Sorghum farming system of Diga, Teff-Millet farming system of Diga and Teff-Millet farming system of Fogera. The result of the overall age at first calving in the present study was slightly lower than the values reported by Tassew (2007).

As reported by Ruiz-Sanchez et al. (2007), early maturing heifers are better milk producers and have lower cost of maintenance, with a positive implication on LWP. The overall estimated average age at first calving as presented in Table 5, indicated that the values were higher than what has been reported by Bitew (1999) for Fogera breed reared at the *Metekel* Ranch. The difference can be attributed to better management interventions delivered in the ranch. However, the values estimated in present study are similar to that reported for *Horro* cattle reared at *Bako* agricultural research centre (Gizaw et al., 1998) and also at West *Wellega* (Tola et al., 2003).

Improved management levels along with optimum nutrition, housing and health care improves the growth rate of the heifers. This assists the animals to come in to heat at an early age, thereby lowering the age at first mating, calving and enhances life time productivity of the animals. However, the results in the present study are higher than the optimal values reported by Nilforooshan and Edriss (2004). The results indicated that introduction of exotic blood may be an option to improve the reproductive traits of the cattle, thereby help to improve the productivity of cattle and improved LWP.

Table 2-4 also indicate that the estimated age at first mating for the bulls, rams, bucks, jack and stallion and slaughter ages for bulls and small ruminants. The result for the bulls is in agreement with the observations of Tola et al. (2003) for *Horro* bulls. The age at first mating of the bulls and equines are quite high indicating delayed maturity thereby leading to more investment and lower efficiency to available feed and water. This may be attributed to inadequate attention and nutrition paid by the smallholders to the males compared to the female animals.

Table 5: Least squares means + standard errors of age at 1st mating/calving and calving interval for cattle in months.

Districts	Farming system	Age at 1st mating for heifers		Age at 1st calving		Calving interval	
		N	LSM +SE	N	LSM +SE	N	LSM +SE
Fogera	Rice-Pulse	27	44.96+1.54^{bc}	27	55.37+1.63^{b}	27	22.48+0.90^{ab}
	Teff-Millet	32	47.44+1.38^{ab}	32	59.44+1.34^{a}	32	24.22+1.00^{a}
Jeldu	Barley-Potato	29	44.07+1.29^{bc}	29	53.03+1.30^{bc}	29	19.83+1.03^{bc}
	Teff-Wheat	30	43.66+1.15^{bc}	29	52.66+1.15^{bc}	29	19.93+0.86^{bc}
	Sorghum	29	41.20+1.25^{c}	30	50.20+1.25^{c}	30	20.63+0.80^{b}
Diga	Teff-Millet	35	50.91+1.44^{a}	35	61.11+1.34^{a}	35	22.29+0.76^{ab}
	Sorghum	30	45.20+1.79^{bc}	30	55.12+1.79^{b}	30	17.30+1.01^{c}
Overall		**212**	**45.51+0.56**	**212**	**55.47+0.58**	**212**	**21.00+0.36**

N = number of respondents; SE = Standard Error; AFC = Age at first calving. Means with different superscripts within the same column for all farming systems are statistically different (p< 0.05).

Average calving interval in the present study was estimated to be 21.0 months. The values however varied between the study areas and was lowest in the Sorghum farming system of Diga and was highest at the Teff-Millet farming system of Fogera. The differences may be attributed to non genetic differences only and hence can be lowered by proper and balanced nutrition besides other management interventions. However, the age at first calving is lower than the values reported by Tola et al. (2003) for *Horro* cattle.

The overall average age of first service for ewes and does was comparable to the reports of Gizaw et al. (1995) for *Horro* ewes and lower than the values reported by Mukasa-Mugerwa et al. (1994) for Menz sheep. The overall average age at first kidding and lambing in the study areas were lower than the values assessed by Otte and Chilonda (2002).

