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# International Journal of Livestock Production

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## ARTICLES

**International Journal of Livestock Production**

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*Full Length Research Paper*

# Effects of L-Arginine supplementation of drinking water on the kidney and liver of Sasso chickens

**Alabi, O.O.[1]\*, Shoyombo, A.J.[1], Animashahun, R.A.[1], Olawoye, S.O.[1], Abdulazeez, J.O.[2], Faduhunsi, O.O[2] and Oladehinbo, D. O.[1]**

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The present study was conducted to determine the effects of L-arginine supplementation of drinking water on the kidney and liver of Sasso chickens. The study comprised 297 mixed sex Sasso chickens of twelve-weeks old raised in floor pens, the birds were randomly distributed into three treatments and three replicates with thirty-three birds per replicate. The design of the experiment is the completely randomized design (CRD). The birds were fed with grower's mash and given different treatment of 0 mg/L (Treatment A at 0% supplementation), 167 mg/L (Treatment B at 50% supplementation), and 334 mg/L (Treatment C at 100% supplementation) of L-arginine supplement in drinking water of 9 L per replicate daily for a period of five consecutive weeks, after which the birds were decapitated. The kidney and liver were removed and taken to histopathology laboratory for histological analysis. The chickens administered 0 mg/L L-arginine (0%) supplementation was without lesions. However, kidney and liver of chickens that received 167 mg/L (50%) and 334 mg/L (100%) supplementation showed explicit damage. There was congestion of the vascular channels in the kidneys and liver of birds that received 167 mg/L of L-arginine and destruction of the glomeruli and tubules in the kidney and peri portal mononuclear inflammatory infiltration in the liver of those given 334 mg/L of L-arginine. This could possibly be a result of the over-expression of nitric oxide which is a vasodilator. These present findings showed that supplementing the diets of Sasso chickens with L-arginine of 50 and 100% have detrimental effect on the structure and functions of the kidney and liver.

**Key words:** L-Arginine, Sasso chickens, kidney, liver, dosage.

## INTRODUCTION

Good meat quality attracts favorable attention from consumers as compared to meat with excess fat and excess fat deposition is a major factor of poor meat quality of broilers. Excess fat can result in reduction of carcass yield and difficulties in processing. White meat such as chicken meat is considered superior for health reasons to red meat because of comparably low contents of fat, cholesterol and iron. Manipulation of trait depends on the combined genetic and nutrition. Some of the selection strategies results in accumulation of excessive fat in the body that negatively affects production efficiency, consumer perception and marketability of

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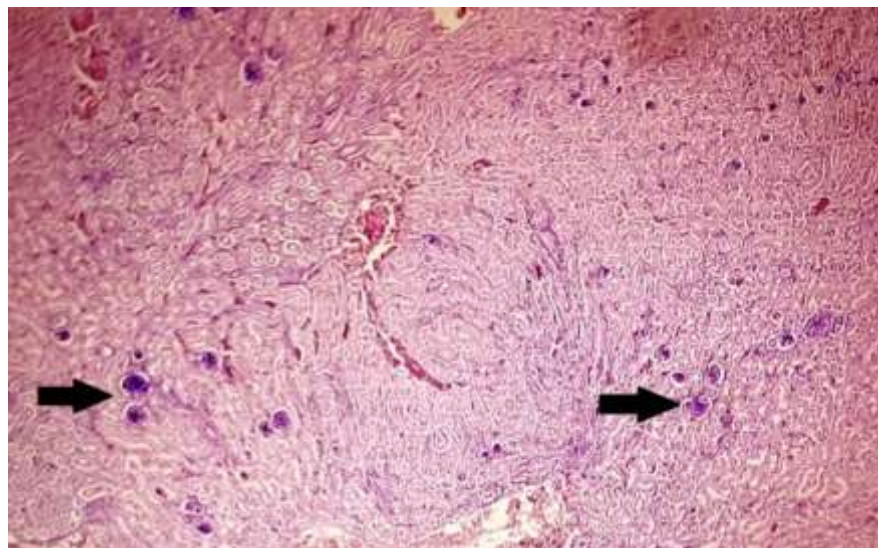
**Plate 1.** Kidney with 0 mg/L intake showing normal tissues with glomureli and tubules, H&E X100.

chickens (Zhou et al., 2006). The success in poultry meat production has been strongly related to improvements in body growth and carcass yield, mainly by increasing breast proportion and reduction in abdominal fat. Al-Daraji et al. (2011) demonstrated that increasing L-arginine supplementation level in broilers diet reduced total body fat deposition (Hyun-Seek et al., 2017). L-Arginine, an amino-acid reported to be the sole precursor of nitric oxide, with lots of immune functions (Kang et al., 2014) and growth performance. Nitric oxide (NO) plays an important role in modulating both the hepatic and renal circulation under physiological and pathological conditions. Addition of L-arginine in poultry diets is required to avoid the harmful influences of excessive free radicals produced during normal metabolism (Atakisi et al., 2009). Methionine and arginine are two amino acids that have proven immune regulatory action (Tayade et al., 2006). Arginine is involved in a number of other metabolic functions in the body, such as its potential to be converted to glucose (hence, its classification as a glycogenic acid), and its ability to be catabolized to produce energy (Tan et al., 2014; Tong and Barbul, 2004). It is also a vasodilator (Melik et al., 2016). Dietary L-arginine supplementation plays key role in enhancing meat quality. It was recently demonstrated that L-arginine increases specific immune response against infectious bursal disease (IBD) in chickens (Jeffery et al., 2014). In the liver, nitric oxide synthase (NOS) may be expressed by hepatocytes, cholangiocytes, hepatic stellate cells, and Kupffer cells (Trauner and Boyer, 2003). NO is able to exert dichotomous effects under physiological and pathological conditions. The induction of NOS in phagocytic cells by a variety of noxious stimuli may lead to high and sustained levels of NO, which may cause cytotoxicity through nitrosative stress (Pacher et al., 2007). The aim of this study is to determine the effect of L-arginine on the kidney and liver of Sasso chickens.

## MATERIALS AND METHODS

This experiment was carried out at the Poultry Unit of Landmark University Teaching and Research Farms, Omu-Aran, Kwara State, Nigeria. A total of 297 mixed sex Sasso chickens were used for the study. The chickens were randomly distributed into three treatments containing three replicates of thirty-three birds each in a completely randomized design (CRD). The birds were fed with grower's mash and given different treatment of 0 mg/L (Treatment A at 0% supplementation), 167 mg/L (Treatment B at 50% supplementation) and 334 mg/L (Treatment C at 100% supplementation) of L-arginine supplement in drinking water of 9 L per replicate daily for a period of five consecutive weeks; after 5 weeks, three birds from each treatment was decapitated at the Landmark University Teaching and Research Farms, the organs were removed and put in 10% phosphate buffered formaldehyde buffer solution in well labeled containers. The organs (kidney and liver) were taken to Federal Medical Center, Lokoja Histopathology Laboratory for analysis. For histopathological analysis, the tissue samples (the kidney and liver), were fixed in neutral phosphate buffered 10%-formalin solution, embedded in paraffin and 4 mm thick sections were prepared. After deparaffinization, the sections were stained with haematoxylin and eosin (HE). The slices were examined under the light microscope and images were captured with digital camera at the magnification of 100.

