Water Balance in Crop-Livestock Farming System in Lenche Dima Watershed, Gubalafto Woreda, Amhara Region

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Abstract

This study was undertaken to investigate the water balance of crop-livestock farming system in Lenche Dima watershed, Gubalafeto Woreda, North Wello zone, Amhara Regional State. The water balance has two components: the water supply component (rainfall, ponds and ground water) and water demand component (crops, livestock and domestic use). Based on meteorological, crop, and soil data, the crop water requirements were calculated using CROPWAT software. Additionally, a total of 120 households were randomly selected and surveyed for evaluating the water demand and supply of livestock and domestic use including socio-economic characteristics of the watershed. The standard deviation and coefficient of variation of the rainfall ranges from 18 to 75mm and 41 to 94%, respectively, indicating the uncertainty in rainfall over the study area. Results show that the seasonal crop evapotranspiration (ET_c) and effective rainfall in the watershed area are 652 and 419 mm for sorghum, 371 and 300 mm for tef, 307 and 177 mm for chickpea, and 731.1 and 403 mm for maize. Hence, seasonal water shortage was observed for all of the crops. On the other hand, the total depleted water in the watershed for feed production is 6.46 mill. m^3 $year^{-1}$ and water consumption for livestock is 36677 m^3 $year^{-1}$ summing up to 6.49 mill. m^3 $year^{-1}$. The total domestic water use is about 11065 m^3. The water supply for domestic use was from ground water estimated to be 11408 m^3. The results also show a discrepancy between water supply and demand in the crops-livestock farming system. Crops and vegetation have by far the largest user of the water that is 14.34 mill. m^3 (95%), whereas domestic use is the lowest (11,065 m^3, 0.36%).

The estimated water supply from rainfall, ponds and water pumps for domestic and livestock use are 10.79 million, 10,632 and 11,408 m^3 respectively. Comparison of supply and demand shows that water availability is significantly lower than the demand. The supply is covering only 75% of the water demand in the watershed. This indicates that the water needs for the production of crops, livestock and domestic water use are not adequate. Therefore, to mitigate the shortage of water in the watershed, development of rain water harvesting technologies, growing low moisture demanding crops, improving the vegetation cover, enhancing soil and water conservation are suggested to promote productivity and sustainable intensification of the rain fed agriculture.

Key words: Water balance, Crop-livestock water requirement, Lenche Dima

Introduction

In Ethiopia, agriculture is mainly rain-fed, subsistence and small scale with low input use, which often leads to low productivity. This is further aggravated by water shortage due to shortage of rainfall and land degradation caused by excessive soil erosion. Rainfall is the major source of agricultural water and most important environmental factor limiting agricultural activities in the arid and semi-arid regions of the tropics. Rainfed agriculture is still the dominant practice in most developing countries. Soil moisture management in semi-arid and arid areas of the tropics is faced with limited and unreliable rainfall and high variability in rainfall pattern (Kipkorir, 2002). Even though the country has huge water resources, water is a very scarce commodity for many of the smallholder farmers and their livestock, and the situation is aggravated by seasonal variations in availability of water (Zinash Silesh *et al.*, 2003).

As noted above, rainfall in Ethiopia is characterized by high degree of spatial and temporal variability. The rainfall is highly variable both in amount and distribution across regions and seasons (Mersha Engida, 1999). The seasonal and annual rainfall variations are results of the macro-scale pressure systems and monsoon flows which are related to the changes in the pressure systems (NMSA, 1996).

To alleviate the above stated problems and to increase production, water balance study (supply-demand gap analysis) is needed to determine the deficiency of water in crop-livestock farming system at watershed scale. Water scarcity due to the unpredictable, spatial and temporal variability of rainfall and its relationship to food security rationalize the need for conserving all the available water resources. In this respect, there is special need for determination of the different water balance components in relation to the temporal and spatial distribution of water supply and demand for enhanced livelihoods of farmers. Therefore, the overall objective of the study was to determine the water balance in crop livestock farming systems for the Lenche Dima watershed. And the specific objective was to estimate the water demand and supply components for crop and livestock production and the water balance for the whole watershed area.

Materials and Methods

Description of the Study Area

The study was conducted in Lenche Dima watershed in Gubalafeto Woreda, in North Wello zone of Amhara Regional State. Geographically, the watershed extends from 22 5: 24‘ ! up! 22 62 68‘ ! O! mbujuvef! boe! gspn ! 4: 51 18‘ ! up! 4: 55 33‘ ! F! mpohjuvef/! Uif! watershed drains to Alewuha River and eventually into Awash River Basin (Figure 1). The climate of the watershed is characterized by dry sub humid with 687 mm mean annual rainfall (NMSA, 2008) and mean monthly maximum temperature of 32^{o}C in June and the mean monthly minimum temperature of 12^{o}C in November (Figure 2). The rainfall distribution is bimodal with a small rainy season during March - May (*Belg*, with a mean of 140 mm*)* and main rainy season during July October (Kremt, mean 421 mm) (NMSA, 2008). The rainfall is characterized by intense erosive storms with high temporal and spatial variability. Even during normal non-drought years, the area suffers from recurrent dry spells (Solomon Gizaw *et al*., 1999).

