IJASRM International Journal of Advanced Scientific Research and Management, Vol. 1 Issue 3, March 2016.
www.ijasrm.com
ISSN 2455-6378

Increasing Agricultural Water Productivity through Improved Access to Animal Power in the Ethiopian Highlands

A case study from Fogera, Diga and Jeldu Districts (Ethiopia)

Ayele Abebe [1]

[1] Hawassa University, Awassa College of Agriculture, Hawassa, Ethiopia

Abstract

The study about access to animal power & its implication on Livestock Water Productivity (LWP) was conducted in the rain-fed crop-livestock systems 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. In the study areas, the major objective of livestock keeping was draught power. The average number of days oxen were used for tillage and threshing was about 132 and 7 days, respectively. There was significant ($p<0.05$) difference in the number of days oxen were used for tillage purpose among the different farming systems. The present study identified that donkeys were used for 173 days in a year for marketing, transporting crops to home & fetching water, while horses were used for 60 and 47 days for transporting merchandize & human, respectively. The average value of LWP per HH per year obtained in this study was 0.16USD/ m-3. Values of LWP across districts & farming systems did not show significant differences ($p>0.05$) which can be accounted to low total beneficial outputs ultimately by the low power & production efficiencies. More interesting was a huge gap between the minimum (0.001) & maximum values of LWP (0.627 USD/ m-3).

Although sufficient draught power is one of the determinant factors for timely performances of cropping activities & therefore positive influences on crop water productivity & LWP, contrastingly the fact that oxen are usually providing power for only fraction of a year whereas fed throughout the year might have reduced their benefits & water cost ratio: lower LWP. Therefore, mechanism for improving the efficiencies of draught power must be sought. It can be concluded that there is huge potential to improve LWP in mixed crop LS systems of the BNB & improving animal power efficiency could have the higher share.

Keywords: *Animal power, Livestock water productivity, Farming systems, Rain-fed*

1. Introduction

The contribution of livestock in the mixed crop livestock production systems is so immense. Farm power needs like cultivation, threshing, water lifting and transport of goods is obtained from the different livestock species. To this end, draught animals contribute significantly to agricultural livelihoods of smallholder farmers and provide more than 80% of farm power in Sub-Saharan Africa (Amede, 2010). In Ethiopia, rearing oxen for draft purposes is rarely efficient because they are used for about 14-50% of the year by the poor and better-off farmers, respectively, but must be fed year round (Abebe et al., 2012, Mekonnen, 2009, EARO 2000).

Although domestic livestock provide multiple products and services, farmers' highest priority for them is often draught power. However, these farmers must overcome several challenges in their efforts to access sufficient animal power to meet their needs. Key constraints include feed shortages and animal diseases (Wuletaw, 2004; Anteneh et al., 2010, Abebe et al., 2012). Similarly, Eba et al., 2012 in their study have discovered that livestock production, productivity and efficiency of animal power are mainly affected by feed shortage (quantity and quality), livestock diseases,

IJASRM
International Journal of Advanced Scientific Research and Management, Vol. 1 Issue 3, March 2016.
www.ijasrm.com
ISSN 2455-6378

and shortage of initial capital and poor genetic makeup of foundation stock. Abebe et al., 2012 in their study at the Blue Nile Basin (BNB) have disclosed that the most important diseases that hinder livestock's productivity and animal power delivery in the Blue Nile Basin included, Trypanosomiasis, Anthrax, Blackleg, internal and external parasites; a situation that invoke to an increase in livestock morbidity and mortality necessitating keeping more animals to meet farm power requirements.

Demands for land, feed, and water required to sustain draught animals also compete with other potential uses for these resources. One key development challenge is the identification and adoption of options that enables farmers to meet their farm power requirements while reducing the land, feed, water and labour costs of doing so. (Eba et al., 2012; Mekonnen, 2009) in their studies have noticed the higher labour requirement and related costs needed to herding, feeding and management of draught animals that are only used for a short period of time (97 to 184) days per year.

According to Abebe et al., 2012, under the current settings of the purpose of livestock management in the Blue Nile Basin, traction is important. Mekonnen (2009) in her study at *Lencha Dima* watershed declared that much of the beneficial outputs valued for the livestock mainly were accounted from their traction and transport services. But this is only part of the year (3-4 months). A farmer has to feed, spend time and labor in herding and managing the ox for the rest of the year free. This is high investment in terms of resources and water. For improved water productivity emphasis should be given towards efficient utilization of farm power obtained from the livestock to ensure all the broader livelihoods services provided by livestock, which represent, inter alia, a source of food, income, manure, draught power and hauling services, savings, insurance and social capital.