Life time reproductive performances of different livestock species

The overall estimated average life time reproduction of cows, does, ewes, mares and Jennies are presented in Table 6. It indicates the average estimated number of off-springs delivered by a cow, doe, ewe, mare and jenny. This result as obtained is in agreement with the results published by ILCA (1990) for African domestic livestock. The average total numbers of offspring's is an indication of the productivity of the livestock and also is fall out of optimum physiological activity, thereby highlighting the efficiency of utilization of invested water.

Table 6: Least squares means + standard errors of lifetime young production (number) by the different livestock species.

Districts	Farming system	Number of young produced in life time									
		Cow		Ewe		Doe		Jenny		Mare	
		N	LSM +SE	N	LSM +SE	N	LSM +SE	N	LSM +SE	N	LSM +SE
Fogera	Rice-Pulse	27	5.8+0.3	7	24+3.8	3	17.2+7.4	9	14.0+0.9	-	-
	Teff-Millet	32	5.1+0.3	1	9.5+9.5	17	19+2.1	16	10.4+1.3	-	-
Jeldu	Barley-Potato	29	5.6+0.2	25	10.2+0.9	3	13.2+4.2	4	8.1+1.4	19	10.1+1.1
	Teff-Wheat	29	5.8+0.3	24	10.9+1.1	1	9.0+9.0	9	9.7+1.7	25	10.3+0.8
	Sorghum	30	6.5+0.4	11	8.4+0.7	4	10+2.1	11	7.8+1.1	8	9.9+1.5
Diga	Teff-Millet	35	6.8+0.3	24	7.6+0.7	13	9.4+0.9	7	8.9+1.9	-	-
	Sorghum	30	8.1+0.4	14	11.8+1.7	2	5.3+1.8	9	11.8+1.4	-	-
For all farming systems		**212**	**6.3+0.1**	**106**	**10.7+0.6**	**43**	**14.0+1.3**	**65**	**10.3+0.6**	**52**	**10.1+0.6**

Means with different superscripts within the same column (for all farming systems) are statistically different (p< 0.05).

Livestock Off-take rates

The results of the overall off-take rates for cattle, sheep, goats, donkey and horse are presented in Table 7. There was significant difference (*p<0.05*) in the off take values of cattle among the study farming systems. Higher off-take rates for cattle were observed in Teff-Millet Fogera and Sorghum farming systems of Jeldu. Off-take rates for sheep in Rice-Pulse –Fogera, Sorghum farming system –Diga were significantly higher than (*p<0.05*) off-take rates of sheep in Teff-Millet –Diga. The finding of the present study was in agreement with the observations of Menbere (2005) but lower than what is reported in EPA (2002). However, Dibissa (1990) reported an annual off-take of 18.4 and 7.3% in sheep flocks raised in highlands of Ethiopia which could be attributed to both livestock sales and home consumption. These lower off-take values for different livestock in the study areas have two implications: the low growth rate of the animal and sharp increase in population and thus adversely affect LWP.

Table 7: Least squares means ± standard errors of off-take rates (%) for cattle, sheep /goats and equine in the study area.

Districts	Farming System	Off-take rates									
		Cattle		Sheep		Goats		Donkey		Horses	
		N	LSM ± SE	N	LSM ± SE	N	LSM ± SE	N	LSM ± SE	N	LSM ± SE
Fogera	Rice-Pulse	29	6.0 ±1.45[ab]	10	35.5 ± 11.5[a]	4	40.3 ± 14.2	13	3.8 ± 3.8[b]	-	-
	Teff-Millet	32	10.8 ± 2.1[a]	2	15.0 ± 15.0[ab]	17	17.2 ± 3.8	20	19.2 ± 7.5[a]	-	-
Jeldu	Barley-Potato	29	3.9 ± 1.3[bc]	29	19.3 ± 3.5[ab]	4	12.5 ±12.5	6	0.0 ± 0.0[c]	24	5.6 ± 2.7[a]
	Teff-Wheat	29	8.4 ± 2.0[ab]	23	15.9 ± 3.7[ab]	2	41.7 ± 25.0	11	4.8 ± 3.4[b]	26	3.7 ± 2.2[a]
	Sorghum	29	10.6 ± 2.2[a]	12	22.2 ± 9.1[ab]	4	16.7 ± 9.6	13	11.5 ± 7.9[ab]	13	0.00
Diga	Teff-Millet	34	6.8 ± 1.8[ab]	19	8.00 ± 3.9[b]	7	14.7 ± 7.7	14	5.3 ± 5.3[b]	-	-
	Sorghum	31	9.7 ± 3.4[ab]	13	25.6 ± 10.5[a]	2	25.0 ± 25.0	19	0.0 ± 0.0[c]	-	-
Overall		213	8.1 ± 0.80	113	18.6 ± 2.4	40	20.2 ± 3.4	96	7.7±2.3	64	3.1±1.8