The major soils of the Lenche Dima sub-watershed are Regosol, Leptosol, Luvisols, Vertisols and Fluvisol. Regosol and Leptosols are formed on high gradient dissected hills and mountains (> 30% slopes), covering 508 ha. The soils of the lower foot slopes (8-15% slope) and the upper foot slopes (15-30% slope) are classified as Vertic Luvisols and Regosols, respectively with a total of 371 ha. Most of the cultivated lands (2-5% slope) are covered by Vertisols of area 544 ha. The plain area (0-2% slope) which receives fresh alluvial sediments at regular intervals is dominated by Fluvisols with an extent of 123 ha (FAO, 1998).

Methods of Data Collection

Pre-tested questionnaires, group discussion, interview of key informants, field soil sampling and laboratory analysis and secondary data were used for data collection. Bulk density from 0-30cm and 30-60cm depths with two replications was determined using core-sampling method (BSI, 1975). The samples were oven dried at 105 ^{0}C to constant weight for 24 hours in laboratory. Then the dry weight was measured, and bulk density was calculated as:

$$\text{Bulk density } (P_b) = \frac{mass\ of\ dry\ soil}{bulk\ volume\ soil} \qquad (2)$$

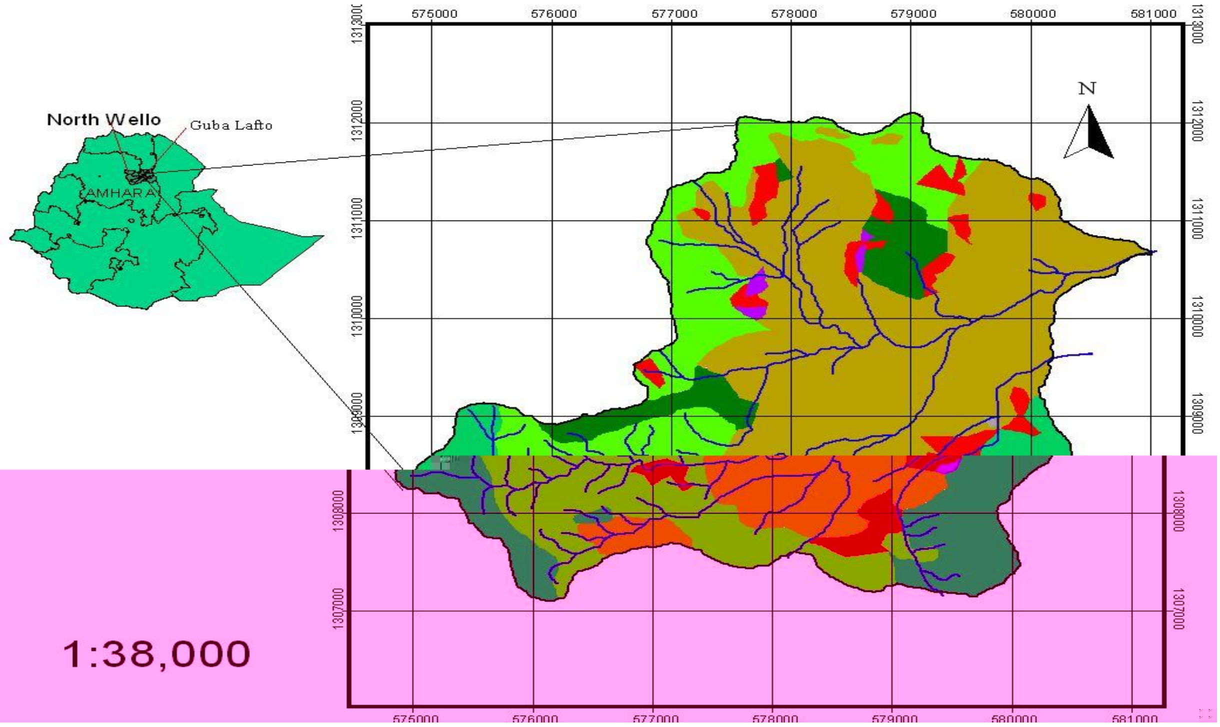

Figure 1. Location map of Lenche Dima Watershed

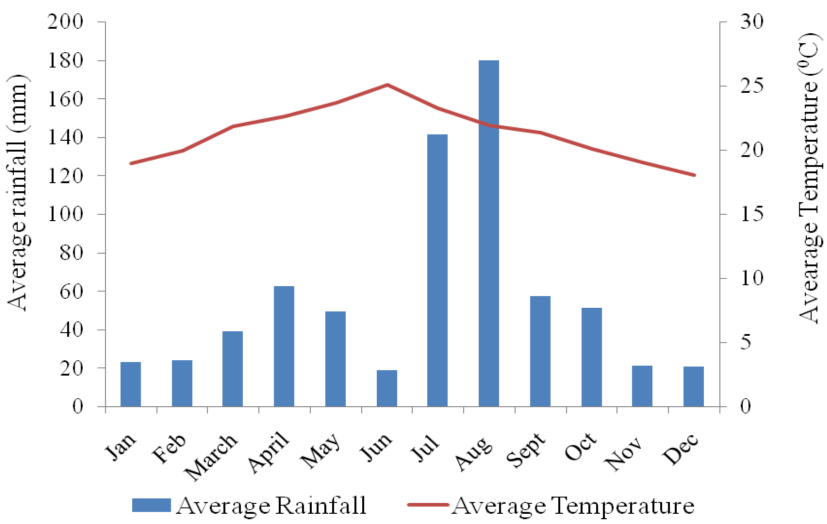

Figure 2. Mean monthly rainfall and temperature (1976-2007) for Lenche Dima watershed