Improved access to the desired animal power could be obtained through use of improved breeds for traction, maintaining animal's health, multiple uses of the different animals, employing better animal feeding systems and improving farm equipments Therefore, this work was undertaken to access the current animal power delivery status and its implication for improved agricultural water productivity in the highlands of Ethiopia.

Objective

- To access the current animal power delivery status in the Ethiopian highlands;
- To analyze and contextualize implications of current animal power delivery status on livestock water productivity*;*

2. Materials and Methods

2.1. Location and biophysical characterization of the study sites

The highlands of the 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).

2.2. 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 performances, livestock service delivery etc. were prepared, pretested and implemented.

2.3 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.

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

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).

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.

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.

Harvest index value from literature was used to estimate the amount of crop residues from grain yield.

Crop residues yield (kg) = Conversion factor * grain yield (kg/yr). Conversion factors established by FAO (FAO, 1987) and other sources from literature were used.

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).

Used for feed (kg) = Total residue or grass available (kg) * use factor%

Evapotranspiration and total water requirement

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

ETcrop = (ETo in farming system * Kc factors)

Total water requirement

GP = Growing Period for each crop and feed resource were obtained from literature and district agricultural office.

Total Crop Water Requirement (CWR)/ m^3/ annum = (ETm * GP) * area (m^2)

Residues CWR/ m^3/ annum = (Total CWR/ m^3/ annum * harvest index) * use factor%

Grass CWR/ m^3/ annum = (Total CWR/ m^3/ annum * % total grass yield) * use factor%

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

[1] Kebele is the smallest administrative unit in Ethiopia

ISSN 2455-6378

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 * TLU2[1] 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.

Livestock Outputs

Milk Yield

To calculate the total milk yield the following data were generated

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

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

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.

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.

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

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

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.

Traction animal Nr * Traction Values (ETB) * Time spent

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

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

2.4 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 Packages for Social Sciences ((SPSS) version 16.0, 2007)) and Excel for windows 2003 were used to enter and summarize the data. The Least-squares means (LSM) and standard errors (SE) for quantitative characters at each level of the fixed factors were analyzed by PROC GLM procedure (SAS 9.1) and separated statistically using the PDIFF option of SAS (2003). An index was calculated to provide overall ranking of the preferred livestock species reared according to merit.

Model: Yijk = μ + Fi + εi. Where,
Yijk = Dependant variable

[1] A TLU is equivalent to 250 kg live weight of tropical livestock.

(TLU, number of service in days, traction value, beneficial output, 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

3. Results and Discussion

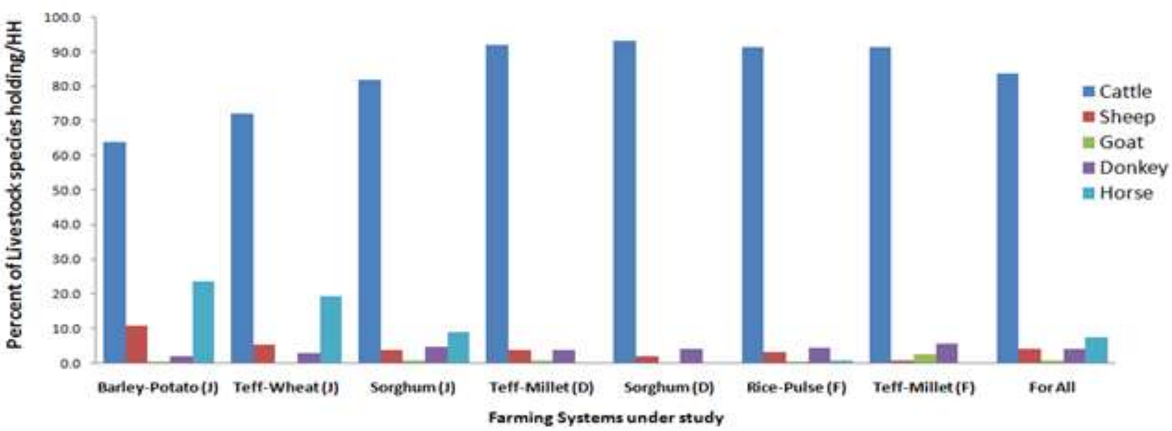
3.1. Livestock holding and species composition

The average numbers of livestock holdings per HH is presented in Table 1. It shows that Tropical Livestock Unit (TLU) values ranged between 5.61 and 9.25 per HH. The highest value was estimated for Teff-Wheat farming system. More numbers of livestock were observed in the Jeldu district compared to the other two districts.