N = number of respondents; SE = Standard Error, Means with different superscripts across the same column (for all farming systems) are statistically different (p< 0.05)

Livestock water productivity

Tables 8 revealed that there were no significant differences in LWP among the study districts and systems. However, our results for all farming systems revealed that there were a huge gap between the minimum and the maximum LWP values. More interesting is a huge gap between the minimum (0.001) and maximum values (>0.6 USD /m^{-3}) of LWP. It can therefore be suggested that there is huge gap between the potential and actual LWP.

Two major points can be drawn from the present study of LWP: LWP in all study areas is low because of poor returns from the livestock sector including slow growth and high mortality as in the observations by Negassa and Jabbar (2008) which account to low off take and ultimately total beneficial outputs. Obviously, high evapotranspiration and low biomass yield also contributed a lot. On the other hand, there are LWP study results based on data from controlled experiment which suggests higher value LWP as indicated in Gebreselassie et al. (2009). From this it can be concluded that there are ample opportunities to improve LWP. Descheemaeker et al. (2010) indicated that prevailing poor veterinary coverage, un organized and poor extension services, traditional livestock management practices, agronomic practices for cultivation of fodder processing of the feed resources and marketing intelligence and support affect the LWP either directly or indirectly and if improved can surely promote livestock sector and associated livelihoods and ecosystem health.

Table 8: Least squares means ± standard errors & ranges of LWP estimates for different farming systems (USD m^{-3} water)/HH/year

Farming Systems	N	LWP		
		LSM ± SE	Minimum	Maximum
Rice-Pulse	30	0.15±0.02	0.01	0.30
Teff-Millet	32	0.18±0.01	0.07	0.35
Barley-Potato	31	0.15±0.02	0.00	0.63
Teff-Wheat	30	0.16±0.01	0.01	0.43
Sorghum	30	0.16±0.02	0.03	0.37
Teff-Millet	35	0.19±0.02	0.00	0.48
Sorghum	32	0.16±0.02	0.02	0.38
For all farming systems	220	0.16±0.01	0.001	0.63

Compressions were made within column for farming systems; letters with different superscript within column shows significant differences at p<0.05.

CONCLUSION AND RECOMMEDATION

Production and reproduction performances of livestock were low and variable among the different farming systems. Lower milk yield & shorter lactation lengths, higher age at mating & calving, longer parturition intervals for female animals and higher age at first effective mating for breeding purposes by the bulls, jack & stallion were observed. Higher mortality and low off-take rates for different livestock species were observed. Variability between minimum and maximum values observed in this study are major indicators of potential to improve production and reproduction traits and therewith LWP.

Values of LWP across the study systems were lower and the differences among systems were not as such apparent. More interesting is a huge gap between the minimum (0.001) and maximum values (0.627 USD m^{-3}) of LWP. It can be concluded that there is huge potential to improve LWP in mixed crop livestock systems of the BNB through:

- **Enhancing animal productivity and reducing herd sizes**: Establish community based veterinary services & other infrastructural facilities, upgrading the genetic potential of native breeds by introduction of selective breeding, community based livestock improvement schemes and better husbandry techniques.
- **Improve off-take rates reduce mortality and morbidity rates and this improves LWP**
- **Improve access** to watering point, feed conservation practices, pasture and grazing land management; delivery of improved fodder/housing, indoor feeding, cut and carry system, and tethering of livestock, should be encouraged for the betterment of livestock production, productivity and thereof LWP.

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