## RESULTS AND DISCUSSION

After carrying out the histological analysis on the kidney, there was no notable change in the heart of Sasso chickens administered treatment A, no dose of L-arginine (Plate 1).
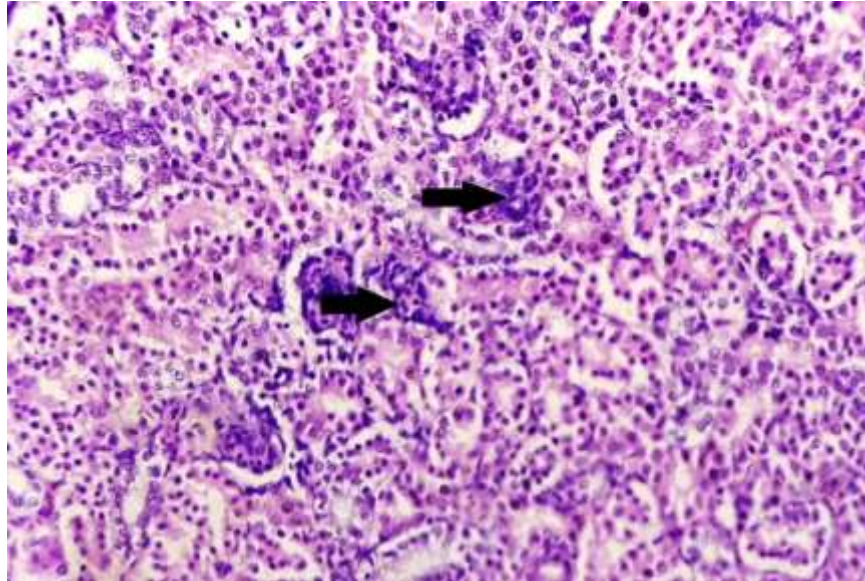
**Plate 2.** Showing destruction of renal vascular channels with 167 mg/L intake, H&E X100.
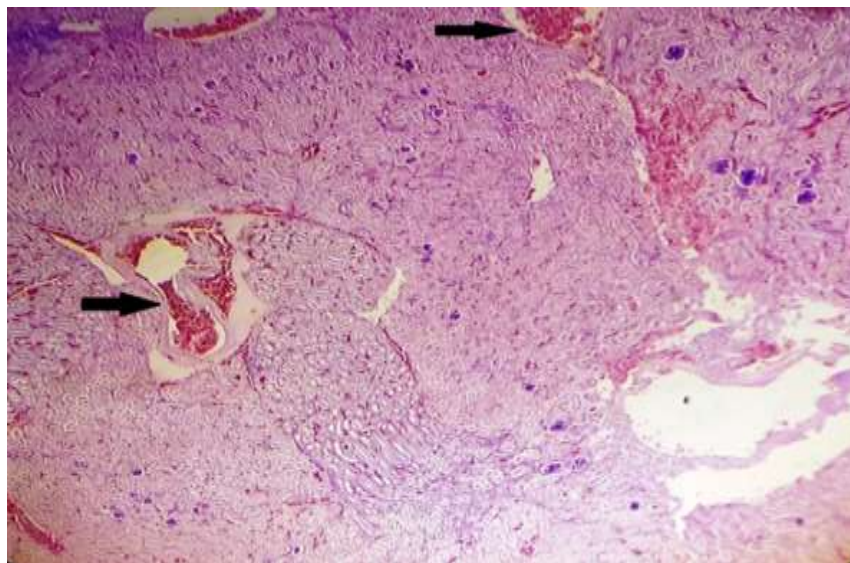


**Plate 3.** Showing kidney having congested vascular channels with 334 mg/L intake, H&E X100.

Findings showed that the microscopic structure of the kidney of Sasso chickens given 0 mg/L has typical structure with no lesion as reported by Wideman (2001). Although, it was reported that increasing L-arginine level in broilers diet reduced total body fat deposit (Hyun-Seek et al., 2017), However, the kidney structure of chickens given 167 mg/L of L-arginine showed congestion of vascular channels, destruction of the glomeruli and tubules in line with Pacher et al., (2007). L-arginine

caused desquamation of the epithelial cells lining the tubules with lymphoid follicle formation in the interstitium, which is the shedding off of the outermost layer of the tissue in all replicates given 334 mg/L, in line with Johnson (1979). Plate 4 shows a typical structure with no lesion as reported by Trauner (2003). The liver in Plate 5 shows the liver under 167 mg/L intake had congested vascular spaces. The liver in Plate 6 shows that the liver under 334 mg/L intake had congested vascular spaces
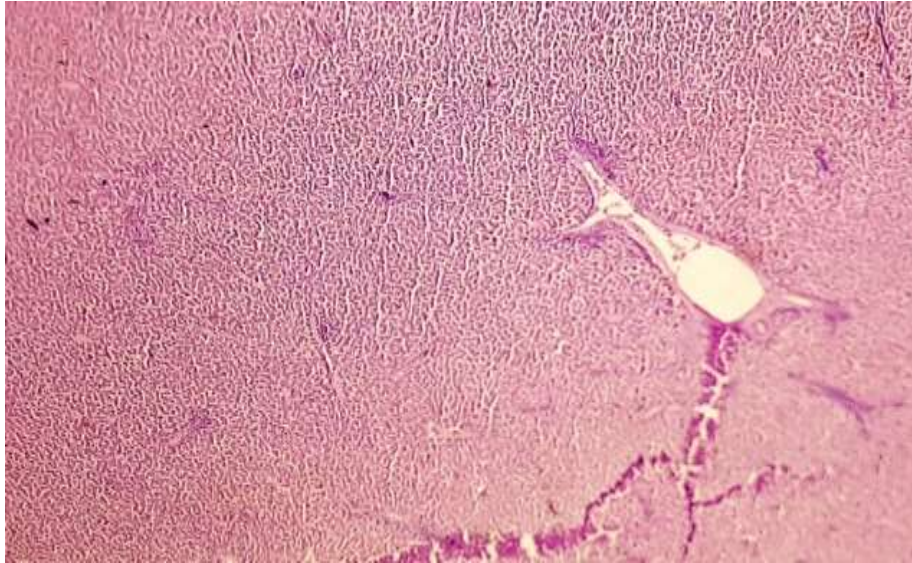
**Plate 4.** 0 mg/L intake showing normal liver cords, H&E X100.
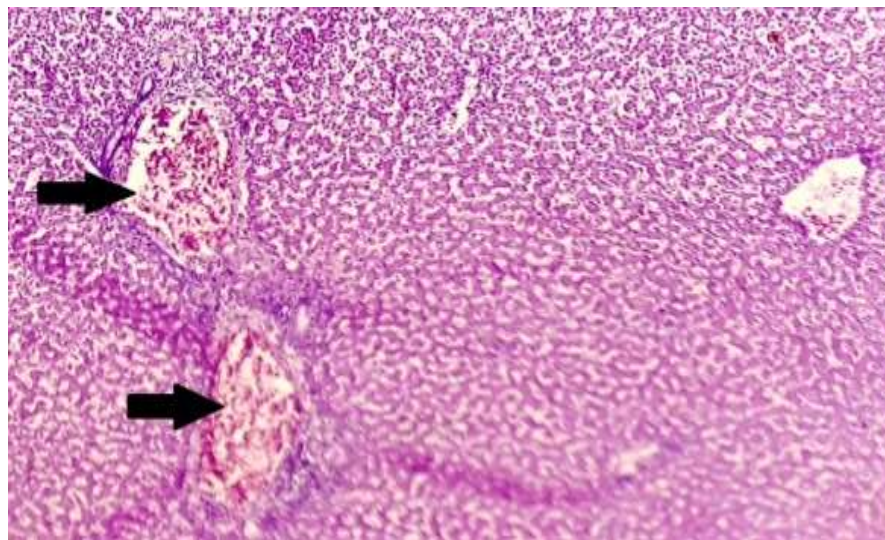