Livestock species composition varies across the study systems but consistently cattle were the major livestock species (Figure 1). The result of the present study was in good agreement with the findings of Anteneh (2006) from Fogera area. The composition of herd generally suggests that farmers depend mainly on crop husbandry and cattle rearing, the latter being a power house for the former.

The proportions of oxen and steers constituted a lion share (51%) and wide ranges were observed among farming systems (48-60%) probably which can be accounted for by to intensification of crop production practices and the benefits obtained from the services from male animals. The point here is as to whether the differences in herd composition will strongly affects the level of LWP and also to understand the optimum combination of livestock species to achieve optimum values from services and higher LWP values

Figure1: Proportions of different livestock species in the study areas (TLU.)



3.2. Livestock Husbandry Practices

3.2.1. Purpose of keeping livestock

Cattle were the most important component of herd in the study areas. In the study areas, the major objective of livestock keeping is draught power and this is consistent with Descheemaeker (2010). Table 1 indicated that oxen were reared primarily for draught power followed by income from sales, manure production and insurance. Meat and dowry/prestige from oxen/cow ranked 4^th. The result obtained in this study is similar with that noted by earlier authors Tasew (2007), Bogale (2004) and Wuletaw (2004).

ISSN 2455-6378

Table 1: Purpose of keeping oxen by the study respondents in the study areas

Purpose of keeping oxen	Rank 1st	Rank 2nd	Rank 3rd	Rank 4th	Index	Ranks
Plow and thresh	219	3	0	0	0.43	1st
Income source	1	128	62	9	0.25	2nd
Manure	0	69	94	25	0.21	3rd
Meat/Insurance /Prestige	0	11	55	79	0.11	4th
Total	220	211	211	113		

Index= sum of [4 X number of HHs ranked 1st + 3 X number of HHs ranked 2nd + 2 X number of HHs ranked 3rd + 1 X number of HHs ranked 4th] for each purpose of keeping oxen divided by sum of [4 X number of HHs ranked 1st + 3 X number of HHs ranked 2nd + 2 X number of HHs ranked 3rd + 1 X number of HHs ranked 4th] for all purpose of keeping Oxen.

Table 2 indicated that equines were primarily raised for transportation of both people and agricultural inputs and outputs. The results are similar with the reports of Yitaye (1999) and Bogale (2004). In their study (Starkey et al., 1994) have noticed that large numbers of pack donkeys are used in Ethiopia, particularly, in the highland areas; they carry fuel wood, building materials, fodder for animals and goods for marketing. The different types of livestock species provide multipurpose benefits to the community and the benefits obtained from services is higher than the products (Table 1, 2).

Table 2: Purpose of keeping equines by the study respondents in the BNB

Purpose of keeping equines	Rank 1st	Rank 2nd	Rank 3rd	Index	Ranks
Transportation	144	9	2	0.50	1st
Income/Replacement	10	92	84	0.33	2nd
Manure	2	47	52	0.17	3rd
Total	156	148	138		

Index= sum of (3 X number of household ranked first + 2 X number of household ranked second + 1 X number of household ranked third) given for purpose of keeping equine divided by sum of (3 X number of household ranked first + 2 X number of household ranked second + 1 X number of household ranked third) for all purpose

3.3. Animal power delivery status

Table 3 indicates that, in the study area, an ox is used for an average of 132 days for plowing purpose. The values however range between 123 days in the Sorghum farming system of Jeldu district and 140 days at Teff-Millet farming systems of Fogera district. The average numbers of days oxen are used for the purpose of threshing was about 7 days. The values range between 3 days at Teff-Wheat farming system at Jeldu to 12.5 days at Rice-Pulse farming systems of Fogera. It was also observed that equines (horses) were used for threshing purpose especially in the Barley-Potato, Teff-Wheat and Sorghum farming systems of Jeldu. The studies indicated that on average the horses were used for 3-5 days for threshing purpose.