The moisture content on weight basis of each soil samples was calculated using the following equations (FAO, 1987; Kamara and Haque, 1991)

$$W\% = \left(\frac{Ww - Wd}{Wd}\right) * 100 \quad \text{..} \quad (2)$$

Where:

W % = soil water content on a dry weight basis, %

$\mathbf{W_w}$ = wet weight of the soil, g

$\mathbf{W_d}$ = dry weight of the soil, g

Ui f! n pjtuvsf! dpoufout! jo! wpmvn f! c btf t!) ! !pg ui f! t pjm! dpmmfdufe! gspn ! ui f! gbsn fst ! fields at different depths were determined.

$$\text{Soil moisture content } (\theta\%) = (W\% \times P_b) \quad \text{...} \quad (3)$$

The normal ratio method was used to estimate the missing rainfall data (Dingan, 2002). This approach enables to estimate missing data by weighing the observation at five stations by their respective annual average rainfall values and expressed by the equation;

$$P^0 = \frac{1}{G} \times \sum \frac{Po}{Pg} \times PG \quad \text{//. (4)}$$

Where

P^o = the missing data

P_o = the annual average precipitation at the station gauge with missing data

Pg = monthly rainfall data in station for the same month of the missing station,

P_G = annual average of neighboring station

Rainfall over arid and semiarid areas present difficulties not only due to its insufficient amount but also due to the inherent degree of variability associated with it. In order to indicate month to month and year-to-year variability of the rainfall for the selected station, percent deviation and coefficient of variation from the mean were used. These were calculated as follows:

$$\%\text{Deviation}(\text{annual}) = \left(\frac{\text{Annual rainfall} - \text{Mean annual rainfall}}{\text{Mean annual rainfall}}\right)*100 \text{ --------- } (5.1a)$$

$$\%\text{Deviation}(\text{monthly}) = \left(\frac{\text{Monthly rainfall} - \text{Mean monthly rainfall}}{\text{Mean monthly rainfall}}\right)*100 \text{ ---- } (5.1b)$$

$$CV = \left(\frac{\text{Standard deviation of monthly or annual rainfall}}{\text{Mean monthly or Annual rainfall}}\right)*100 \qquad \ldots (5.2)$$

Determination of Water Supply Components

Runoff measurements have been carried out on different land use types for the study area and the result of this study was used for estimation of runoff depth (Mc Hugh, 2006). Twenty dome shaped private ponds were constructed by 19 individual farmers with the help of the AMAREW project in 2002. Each pond has a storage capacity of $60m^3$ of water. Community and private ponds are characterized as a small reservoir managed at a community and household level and located around their homestead that allows farmers to capture runoff water from nearby micro-catchments, gully or streams with a diversion structure. During the survey period, the common means of water lifting used by pond owners was using the bucket and rope method to irrigate their backyard plots.The water is used to grow vegetables and fruit trees at backyard and farm plots, provide water for their livestock and used for domestic use. The total water volume of community ponds and private ponds for use by the watershed community is the sum of water volume stored of both community and private ponds minus the evaporation losses.

Volume of ponds was determined based on its area and average pond depth. The shape of the pond is assumed to be trapezoidal. Area of trapezoidal pond was determined by the following formula.

$$A = \left(\frac{b1 + b2}{2}\right) \times W \cdots\cdots (6.1)$$

$$V = \left(\frac{A + 4B + C}{6}\right) \times D \cdots\cdots (6.2)$$

V= volume of trapezoidal pond

A = area of the pond at ground surface

W= Width of the pond

B= Area of at mid depth (D/2)

C= Area at the bottom of the pond

D= average depth of the pond

b1 = base of lower floor

b2 = base of upper part

Serving Period of Communal Ponds is the period of time during which the water stayed in ponds to serve for livestock watering and domestic uses. It is a function of the stored volume of water, the evaporation loss, seepage and siltation. In this study only the volume of stored water and the evaporation loss were considered as there was lack of data on seepage losses and yon siltatio71(T of h(a)4(ge)4(fol3(27(duri70( )-29(mul9(lo)-99(a)280(

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$$\mathbf{E}Tc = \left(Kc \times ET_0\right) \quad // (8)$$

Where:

ETc = Crop water requirement (mm)

Kc = Crop coefficient (dimensionless)

ET_0= Reference crop evapotranspiration (mm)

The total livestock water demand was estimated based on the feed intake and average livestock water required per tropical livestock unit (TLU). Total livestock population per household was converted to TLU using a conversion factor of 0.7 for cattle, 0.1 for sheep and goats, 0.5 for donkeys and 1.0 for camels (Jahnke, 1982). Depleted water for Livestock Feed Production, which is the amount of water consumed or removed by evapotranspiration. The crop residues were then calculated based on the harvest index for each crop type (FAO, 1987). The water depleted on the grazing land was adjusted based on the amount of grass assumed to be available for livestock grazing. Utilization and recoverable factor of 50% and 75% were applied for crop residue of crops and grazing land respectively (WBISPP, 2000).