**Plate 5.** 167mg/L intake showing congested vascular channels. H&E X100.

and periportal mononuclear inflammatory infiltration as reported by Pacher et al., (2007). The degenerations observed in the kidneys and livers of the birds indicate that 167 and 334 mg/L L-arginine supplementation induced adverse effects on the organs as reported by Ichihara et al., (1999). NO is a powerful vasodilator and it blunts the expression of the tubuloglomerular feedback and acts as a vasoconstrictor; these result is expected (Dai et al., 2013). The result from this experiment shows that oral supplementation of high dosage of L-arginine had a negative effect on the structure of the kidney and liver of the Sasso birds given 50 and 100% L-arginine

supplementation. Not ignoring its benefits, L-arginine could still produce its positive effects if used at a lower dosage of less than 50% supplementation level.

## Conclusions

One of the benefits of L-arginine is that it increases renal plasma flow (RPF) and glomerular filtration rate (GFR). However, from this study, high dosage of oral supplement can lead to the over-expression of nitric oxide in the organs causing a negative effect on the microscopic
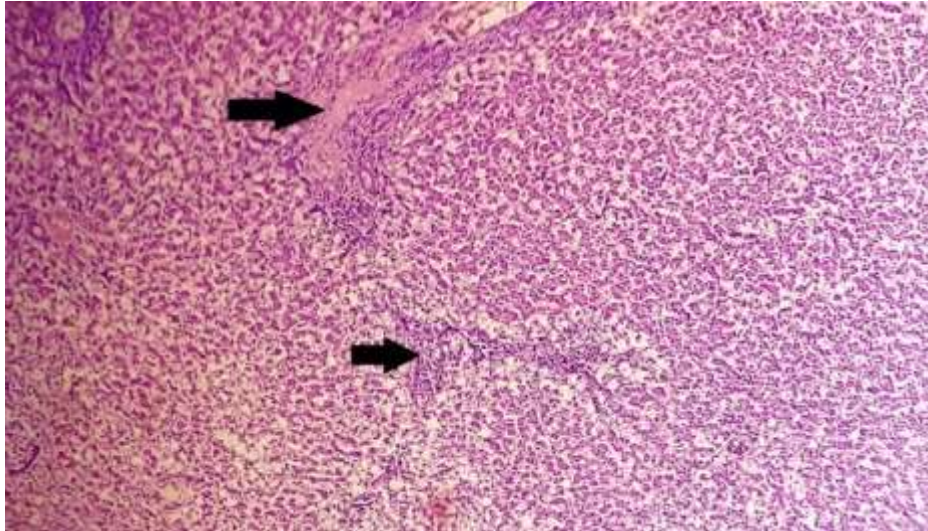
**Plate 6.** Showing the mononuclear inflammatory infiltration of the portal tract and perivascular inflammation with 334 mg/L intake, H&E X100.

structure of the kidney and liver of the Sasso chickens. Based on the finding from this experiment, further research should be done with lesser dosage less than 50% supplementation level of L-arginine supplement on the Sasso chicken to maximize the benefits such as reduction of total body fat deposit without any negative form of alteration in the structure of the organs.

## CONFLICT OF INTERESTS

The author has not declared any conflict of interests.

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**International Journal of Livestock Production**

*Full Length Research Paper*

# Livestock-feed balance in small and fragmented land holdings: The case of Wolayta zone, Southern Ethiopia

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Ethiopia owns immense but largely untapped livestock resources scattered over diverse agro-ecologies. Feed scarcity is one of the major technical constraints in livestock production and thus challenges the economic contribution of the livestock sub-sector. For optimum and sustainable livestock productivity, the available feed resource should match with the animal population in a given area. This study was aimed at assessing livestock feeds and analyzing the balance between feed supply and demand in small and fragmented land holdings of three different agro-ecologies (Dega, Woina-dega and Kolla) of Wolayta zone, southern Ethiopia. Data were collected through discussions with individuals, groups and key informants, observations and formal surveys and analyzed using R software. The dry matter (DM) requirements of the livestock population were calculated according to the daily DM requirements for maintenance of 1 tropical livestock units (TLU) (250k livestock consumes 2.5% of its body weight (BW) (6.25 kg DM/d). Livestock holding in TLU and total DM productions from all feed resources were not significantly different across all agro-ecologies (P > 0.05). However; land which was the most important production factor in the study site was significantly (P < 0.05) different with average ownership of (1.5 ± 0.081 ha). The largest proportion of feed (517.35 ton of DM/year, 58.9%) came from crop production followed by natural pasture (356.62 ton of DM/year, 40.6%). The remaining small amount of feed was obtained from trees and shrubs (3.36 ton of DM/year, 0.5%) as farmers lop the leaves and branches of various trees and shrubs and feed them to their animals during the dry season. Total amount of feed obtained from all sources was 877.33 ton/year in DM and the total livestock population of the sampled households was 602.24 TLU. The total feed required for this amount of TLU in terms of DM was therefore, 1373.1 ton/year (with negative balance of 495.77 ton DM). Thus, the total feed available addressed only 63.9% of the annual DM requirement which was able to support existing stocks for only 7.7 months. The feed gap was significantly (P<0.05) higher at Woina-Dega, followed by Dega and it was better comparatively at Kolla agro-ecology. Hence, feed shortage was a big problem in terms of quality and quantity in the study site which needs due attention from all responsible bodies.

**Key words:** Feed availability, feed shortage, requirement, dry matter, feed-gap.

## INTRODUCTION

Ethiopia owns immense but largely untapped livestock resources scattered over diverse agro-ecologies.