There was significant (*$p<0.05$*) difference in the number of days oxen were used for plowing purpose which of course varied according to the prevailing farming system. In the Teff-Millet farming system (Fogera) oxen were used considerably for higher number of days while they were used for least number of days in the Sorghum farming system of Jeldu, however, no significant differences were observed among the rest of the farming systems. Significant (*$p<0.05$*) differences were also observed in the number of days oxen were used for threshing in the studied farming systems. Oxen were used for 11-13 days in Fogera while they were used for only, 3-5 days in the rest of the farming systems.

From the present study it can be concluded that oxen were grossly underutilized. Results obtained in this study were similar with the reports of EARO (2000) which was 131 days in the highland of *Ginchi*. However, lower values were reported by Gryseels and Anderson (1986). The findings of the present study are in line with the observations of Mekonnen, (2009) at *Lenchedima* watershed. This may be is attributed to the use of oxen for draught purposes only in the cropping and harvesting seasons. Normally oxen are kept for more number of days without any appreciable work. This indicates also huge water cost of keeping draught oxen at the farm throughout the year (Agymang et al., 1991). As suggested by Astatke et al., 2001 if improved animal-drawn implements are utilized for additional farm power needs by farmers and intensified it assists in utilizing the animal power for more number of days in a year signifying the benefits obtained from the draught animals and improve efficiency of water utilization through animal feed.

Table 3: Least squares means ± standard errors of number of days the Oxen were used for different activities

		Oxen			
Districts	Farming system	Tillage		Threshing	
		N	LSM ± SE	N	LSM ± SE
Fogera	Rice-Pulse	30	134.8^{ab}±4.8	30	12.5^{a}±1.3
	Teff-Millet	30	140.0^{a}±5.1	31	11.1^{a}±0.9
Jeldu	Barley-Potato	27	134.3^{ab}±6.9	11	4.6^{b}±0.6
	Teff-Wheat	29	130.6^{ab}±4.0	23	3.1^{b}±0.4
	Sorghum	30	123.4^{b}±6.3	27	3.7^{b}±0.3
Diga	Teff-Millet	35	131.5^{ab}±5.1	35	5.2^{b}±0.5
	Sorghum	30	131.8^{ab}±4.1	30	5.1^{b}±0.6
For all farming		**210**	**132.4±1.9**	**187**	**6.8±0.4**

Comparisons were made among the different farming systems along the column, significant at (p<0.05)

Considering the size of land holdings, the characteristics of the terrain and the economic conditions of the farmers' animal power is likely to continue to play an important role on smallholder farms of the BNB. Research experiences in the highland of Ethiopia suggest that the use of crossbred dairy cows for milk production and traction as an option to alleviate the existing farming problems, which would allow for a better feed utilization by the different classes of livestock available at the farm (Alemayehu et al., 1999).

Although sufficient draught power is one of the determinant factors for timely performances of cropping activities and therefore positive influences on crop water productivity and LWP, contrastingly the fact that oxen are usually providing services for only fraction of a year whereas fed throughout the year might have reduced their benefits and water cost ratio: lower LWP. Therefore, mechanism for improving the service efficiencies of draught power must be sought. In general, the result of this study was consistent with Mukasa-Mugerwa (1989) in the central highland of Ethiopia and Alemayehu et al., (2001) in southern region, Laval and Workalemahu (2002) in West *Wollega* and Tasew (2007) in *Bahirdar-Zuria* and *Mecha* districts.

Table 4 indicates that donkeys were used for several purposes which included marketing, transporting crops to home and fetching water. The present study also identified that donkeys were used for 173 days in a year. The results of this study are in good agreement with observation of Mekonnen (2011) in the *Lenche Dima* watershed. Generally it can be concluded that the service currently rendered by the livestock is by far lower than the potential they can offer. If multiple uses with accompanying technologies could be put in place farmers need obviously less livestock for the traction and threshing. This reduces the volume of water invested in feed and increase LWP.

Table 4: Least squares means ± standard errors of number of day equines was used for different activities