In order to estimate depleted water for crop residue, the total water requirement of the particular crop was partitioned into grain and crop residues water requirement according to the conversion factor (i.e. grain-residue ratios) (FAO, 1987). To obtain crop water use per kg of residue, conversion factors from grain to residues were derived from Kossila (1988) and Herrero *et al*., (2008). The total depleted water for crop residue at household level was then estimated based on the crop evapotranspiration and area covered for each crop grownin the watershed.

$$WRCR_{il} = \frac{R_i * ET_{cil}}{1 + R_i} \quad / \quad (9)$$

Where

$WRCR_{il}$ = water requirement of i^{th} crop residue in l^{th} location (mm)

R_i = conversion factor for grain yield to crop residue yield of the i^{th} crop type

ETc_{il} = crop water requirement in mm per unit of time of the i^{th} crop type at l^{th} location.

Then the water requirement for the total crop residue production was estimated in m^3.

$$WRCR_j = \sum_{il} WRCR_{il} \times AC_{il} \qquad (10)$$

Where:

$WRCR_j$ = the water requirement of total crop residue type in j^{th} household during the reference year (m^3)

$WRCR_{il}$ = water requirement of i^{th} crop residue in l^{th} location (m)

AC_{il} = total area of i^{th} crop type cultivated by the j^{th} household in the reference year (m^2).

The water requirement for Grazing (grass and shrub) lands was calculated as follows:

$$GLWR_{ij} = Kc * ETo * GLA_j * GLU * LGP \qquad . (11)$$

Where:

$GLWR_j$= grazing land water requirement in mm per square meter of jth household (= Depleted water of grazing land that is utilized by livestock),

GLA_j = Grazing land area in square meter of the jth household

GLU = Utilization factor of grazing land by livestock (proportion of the grass biomass production that is available for livestock feeding,

Kc = crop coefficient for grazing land (Kc value of extensive grazing)

ETo = Reference evapotranspiration in mm per unit time

LGP = Length of growing period in days.

The water requirement livestock feed was calculated as

$$DWLF = \sum_{j=1}^{n} WRCR_j + \sum_{j=1}^{n} GLWR_{ij} \qquad // \qquad \text{Eq. (12)}$$

Where:

$DWLF_l$ = Depleted water in mm per square meter for livestock feed in the watershed

$WRCR_j$ = the water requirement of total crop residue type in j^{th} household during the reference year (m^3)

$GLWR_{ij}$= grazing land water requirement in mm per square meter of in j^{th} household (Depleted water of grazing land that is utilized by livestock)

Determination of Water for Livestock

Data on total livestock numbers and species of the watershed were collected from the development agent of the watershed. Water consumption by livestock based on TLU per day were generated from survey results. Finally, the total consumption per day was calculated by multiplying the total TLU values with daily water requirement.

Determination of Domestic Water Consumption

The following steps were carried out to determine domestic water consumption: 1) Data on total number of households within the watershed area was collected, 2) The average water consumption for domestic uses per household per day in liters from different water points were collected from the survey data and literature, and 3) The total water consumption was calculated based on step 1 and 2.

Water Balance Model

A water balance considers parts of the hydrologic cycle. A water balance is calculated for a specified period of time with the resulting net surplus or deficits. It is expressed as seasonal or annual values. The water balance is expressed as an equation relating these components:

Change in storage = Water Supply - Water Demand or

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Where:

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Effrain = Effective rainfall

P= ponds (communal and private)

GW= ground water.

Results and Discussion

The major crops grown in the study area are sorghum, teff, maize, and chickpea under rainfed conditions, whereas onion (Allium cepa), tomato (Solanum lycopersicum) and pepper (Capsicum annuum) are grown under irrigated conditions outside of watershed area. Within the watershed, irrigation is not used for crop production due to the absence of perennial rivers or other water sources.

Of the total 318 ha of cultivated land by the respondents, sorghum covered 48% (153 ha) of the cropped land area with an average of 1.3 ha per household and followed by tef covering 45.06% (143.2 ha) with1.2 ha per household. Chickpea covered the lowest share at 2.73% (8.7ha) of the total cropped land with an average 0.07ha per household. Maize covered 4% (12.54ha) of the cropped land area with an average 0.1ha per household (Table 1). Sorghum and tef were the two most widely grown crops in the watershed. According to the survey result, the average cultivated cropland area was 2.7 ha per household per year (Table 2).

Table 1. Cultivated lands (ha) by sampled households for each crop grown at Lenchdima watershed in 2008

Sub-watersheds	**Total cultivated land (ha) covered by different crop types**				
	Sorghum	**Teff**	**Chickpea**	**Maize**	**Total cropped area (ha)**
Oromo	68.2	64.0	4.4	6.6	143.3
Kolokobo	58.9	51.8	2.8	3.5	116.9
Lench dima	26.3	27.4	1.5	2.4	57.5
Over all (ha)	**153.4**	**143.2**	**8.7**	**12.5**	**317.8**
Over all (%)	**48.3**	**45.1**	**2.7**	**4.0**	**100**

Table 2. Area (mean and standard error) of cultivated land per household at Lenchdima watershed

Land use	**Oromo**	**Kolokobo**	**Lench dima**	**Overall**
	Mean±SE	**Mean±SE**	**Mean±SE**	**Mean±SE**
Total crop land	2.3±0.2	2.9±0.2	3±0.3	2.7±0.2
Total Sorghum	1.3±0.2	1.09±0.1	1.46±0.2	1.3±0.1
Total Tef	1.1±0.1	1.2±0.1	1.37±0.2	1.2±0.08
Total Chick pea	0.06±0.2	0.10±0.04	0.07±0.05	0.07±0.02
Total Maize	0.05±0.01	0.1±0.02	0.14±0.03	0.1±0.01

Based on the above total area coverage by each crop type, total grain and crop residues production was calculated for each type of crop cultivated under the three sub-watersheds. The contribution of sorghum (1.5t per household) was higher in grain than the other two crops, and tef (4t per household) had higher crop residue (Table 3).