According to Desta et al., 2000, inadequate feed, spread of diseases, poor breeding stock and inadequate

livestock policies with respect to credit, extension, marketing and infrastructure are the major constraints affecting livestock performance in Ethiopia. Feed scarcity is one of the major technical constraints in livestock production and thus it challenges the economic contribution of the livestock sub-sector. Feed resources are classified as natural pasture, crop residue, improved pasture and forage, agro-industrial by-products, other by-products like food and vegetable refusal, of which the first two contribute the largest feed type (Alemayehu, 2005); Adugna et al., 2012). In the highlands, crop residues and agro-industrial by-products augment natural pasture and in the pastoral system, livestock production is almost totally dependent on native pasture and woody plants (Daniel and Tesfaye, 1996; Zinash et al., 1998).

For optimum and sustainable livestock productivity, the available feed resource should match with the animal population in a given area (Kechero and Geert, 2014). The major feed resources in Wolayta zone are natural pasture, stubble grazing, crop residues and some non-conventional feeds like enset parts, kitchen wastes and fruit and vegetable rejects. Farmers also lop the leaves and branches of various trees and shrubs and feed them to their animals during the dry season. They also collect herbaceous wild plants, mostly legumes, as feed for lactating cows (Adugna 1990). Though there are many studies on the availability and type of feeds in the Wolayta, limited work has been done to identify current gap between demand and supply of feed in terms of dry matter. This, on the other hand, creates a great problem to stakeholders at different levels to recommend possible solutions for livestock production improvement. Therefore, it is very imperative to assess the already existing feed resources in relation to the annual requirements of livestock in order to suggest either improving the existing feed resources, introduce another feed alternatives or suggest development and policy intervention options. The objectives of this study were therefore, to assess livestock feeds and analyze the balance between feed supply and demand in small and fragmented land holdings of Wolayta zone, southern Ethiopia.

## MATERIALS AND METHODS

### Description of the study area

The study was conducted in four districts/woredas of Wolayta zone, Southern Nation Nationalities Regional State, Ethiopia (Figure 1) from November 2016 to October, 2017. Wolayta zone (6.40 - 7.10 N and 37.40 - 38.20E) is located 390 km southwest of Addis Ababa. The zone has a total area of 4,541 km$^2$ and is composed of 12 woredas and 3 registered towns. It is approximately 2000 m above sea level and its altitude ranges from 700 - 2900 m above sea level.

The population of Wolayta zone is about 1,527,908 million of which 49.3% are males and 51.7% are females. Out of these, 11.7% live in towns and the rest 88.3% live in rural areas. The annual population growth rate of the zone is 2.3%. It is one of the most densely populated areas in the country with an average of 290 people per km$^2$ (Thrustfield 2005). The area is divided into three ecological zones: *Kolla* (lowland <1500 m), *Woina-Dega* (mid-altitude 1500-2300 m) and *Dega* (highland > 2300 m) with the most of the area lies within the mid altitude zone (Berhanu 2012).

Wolayta had a bi-modal rainfall pattern that extends from March to October. The first rainy period occurs in March to May, while the second rainy period covers July to October, with its peak in July/August. The average annual rainfall over 43 years is 1,014 mm (Gian 2017). Mean monthly temperature vary from 26°C in January to 11°C in August (Ayele and Shanmugaratnam 2008).

Soils (Eutric Nitisols associated with Humic Nitisols, which are dark reddish brown with deep profiles and vertisoils), are the most prevalent types in Wolayta zone (Tesfaye 2003; Ayele and Shanmugaratnam, 2008]. Primary occupation of the zone is farming. Also, mixed crop-livestock production predominates the farming system, but there are some pastoralists in the lowlands. Livestock production in Wolayta zone includes cattle (oxen, milking cows and young stock), goats and sheep, equines (horses and donkeys), poultry (local and improved breeds). Cattle that are kept for milk production, draught power, cash and manure, dominate livestock numerically. Animals are fed in open grazing, stall feeding and tethered (small area of open grazing left in front of a house). Generally, the climatic condition is conducive to livestock production (Berhanu, 2012).

### Sampling techniques

Multi-stage sampling procedure was used to collect series of data. In the first stage, Wolayta zone was selected purposively taking into account livestock production and feeding problems, representation of mixed crop-livestock farming systems in small and fragmented plot of lands in southern Ethiopia as well as logistic and coordination issues. Based on (Berhanu, 2012), the 12 woredas of Wolayta zone were stratified in to three agro-ecologies (strata), namely *Kolla, Dega* and *Woina-Dega*. Accordingly, four woredas (one from each of *Kolla* and *Dega,* and two from *Woina-Dega* agro-ecology) were randomly selected as most of the area lies with in mid altitude (*Woina-Dega*). From the selected 4 woredas, a total of 8 kebeles (PAs), two from each were taken randomly. Subsequently, a total of 176 farmers that owned any livestock species from the 8 kebeles/PAs (22 farmers from each kebeles) were interviewed (Figure 2). The total number of households sampled for the study was calculated based on the formula given by Kechero and Geert, 2014; Cochran 1977; Thrustfield 2005. A precision level of 5 and 95% confidence interval was used to calculate the sample size using the $n= (Z^2pq)/d^2$, where, n, desired sample size; Z, abscissa of the normal curve (The acceptable likelihood of error of 5%): 1.96, the value of Z at 95% confidence interval; P, estimated proportion that one is trying to estimate the population; q, is 1-P; d, desired absolute precision level at 95% confidence interval, the probability of Type I error (Called alpha).