	Donkey								Horses					
Farming system	For marketing		Crop transport		Fetching water		Milling		*For Threshing*		*Transport Merchandise*		*Transport human*	
	N	LSM ± SE	N	LSM ± SE	N	LSM ± SE	N	LSM ± SE	*N*	*LSM ± SE*	*N*	*LSM ± SE*	*N*	*LSM ± SE*
Rice-Pulse	12	33.3±3.6	11	6.5±1.2	1	122.0±0.0	12	13.9^{d}±1.5	-	-	-	-	1	50.0±0.0
Teff-Millet	16	25.8±3.5	15	8.3±2.4	3	122.0±0.0	20	20.3^{bcd}±2.4	-	-	-	-	-	-
Barley-Potato	5	21.0±8.9	4	6.8±1.8	5	107.2±14.8	5	21.6^{bcd}±2.4	22	5.4^{a}±0.5	19	67.7±10.7	23	61.2±10.7
Teff-Wheat	11	25.9±4.8	9	5.9±2.4	9	122.0±0.0	11	18.7^{cd}±1.9	26	4.2^{ab}±0.5	20	62.0±12.2	24	39.3±7.4
Sorghum	11	35.7±8.4	6	11.0±7.4	6	122.0±0.0	13	29.1^{ab}±3.7	9	3.1^{b}±0.5	10	41.5±7.9	12	33.5±5.6
Teff-Millet	17	19.3±3.6	17	6.9±1.7	5	102.4±19.6	16	31.5^{a}±3.6	-	-	-	-	-	-
Sorghum	10	25.8±5.4	12	6.5±1.1	11	113.5±7.0	14	25.1^{abc}±2.9	-	-	-	-	-	-
For all farming systems	**82**	**26.6±1.9**	**74**	**7.2±0.9**	**40**	**115.4+3.5**	**91**	**23.3±1.3**	**57**	**4.5±0.3**	**49**	**60.0±6.7**	**60**	**46.7±5.3**

(*Comparison was made across column only for the different districts, supper scripts with different letters indicate significance at (p<0.05)*)

3.4. Livestock water productivity

The average value of LWP per HH per year obtained in this study was 0.16 USD m^{-3}.Values of LWP across districts and farming systems did not show significant differences ($p>0.05$) (Table 5). The beneficial livestock outputs and power assessed in terms of monetary values (USD) was highest in Teff-Wheat farming system of Jeldu followed by Teff-Millet farming system of Fogera (1092 and 906), while the lowest value (679) was assessed in Teff-Millet at Diga district. But LWP value is the function of both depleted water and beneficial outputs and thus beneficial outputs alone does not determine LWP (Haileslassie et al. (2009a).

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, livestock power access only for few days per year as in the observations by Jabbar and Negassa (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, use of cows as alternative draught power and use of improved animal-drawn implements affect the LWP either directly or indirectly and if improved can surely promote livestock sector and associated livelihoods and ecosystem health.

Table 5: Least squares means $\pm$ standard errors & ranges of LWP estimates for different farming systems (USD m^{-3} water)/HH/year

Farming Systems	N	LWP		
		LSM $\pm$ SE	Minimum	Maximum
Rice-Pulse	30	0.15$\pm$0.02	0.01	0.3
Teff-Millet	32	0.18$\pm$0.01	0.07	0.35
Barley-Potato	31	0.15$\pm$0.02	0	0.63
Teff-Wheat	30	0.16$\pm$0.01	0.01	0.43
Sorghum	30	0.16$\pm$0.02	0.03	0.37
Teff-Millet	35	0.19$\pm$0.02	0	0.48
Sorghum	32	0.16$\pm$0.02	0.02	0.38
For all farming systems	220	0.16$\pm$0.01	0.001	0.63

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

4. Conclusion

In view of the current trends of livestock service delivery status in the mixed crop livestock production systems of Blue Nile Basin and its implication for LWP, the following preliminary conclusions can be drawn:

In the study areas teff, barley, wheat, rice, finger millet, maize, sorghum based farming systems were dominant and the services needed and delivered by the existing livestock for cultivation and transportation purposes are so immense. The objective of integrating livestock into crop is mainly for power. Across the study areas oxen were reared for the purpose of traction followed by income source & manure, respectively. The main purpose of equine was transportation. Farmers' production objective is not market oriented and they are more focused on assisting crop production activity. Services delivered by livestock were low and variable among the different farming systems. Variability between minimum and maximum values observed in this study is major indicator of potential to improve service efficiency and therefore 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 of LWP (0.627 USD m^{-3}). It can be concluded that there is huge potential to improve LWP in mixed crop livestock systems of the BNB and improving efficiency of livestock power could have the higher share. The objectives of crop livestock integration should not be only short term economic return and only service provision oriented. Integration must take environment into account. It would be imperative if future research can explore on how much water can be saved only by focusing on improvement of animal power efficiencies and also policy incentive mechanisms to transform current livestock production objectives.

Acknowledgments
This paper arises from a project called "Nile Basin Development Challenge". The authors like to acknowledge the generous financial support from the Challenge Programme for Water and Food (CPWF) and ILRI/IWMI.

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