Livestock numbers and holdings in the three sub watersheds and the entire watershed area are presented in Table 12. The overall livestock holding was 2.9, 2.0, 2.3 and 2.6 TLU per household for Oromo, Kolokobo, Lenche Dima and the entire watershed, respectively. The highest proportion of TLU holding was for cattle followed by donkey. This might be due to the importance of cattle for farm draught power.

Table 3. Average grain and crop residues production (ton) per households at Lench Dima watershed

Watershed	**Production**	**type of production**	**Crop type**			
			Sorghum	**Tef**	**Chick pea**	**Total**
Over all	Total production	Grain	179.1	118	4.3	301.3
		Residue	447.7	475	5.2	927.9
	Average production	Grain	1.5	1	0.04	2.5
		Residue	3.7	4	0.04	7.7

Water Supply Components

The mean annual rainfall, based on the periods 1976-89 and 1992-2007, over Lenche Dima watershed is 687 mm and varies from 193mm in 1984 to 998 mm in 1978 (Figure 3). The standard deviation and coefficient of variation for the monthly rainfall from 1976 to 2007 range from 18 to 75 mm and 41 to 94 % , respectively, confirming the uncertainty in rainfall over the study area.

The total effective rainfall during 2007/8 for the different land use/cover types was 10.79 million m^3. Cultivated area received 5.29 million m^3 (49%) and areas under rock out crop received the lowest effective rain 0.005 million m^3 (0.04%) (Table 4).

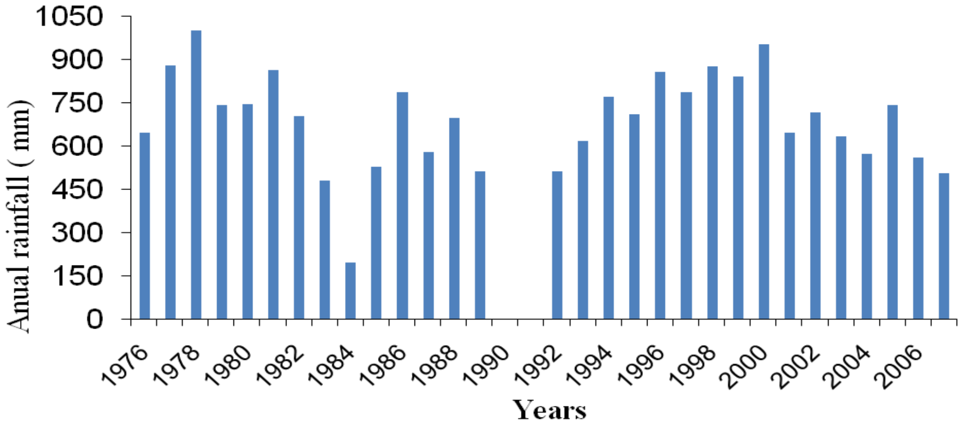

Figure 3. Mean annual rainfall in Lench Dima watershed area (1976-2007)

Table 4. Total and effective annual rainfall in the watershed based on land use/land cover types in Lench Dima watershed

Land use/cover classes	**Area (ha)**	**Total rainfall (mm/year)**	**Total rainfall ($10^6 m^3$/year)**	**Effective rainfall ($10^6 m^3$/year)**
Cultivated Land	962.9	687	6.62	5.29
Forest Land	108.5		0.75	0.6
Grazing Land	11.3		0.08	0.06
Open Shrub Land	517.6		3.56	2.84
Open wooded shrub Land	248.4		1.71	1.37
Rock Out Crop	0.8		0.01	0.005
Village	114		0.78	0.63
Total	**1963.5**		**13.49**	**10.79**

Estimation of runoff was based on the findings of McHugh (2006). The total runoff volume from cultivated land was high (1.79 million m^3) contributing 72% from the total runoff and the lowest total runoff was from grazing lands (0.01 million m^3) contributing only to 0.041%. The reason for high runoff amount from cultivated land was due to high runoff coefficient values and greater area coverage as compared to the other land use/cover types. Actual events of runoff measurements indicate that CROPWAT over estimates effective rainfall so the events should be interpreted in the above way. The total runoff volume for the different land uses in the watershed was 2.47million m^3 (Table 5).

Table 5. Runoff coefficient and volume for different land uses in the Lench Dima watershed

Land use/cover classes	Total annual rainfall ($10^6 m^3$/ha)	Runoff coefficient	Total runoff ($10^6 m^3$/ha)	Runoff (%)
Cultivated land	6.62	0.27	1.79	72.37
Forest land	0.75	0.03	0.02	0.91
Grazing land	0.08	0.13	0.01	0.41
Open shrub land	3.56	0.13	0.46	18.73
Open wooded shrub land	1.71	0.05	0.09	3.46
Village	0.78	0.13	0.10	4.12
Total			**2.47**	**100**

Among the community ponds, Tuluba Dime pond was the biggest pond having a volume of 8478 m^3, representing 74% of the total water stored in pond in the watershed. The smallest pond was Sefede Ameba having a volume of 56.5 m^3, equaling only 0.5% of the harvested water in the watershed using ponds. The estimated volume of water (m^3) stored in all ponds was 10291 m^3 (Table 6).