### Data sources and collection procedures

Both quantitative and qualitative data types were used in
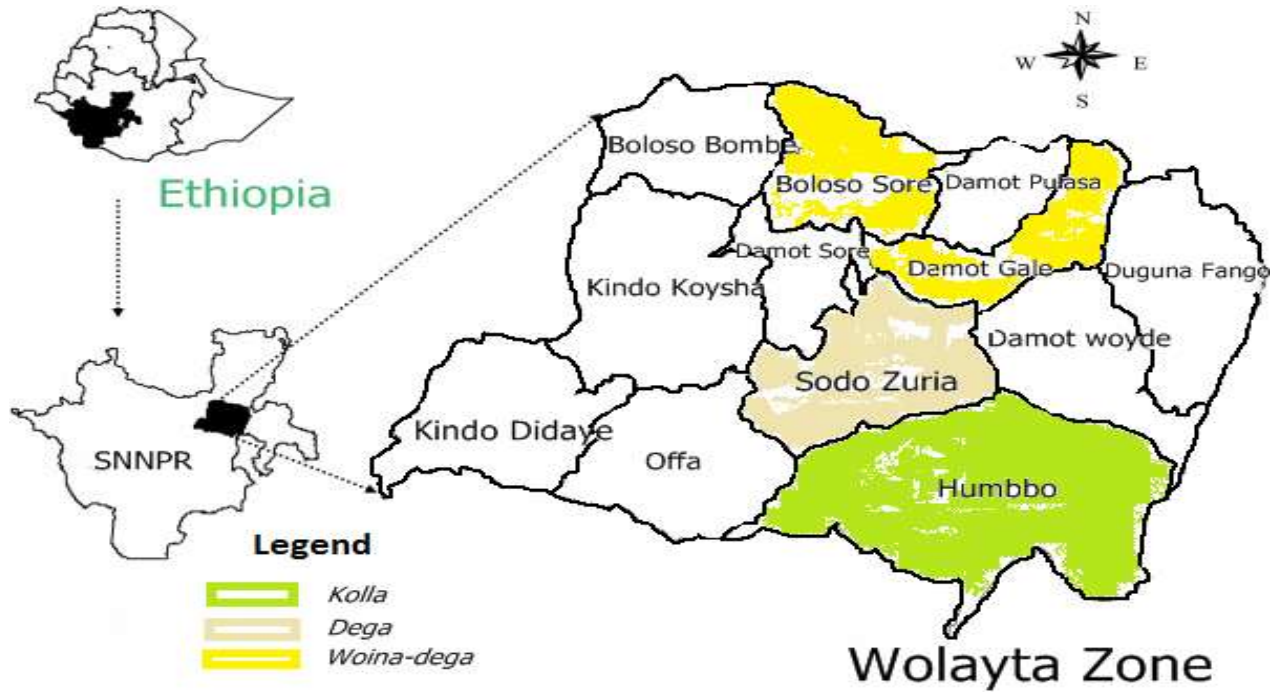
*Corresponding author. E-mail: tibbeecoach49@gmail.com.

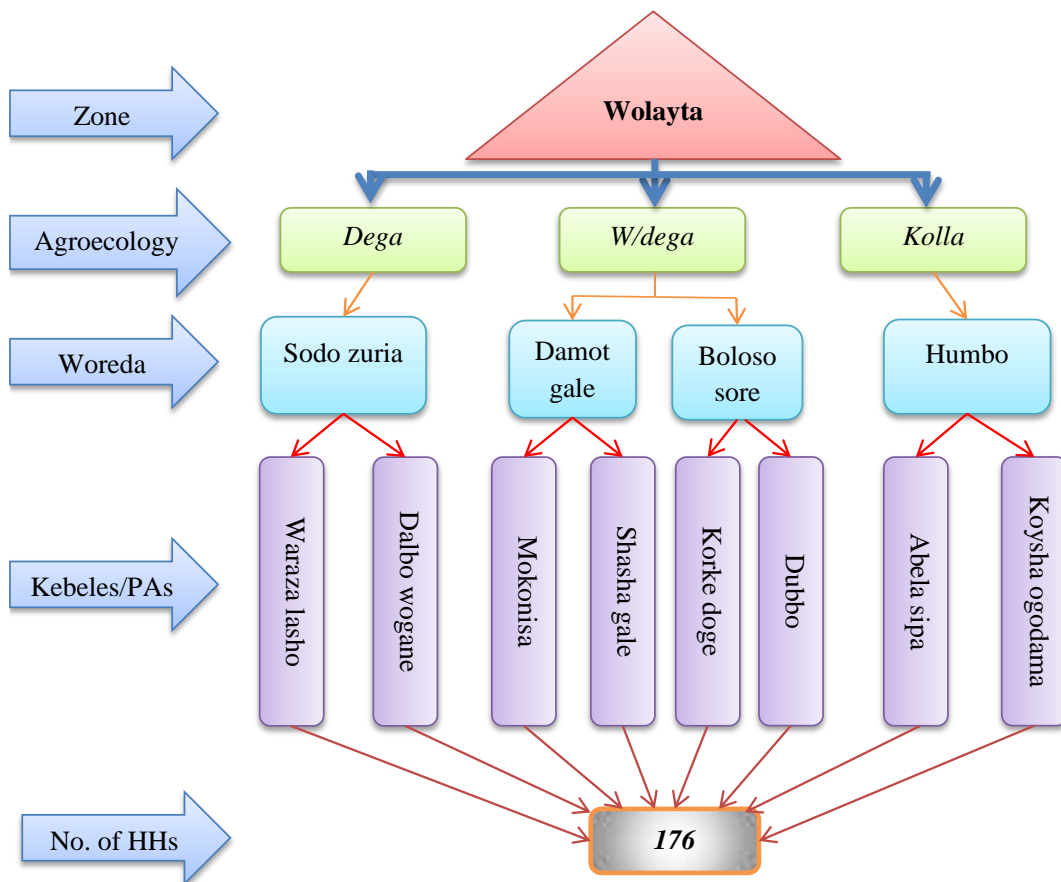**Figure 1.** Map of Wolayta zone.



**Figure 2.** Schematic diagram of selection procedures of study site and sample households.

this study. In order to generate these data types, both secondary and primary data sources were used. Primary data sources include information on crop, livestock and livestock feed production from individuals, zonal and woreda offices, visual observations, livestock farmers and experts from woreda and zonal offices. Secondary sources include reports from zonal and woreda offices, journals, books and internet browsing, among others. Survey questionnaire were prepared and pre-tested for feed types, sources, amount, months of availability and feeding practices. Using the questionnaire, interviews were conducted to gather data on household characteristics, socioeconomic and demographic characteristics, farm information, and livestock holdings. Trained and experienced enumerators (development agents who have diploma in animal husbandry) were hired to collect data from selected livestock farmers. Detailed descriptions of the data collection methods used were presented below.

### Estimation of available feed resources

Dry matter yield of natural pasture: The total amount of dry matter (DM) available in natural pasture was determined by multiplying the average value of grazing land holding with the per hectare DM yield of the natural pastures with conversion factor of 2 t DM/ha/year (FAO, 1987); (FAO, 1995). The amount of DM obtained from communal grazing land was factored into total communal grazing areas for each total households and their associated TLU eligible to graze on this land unit.

**Crop residue, fallow land and after math grazing:** The quantity of available crop residues (DM basis) was estimated from the total crop yields of the households, which was obtained from questionnaire survey, according to conversion factors. The conversion factors are 1.5 for barley, wheat, teff (Eragrostis tef); 2 for maize, 1.2 for pulse and oil crop straws and 2.5 for sorghum. The quantities of available DM in fallow land and aftermath grazing was determined by multiplying the available land by the conversion factors of 1.8 for fallow land and 0.5 for grazing aftermath (FAO, 1987).

**Quantity of trees and shrubs:** The dry matter from browsing trees and shrubs of leaf biomass was estimated at 1.2 ton ha-1(FAO, 1987).

**Estimating available concentrates:** The quantity (DM basis) of non-conventional concentrates (supplements) available for each household was obtained by interviewing the farmers during the cross-sectional questionnaire survey.

### Estimation of annual feed requirements for livestock in terms of DM

Data of livestock population in the sampled households was obtained from the interview of household heads during the survey. The number of livestock population was converted into tropical livestock unit (TLU) using the conversion factors of (Varvikko et al., 1993). The DM requirements of the livestock population was calculated according to the daily DM requirements for maintenance of 1 TLU (250 kg livestock consumes 2.5% of its BW (6.25 kg DM/d) or 2.28 tones/year/TLU (Kearl 1982).