Table 6. Volume of stored water in community ponds in the Lench dima watershed

ID	Location	Average depth (m)	Average area (m^2)	Volume of water stored (m^3)	% from total
1	Gerado	1.2	98	133	2.1
2	Lench $dima_1$	2	189	314	4.3
3	$Kolokobo_1$	1.2	98	133	2.1
4	$Kolokobo_2$	2.2	189	393	5.4
5	Tuluba demi	3	2159	8478	74.8
6	Sefede $ameba_1$	2.2	189	393	5.4
7	Sefede $ameba_2$	0.5	69	57	0.5
8	Bole chaka	2	189	393	5.4
	Total volume			**10,291.0**	**100**

From Table 7, the estimated water consumption for livestock from the 20 ponds was 509 m^3 $year^{-1}$. The total water volume of community ponds and private ponds for use by the watershed community is the sum of water stored in both community and private ponds minus the evaporation losses. The total stored water volume of ponds is 10,291 m^3 and the total evaporated water from ponds is estimated to be 858.6 m^3. Hence, the volume of water in ponds for use is estimated to be 10,632 m^3. Seepage was not accounted because it was assumed to be negligible.

Table 7. Total consumption and storage capacity of private ponds in the Lench Dima

Farmers name	Ponds	Consumption (l/year)			Total water Consumption /year (m^3)	Estimated capacity (m^3)
		Domestic	Irrigation	Livestock		
Desale Belete	1	2040	8232	0	10.272	60
Fantaw Abigaz	1	6000	16820	12000	34.82	60
Abate Neguz	1	4800	6240	6000	17.04	60
Yasin Ahmed	2	6000	46900	15480	68.38	120
Bekaris Molla	1	6900	4640	11700	23.24	60
Mohamed Said	1	2700	11900	9750	24.35	60
Total	**7**	**28440**	**94732**	**54930**	**178.102**	**420**

Determination of Crop Water Requirement

The CROPWAT software results show that the annual crop water requirements are 652.6, 371.8, 307.8 and 731.1 mm per season for sorghum, tef, chick pea and maize, respectively (Table 8). The lowest and peak monthly water requirements for these crops occur, respectively, during the following periods: for sorghum in October (2.2mm) and in July (48mm), for teff in July (9.8mm) and Sep. (45.7mm), for chickpea in November (12.2mm) and October (43.8) and for maize in March (8.8mm) and June (64.7mm). Crop water requirements were found to be higher than total rainfall and total effective rainfall for all the crops in the reference cropping season under consideration. This implies moisture deficit (water shortage) for all crops which is associated with low rainfall resulting in mid and late season drought.

Table 8. Crop water requirement (CWR) of crops (mm/season m^{-2}) at Lench Dima watershed, (2008 cropping season)

Crop	TRF	CWR	TERF	IR
Sorghum	516.6	652.6	419.6	247.6
Tef	373.4	371.8	300.8	170
Chick pea	209.2	307.8	177.8	157.7
Maize	503.8	731.1	403	354.6

TRF=Total rainfall (mm/season m^{-2}) (from planting to harvesting); TERF= Total effective rainfall (mm/season m^{-2}); CWR= crop water requirement (mm/season m^{-2}); IR= Irrigation requirement (mm/season m^{-2})

Figure 4 shows the effective rainfall and crop evapotranspiration (ET_C) and growing stages from April to October for the sorghum crop. The figure shows excess moisture supply during the planting (initial) stage (April mid-May), whereas moisture is in short supply during the development stage and mid-stage (mid may-July). Also excess moisture availability is seen during August, while the period after August is characterized by shortage of moisture. During the critical stages of development and mid-season lack of moisture can reduce the yield.

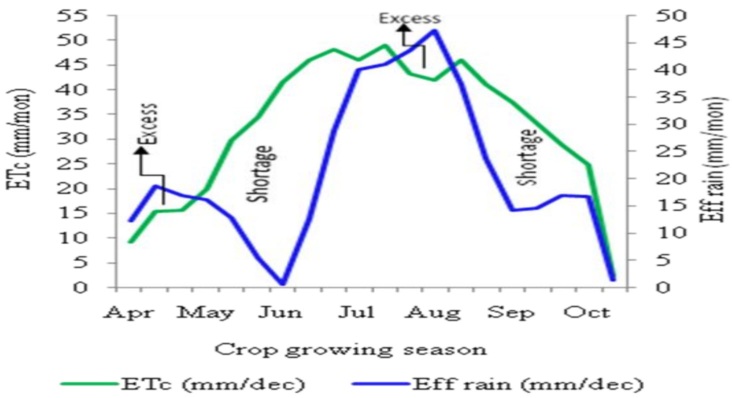

Figure 4. Excess and shortage of water for Sorghum

Figure 5 compares the effective rainfall and crop evapotranspiration (ET_C) in different growing stages for tef. In contrast to sorghum, excess moisture is available during the initial and development stages (July-August). However, shortage of moisture is observed during the mid and late season stages (September- November). This shortage can critically affect yield of tef between September and November.

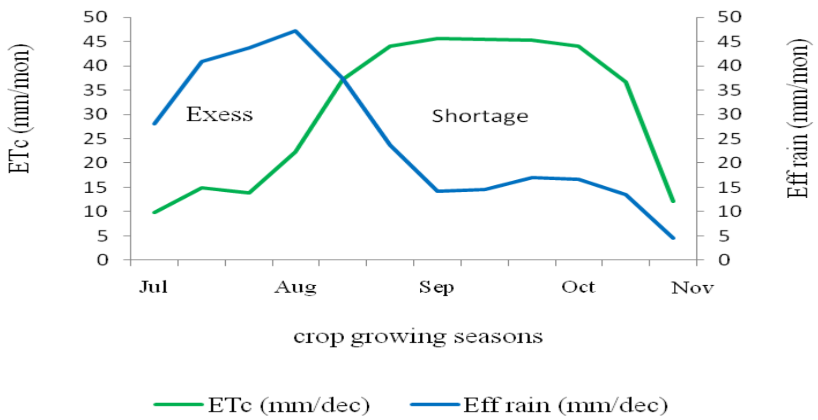

Figure 5. Excess and shortage of water for tef

As seen in Figure 6, excess moisture is available during the initial growth stage of chickpea (August-early September), whereas moisture is critically short during the rest of the growing stages (September-November). Similarly, Fig. 7 shows ample moisture availability during the initial (March-April) and late season (July-August) stages of maize, while the crops may suffer from moisture shortage during the development and mid-season stages (May-July). The peak monthly water requirements happened in the July with 48.1 mm for sorghum, September with 45.7mm for tef, October with 43.3mm for chickpea and June with 64.7 mm for maize.

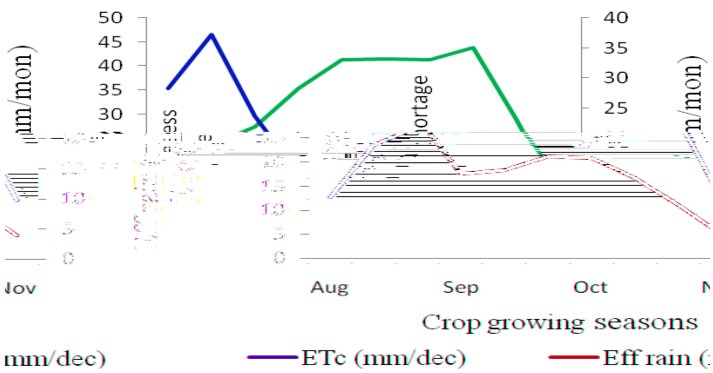

Figure 6. Excess and shortage of water for chickpea

Therefore, as shown in Figs. 4-7, the rainfall amount and distribution does not satisfy the crop water requirement at different stages of crop growth and yield can be adversely affected. Hence, additional water is required to supplement crop growth in the watershed.

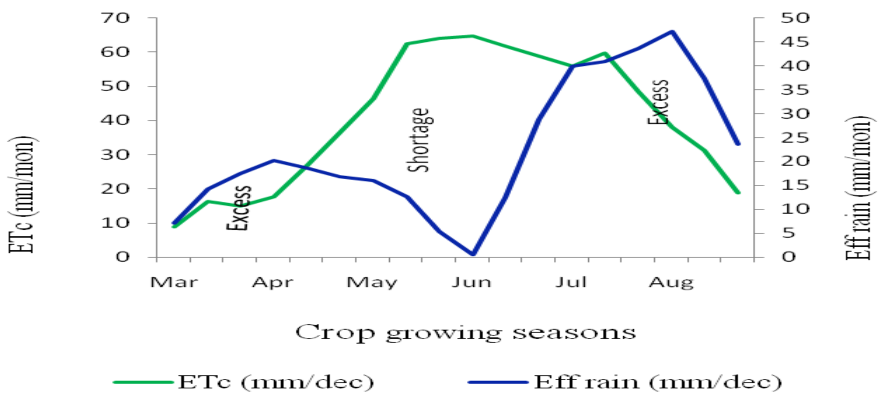

Figure 7. Excess and shortage of water for maize

Table 9 summarizes the total water requirement of the different land use and land cover types for the 2007/2008 cropping season of Lenche Dima watershed. The water requirements of forest (1105 mm per season) are higher than bushes and grazing lands. Grazing land has the lowest water requirement (480 mm per season). In general, due to the largest area coverage of bush land over the watershed, it has the highest total water requirement (demand) (5.1 million m^3 $year^{-1}$) and the lowest water demand is for forest land (1.2 million m^3 per $year^{-}$).

Table 9. Results of forest and range lands water requirement of Lenche Dima watershed for the year 2007/2008

Cover type	Area (ha)	Total rain (mm)	CWR (mm)	P_{eff}(mm)	CWR (10^6 m^3)	Effrain (10^6 m^3)	Deficit (10^6 m3)
Forest land	105.97	689.3	1105.4	579.4	1.2	0.6	0.6
Bush land	766	538.8	664.8	429.6	5.1	3.3	0.3
Grazing land	11.27	417.7	480	339.8	2.5	1.8	1.3
Total			**2250.2**	**1348.8**	**8.8**	**5.7**	**2.2**

For instance, total water depleted for livestock feed production and agricultural production (crop and livestock) were (12,869m^3 $year^{-1}$ hh^{-1}) and (17,718m^3 $year^{-1}$ hh^{-1}) respectively (Table 10). The total depleted water for livestock feed production in the watershed was estimated to be 6.46 million m^3 per year (Table 11).