### Statistical analysis

Data were analyzed using R software version 3.3.3. Mean comparisons of the three agro-ecologies were carried out using Tukey test. Levels of significance were considered at P < 0.05. Accordingly, values of parameters that differed significantly for the Three agro-ecologies of the studied woredas were separately presented. The statistical model used for data analysis was:

$$Y_{ij} = \mu + L_i + e_{ij}$$

Where, $Y_{ij}$, total dry matter yield obtained from grazing, crop residue, green harvests, feed supplements, fodder trees and shrubs; $\mu$, overall mean; $L_i$ is the effect of $i^{th}$ location (agro-ecology), i = 1… 3; $e_{ij}$, random error

## RESULTS

### Household characteristics

A total of 176 households were interviewed for this survey from which, 89.6 and 10.4 were male and female headed households respectively. Average age of the household heads was 45.3 and average household size of the study site was 6.8. The household size significantly (P<0.05) differed across all agro-ecologies. It was higher in *Kolla* agro-ecology (7.61 ± 0.36), followed by *Woina-Dega* (6.77 ± 0.19) and *Dega* (6.18 ± 0.29). The education status of the households heads also showed significant (P<0.05) difference across the agro-ecologies. From the total sampled household heads, 22.7% were illiterate, 47.7% completed primary school, 23.9% completed secondary school and 5.7% completed post-secondary school.

### Land holdings and land use systems

Land holdings per households showed significant (P<0.05) difference across the three agro-ecologies. Average land holding for the sample households was 1.5 ± 0.081 ha. Crops mostly produced in the study area included maize, teff, wheat, barley, sorghum, bean and pea. In addition, sweet potato, potato, cassava, yam, taro and enset were also common root crops. Rate of land allocation for crops showed a reduced trend from year to year due to increased human population and the consequent reduction in land holdings per household. The highest land was allocated for maize (0.4 ± 0.031) followed by teff (0.19 ± 0.028) and peas (0.16 ± 0.012). From the root crops, cassava production accounted for the highest proportion (0.12 ± 0.11) followed by taro (0.11 ± 0.11) and enset (0.08 ± 0.10). Land allocation for feed production/feeding had also been diminishing in size due to population growth which resulted from the use of grazing lands for crop production. The sampled households owned on average (0.14 ± 0.0.17 ha) permanent grazing land and (0.8 ± 0.0.14 ha) fallow land. The proportion of communal grazing land (4.37 ± 0.79 ha) also showed significant (P<0.05) difference across all three agro-ecologies. The *Kolla* agro-ecology (11.82 ± 2.82 ha) had the highest communal land ownership than *Woina-Dega* (2.83 ± 0.31 ha) agro-ecology and the *Dega* agro-ecology had no communal grazing land observed at all.

**Table 1.** Total livestock population of the sampled households in TLU.

| Livestock type | Conversion factor | Total population | Total sum (TLU) |
|---|---|---|---|
| Cattle | 0.7 | 696 | 487.20 |
| Sheep | 0.1 | 289 | 28.90 |
| Goat | 0.1 | 199 | 19.90 |
| Mule | 0.7 | 4 | 2.80 |
| Donkeys | 0.6 | 85 | 51.00 |
| Poultry | 0.01 | 1244 | 12.44 |
| Total | | | 602.24 |

TLU: Tropical Livestock Unit.

**Table 2.** Total feed from natural pasture, fallow land and aftermath grazing in tonne.

| Feed source | Conversion factor | Total sum (ha) | Total DM (tonne) |
|---|---|---|---|
| Fallow land | 1.8 | 47.33 | 85.19 |
| After math | 0.5 | 21.9 | 10.95 |
| Permanent grazing land | 2 | 53.15 | 106.30 |
| Communal grazing land | 2 | 3472 | 45.72* |
| Forest land | 1.2 | 1.52 | 1.82 |
| Road side grazing | 2 | 34.5 | 69.00 |
| River side grazing | 2 | 18.82 | 37.64 |
| Total | | 3649.22 | 356.62 |

*DM obtained from total communal area was factored to total livestock (TLU) grazing this unit of land.

## Livestock holding and composition

Farmers in this study site kept a mix of cattle, sheep, goats, equines and chicken. Most of the households owned local cattle breed. Average livestock ownership in terms of Tropical Livestock Unit (TLU) was 3.42, which was not significantly (P>0.05) different across all the three agro-ecologies. However, average cattle holding was significantly (P<0.05) higher in *Dega* agro-ecology (4.36 ± 0.19) than, *Woina-Dega* agro-ecology (4.1 ± 0.12) and *Kolla* agro-ecology (3.25 ± 0.27) (Table 1).

## Feed resources and availability

### Quantity estimation of available feed resource

**Dry matter yield of natural pasture, fallow land and aftermath grazing:** The total amount of DM obtained from natural pasture (private and communal grazing areas), fallow land and aftermath grazing was 356.62 ton/year (Table 2).

**Crop residues:** The total amount of feed produced from all crops for sampled household was 517.35 ton/year (Table 3).

**Quantity of trees and shrubs:** Farmers used different trees and shrubs as source of feed for animals especially at times of drought and feed shortage. About 2.8 ha of land was covered by trees and shrubs used for livestock feeding in the sample households, producing 3.36 tons of DM feed per year.

**Estimating available concentrates:** Parts of enset plant contributed a lot as basal feed as well as supplement especially for draught animals and milking cows. Small amount of mineral-rich soil locally called (*Aduwa*), kitchen wastes, coffee leaf prepared in liquid form, residues of local drinks like coffee*, chat,* fruits and vegetables rejects were also other concentrates used in the area. In addition to these, there were also other locally available feeds given as concentrate to improve quality and yield of milk and milk products. The common name of such feeds in the area is called *manache maatta.* These feeds are cooked in the pot (used for milk churning (*manaachiya*)), and given to the cows. It also improved the odor, taste and texture of milk and its products as it is cooked in the pot and fed to the animals.

### Livestock feed balance

Total available DM obtained from all sources was

**Table 3.** Total feed produced from crop production in tonne.

| Crop | Conversion factor | Total sum (ha) | Total DM (tonne) |
|---|---|---|---|
| Maize | 2 | 113.63 | 227.25 |
| Teff | 1.5 | 37.28 | 55.92 |
| Wheat | 1.5 | 16.00 | 24.00 |
| Sorghum | 2.5 | 25.63 | 64.16 |
| Barley | 1.5 | 23.75 | 35.63 |
| Bean | 1.2 | 28.25 | 33.90 |
| Pea | 1.2 | 20.16 | 24.20 |
| Sweet Potato | 0.3 | 40.13 | 12.04 |
| Potato | 0.3 | 22.25 | 6.67 |
| Taro | 0.3 | 19.42 | 5.83 |
| Cassava | 1.0 | 20.43 | 20.40 |
| Coffee | 0.4 | 9.50 | 3.80 |
| Irrigation area | 0.3 | 6.07 | 3.64* |
| Enset | NA | 15.00 | |
| Banana | NA | 7.35 | |
| Total | | 404.84 | 517.35 |

* Irrigation areas produce twice within a year.

**Table 4.** Feed balance analysis from all sources.

| Feed supply | Area (ha) | DM (tonne) |
|---|---|---|
| Natural pasture, fallow land and after math grazing | 3649.22 | 356.62 |
| Crop residues | 404.84 | 517.35 |
| Trees and shrubs | 2.8 | 3.36 |
| Total feed supply | 4057.33 | 877.33 (1) |
| | | |
| **Feed requirement** | | |
| Total HHH | 176 = (2) | |
| No of TLU/ HHH | 3.42 = (3/2) | |
| Total no of TLU | 602.24 = (3) | |
| DM required/TLU/ year | 2.28 given = (4) | |
| Total annual DM required | 1373.1072 5= (3*4) | |
| | | |
| **Feed balance** | **-495.77 (1-5)** | |
| Proportion of feed gap (%) | 36.10 | |

compared to the annual DM requirements of the livestock population in the sampled households. The available feed source addressed only 63.9% of the annual DM requirements with the proportion of feed gap of 36.1%. Overall livestock-feed balance of the sampled households was summarized in (Table 4).

## DISCUSSION

### Household characteristics

Wolayta zone has always been characterized by densely populated and intensively cultivated mid-altitude area of Ethiopia for many studies found the average household size of 6.56 (Yishak 2017), 6.74 (Tsedeke and Endrias, 2011) and 5.1 (Leza and Kuma, 2015). The average household size of the zone in this study was 6.8. The household size significantly (P<0.05) differed across agro-ecologies. It was higher in *Kolla* agro-ecology (7.61± 0.36), followed by *Woina-Dega* (6.77 ± 0.19) and then *Dega* (6.18 ± 0.29). Education is another important variable with regard to its association with demographic behavior. The education status of the households heads also showed significant (P<0.05) difference across agro-ecologies. It was higher in *Woina-Dega* areas than *Dega*

and *Kolla,* which could be related to the geographic location advantage of *Woina-Dega* agro-ecology (Sodo zuria woreda) to the central town (Sodo) of the zone. From the total 176 households interviewed for this survey, 89.6 and 10.4 were male and female headed households respectively. Average age of the household heads was 45.3.

## Land holdings and land use systems

The average land holding of the study area was 1.5 ± 0.081 ha. Land was the most important limiting production factor in the study area and the quality and quantity of land available greatly determined the amount of production. Because of the high population density, land holdings per households were small in the study area. Even though there were different studies with varied figures showing land holding of the area like 1.41 ha of (Ayele and Shanmugaratnam, 2008), and 0.62 ha of (Gian, 2017), land in Wolayta continued to be an extremely scarce asset. Crops mostly produced in the study area included maize, teff, wheat, barley, sorghum, bean and pea. In addition, sweet potato, potato, cassava, yam, taro and enset were also common root crops in this area. Rate of land allocation for crops showed a reduced trend from year to year due to increased human population and the consequent reduction in land holdings per household. Rate of land allocation for crops showed a reduced trend from year to year due to increased human population and the consequent reduction in land holdings per household. In line with this, the report by (Yonas, 2011) concluded that population growth and land fragmentation are forcing Wolayta farmers to gradually change the age old traditional land management schemes, cropping strategies and land use patterns and further making the farming system vulnerable.

## Livestock holding and composition

Farmers in the study site kept a mix of cattle, sheep, goats, equines and chicken. Most of the households in the study site owned local cattle breed. Average livestock ownership in terms of Tropical Livestock Unit (TLU) was 3.42 which agreed with the finding of (Gian, 2017).

## Feed resources and availability

Total DM yield estimates from grazing land (pasture, road, river side and fallow), crop residues, foliage of fodder trees and shrubs, green forages as well as non-conventional feed supplements were considered in this study. The largest proportion of feed (517.35 ton of DM/year, 58.9%) came from crop production. Natural pasture was the second most important feed source for

animals (356.62 ton of DM/year, 40.6%) that disagreed with the findings of (Adugna and Said, 1992) and (Zereu and Lijalem, 2016) who concluded that natural pasture was the main source of feed for Wolayta zone. The reason for higher amount of feed to come from crop residues than natural pasture could be population pressure, urbanization and increased cultivation of grazing lands for crop production. Some small amount of feed was obtained from trees and shrubs (3.36 ton of DM/year, 0.5%) as farmers lop the leaves and branches of various trees and shrubs and feed them to their animals during the dry season. The famers in Wolayta zone also collect herbaceous wild plants, mostly legumes, as feed for lactating cows as reported by (Adugna, 1990). The use of concentrate feeds was very limited in the area as some small amount of kitchen wastes, coffee leaf prepared in liquid form, fruits and vegetable rejects were used. The degree by which local residues were produced and used was quite small and the share of it in the total dry matter is of due consideration but needs a clear system of quantifying the dry matter percentages of each residues. In addition to this, crops like inset and banana lacks conversion factor, which could increase the total DM yield.

## Livestock feed balance

The total amount of feed obtained from all sources was 877.33 ton/year in DM and the total livestock population of the sampled households was 602.24 TLU. The total amount feed required for this amount of TLU in terms of DM was therefore, 1373.1 ton/year (With negative balance of 495.77 ton DM) regardless of the nutritional content of the DM yield. That means the total feed available addressed only 63.9% of the annual DM requirement which was able to support existing stock for 7.7 months. Similarly, in most parts of the country livestock-feed balance showed negative balance as reported by (Tadesse and Solomon, 2014) at Gumara-Rib watershed; Amahara region, (Funte et al., 2010) in southern Ethiopia, (Tessema et al., 2003) in Belesa district of Amhara region, (Bedasa, 2012) at highlands of the Blue Nile basin, (Kechero and Geert, 2014) at Jimma; south western Ethiopia, (Yeshitila, 2008); at Halaba; southern Ethiopia, and (Adugna and Said, 1992) at Wolayta; southern Ethiopia. Contrary to these results, (Shitahun, 2009) reported that the existing feed supply on a year round basis accounted for about 104.79% of the maintenance DM requirement of livestock per household in Bure district, Oromia regional state (Endale, 2015).