Table 10. Total depleted water for feed production per year in the Lench dima watershed

Land use types	Area (ha)	Depleted water (m^3ha^{-1})	Total depleted water for livestock feed production (m m^3)
Sorghum	485.08	4662	2.26
Tef	452.83	2231	1.01
Chick pea	27.49	1679	0.05
Grazing lands	528.85	3600	1.9
Enclosure lands	248.43	4986	1.24
Total			**6.46**

NB. For the cultivated land, the depleted water for the crop residues of the three crops were considered
M=million

The results of the survey show that water consumption of livestock varies from water source to water source. Average rates of water consumed in the watershed from different sources were 23±2, 12±1.6, 22±1.75 and 24±2 liters per TLU per day in community ponds, pumps, river and wetland, respectively. On average, the amount of water consumed in the sub-watershed from different sources were 22±2, 21±2.1 and 17±1.8 for Oromo, Kolokobo and Lenche Dima sub- watershed, respectively. At watershed level, the average consumption was 20±2 liters per TLU per day (Table 11).

Table 11. Water consumed (liters day^{-1} TLU^{-1}) by livestock in Lench Dima

Sub watersheds	Community Pond	Pump	River	Wetland	Over all
	Mean±SE	**Mean±SE**	**Mean±SE**	**Mean±SE**	**Mean±SE**
Oromo	23±3	11±2.1	25±3.3	28±3.4	22±2
Kolokobo	23±2.5	16±2.75	20±2.2	24±2.5	21±2.1
Lenche dima	23±3	12±4	11±2	21±3	17±1.8
Overall	**23±2**	**12±1.6**	**22±1.75**	**24±2**	**20±2**

Location and distribution of community and private ponds are presented in figure 5. Private pond is being used to grow fruit trees and vegetables at Lenche Dima watershed

Total water consumption (m^3/year) of livestock is the sum of total water depleted for feed production and livestock water consumption (voluntary water intake) per year. The total depleted water for feed production was estimated to be 6.46 (million m^3/year) and water consumption was 36,677 (m^3/year). Then the total water consumption of livestock for the watershed was 6.49 (million m^3/year). The percentages of water depleted for feed production was 99.5% and depleted water for voluntary intake (drinking) was 0.5% respectively.

The total human water consumption in Lenche Dima watershed was estimated to be 11065m^3 (including drinking, cooking and bathing). Oromo sub-watershed has the highest water consumption (6717 m^3) because of high population living in this sub-watershed and the lowest was for Lenche Dima (1836 m^3) (Table 9). The water supply for domestic use was from water pumps in the watershed and estimated to be 11408m^3 (Table 12).

Water Balance

The water demand estimates were made for three categories of use: crops and vegetation, livestock and domestic. Crops and vegetation has by far the largest demand 14.34 million m^3 and domestic use has the lowest demand 11065 m^3. Crops and vegetation have 95%, livestock 4.64% and domestic 0.36% water withdrawal in the watershed area. On the supply side, the estimated water supply of rainfall, ponds and water pumps for domestic and livestock use are 10.79 million, 10632 and 11408 m^3 respectively. Comparison of supply and demand shows that water availability significantly lower than the demand. The supply is covering only 75% of the water demand. Water supply estimates show that rainfall accounts for 99.5% and the remaining 0.5% is from ponds and This indicates that the watershed does not meet the water demand for the production of crops, livestock and domestic water use. The different components of the watershed water balance are presented in Table 13 and 14.

Table 12. Total water supply (m^3) from water pumps in Lenche Dima watershed

Month	2005 water produced (m^3)	2006 water produced (m^3)	2007 water produced (m^3)	Total water supply (m^3)/2year	Mean water supply (m^3)/year
January		701	941		
February		947	1298		
March		949	740		
April		1192	1273		
May		1498	754		
June		1335	1187		
July		637	637		
August		749	908		
September		754			
October		831			
November	361	1237			
December	594	1388			
Total water supply (m^3)	**955**	**12218**	**7738**	**20911**	**10455**

Table 13. Different components of the water balance for the Lench dima watershed

Water supply components	Water supply ($10^5 M^3$/year)	Water demand components	Water demand ($10^5 M^3$/year)	Balance (10^5M3/year)
Effective Rainfall	108	Crops and Vegetations	143	-35
			0.19	-0.08
Ponds	0.11	Livestock drinking water consumption		
Total	**108.13**	**Total**	**143.5**	**-35.09**

Table 14. Proportion of water supply and demand in the Lench Dima watershed

Water supply components	Water supply (%)	Water demand components	Water demand (%)
Effective Rainfall	75.2	Crops and Vegetations	95.28
		Live stock feed production	4.5
Ponds	0.08	Livestock drinking water consumption	0.14
Water pumps	0.07	Domestic use	0.08
Total	**75.35**	**Total**	**100**

Conclusion and Recommendations

The results show that the water demand of the crops and livestock was significantly higher than the water supply. This indicates that water available in the watershed does not meet the demands for the crop and livestock production. The existing ponds and water pumps had insufficient capacity to meet all domestic and livestock drinking requirements during the year. This suggests the need for interventions that could be considered for improving the water supply in the watershed including;

- Develop roof and other in-situ rainwater harvesting systems
- Improved hillside soil and water management and agronomic practices to increase and conserve soil moisture and replenish groundwater resources in the watershed
- Developing additional community ponds and other water sources to fulfill domestic and livestock water needs

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