To fill the feed gap (36.1%), farmers used different strategies like mixed cropping of many plants species with in the same (small) plot of land and using these plants/crops for food and feed production as shown in (Figure 3a). Crops produced in the mix included maize, banana, pigeon pea, and cassava. Thus such type of
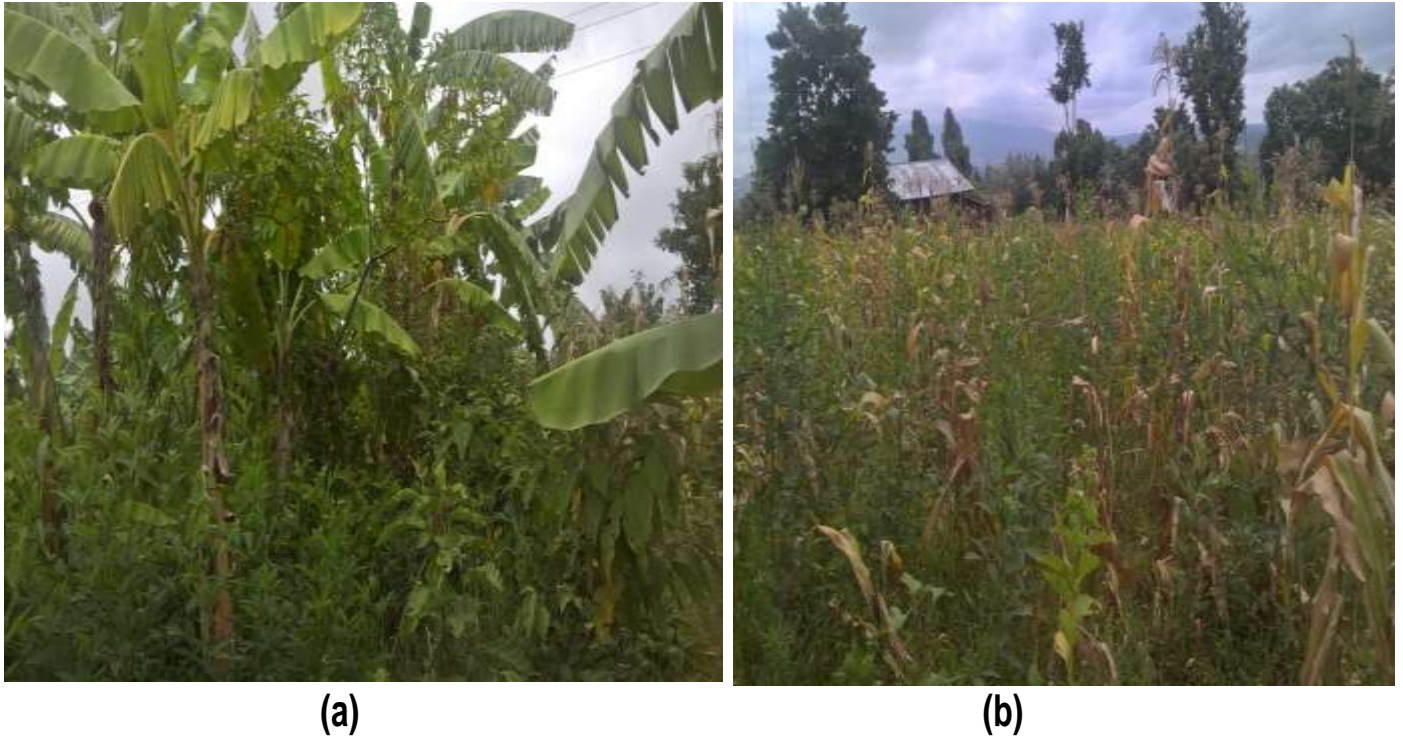
**Figure 3.** Mixed cropping of (a) cassava-banana-pigeon pea and (b) maize-pigeon pea.

cropping helps to make livestock production bearable through improved feeding as farmers in the area own small and fragmented lands. In some parts of the area, maize was constantly intercropped with pegion pea (Figure 3b). The most common mixed cropping system in the area included maize-cassava, maize-pegion pea, banana-pegion pea, banana-cassava-pegion pea, maize-pegion pea-cassava.

In some other parts of the area, households were producing pigeon pea (*Cajanus cajan*) as source of income in addition to feeding animals and using for home consumption. The other feed being produced as cash crop and/or animal feed was *desho grass* (*Brachiaria brizantha*). Different governmental or non-governmental organizations were working on improving animal production through improved feeding by purchasing and distributing different crops/grasses from producing households to other areas at times of drought and feed scarcity.

**Conclusions**

The findings of this study affirm that Wolayta zone is a densely populated and intensively cultivated mid-altitude area of Ethiopia. Because of the high population density, land holdings per household were small in the study area. Crops mostly produced in the study area included maize, teff, wheat, barley, sorghum, bean and pea. In addition

sweet potato, potato, cassava, yam, taro and enset are also common root crops in this area. Rate of land allocation for crops has been reduced from year to year due to reduction in land holding per household. Land allocation for feed production/feeding has also been diminishing on size due to population growth which has resulted in use of grazing lands for crop production. Farmers in the study site kept a mix of cattle, sheep, goat, equines and chicken. Most of the households in the study site owned local cattle. The total amount of DM obtained from all sources addressed only 63.9% of the annual DM requirement. All feed sources were compared for the three agro-ecologies and most of them showed significant (P<0.05) difference as shown in (Table 5).

Even though there was overall livestock feed imbalance in the study area, the gap was not similar throughout all agro-ecologies. The feed gap was significantly (P<0.05) higher at *Woina-Dega* followed by *Dega* agro-ecology. It was better comparatively at *Kolla* agro-ecology as shown in (Table 6).

To fill the gap (36.1%), farmers used different strategies from using uncommon feeds such as trees and shrubs to purchasing feed and practicing new mixed cropping system. However, it was observed that feed is still a big problem for livestock production in Wolayta zone as most of the households reported to have purchased feed in the year 2016/17. In addition to this, the above negative balance between supply and demand of feed in terms of DM shows that livestock feeding still

**Table 5.** Feed resources category and their supply according to agro-ecology.

| Feed supply by source | Agro-ecology mean | | | Overall | | |
| --- | --- | --- | --- | --- | --- | --- |
| | *Dega* (n=44) | *Woina-Dega* (n=88) | *Kolla* (n=44) | Mean | SEM | P |
| Maize production (t) | 1.15[a] | 1.11[a] | 1.80[b] | 1.29 | 0.063 | *** |
| Teff production (t) | 0.18[a] | 0.22[a] | 0.66[b] | 0.32 | 0.035 | *** |
| Wheat production (t) | 0.33[b] | 0.11[a] | 0.00[a] | 0.14 | 0.028 | *** |
| Sorghum production (t) | 0.47 | 0.25 | 0.49 | 0.36 | 0.048 | NS |
| Barley production (t) | 0.26[a] | 0.18[b] | 0.20[ab] | 0.20 | 0.012 | * |
| Bean production (t) | 0.06[b] | 0.26[a] | 0.19[a] | 0.19 | 0.015 | *** |
| Pea production (t) | 0.05[b] | 0.16[a] | 0.18[a] | 0.14 | 0.011 | *** |
| Sweet potato production (t) | 0.09[a] | 0.08[a] | 0.03[b] | 0.07 | 0.004 | *** |
| Potato production (t) | 0.04 | 0.04 | 0.04 | 0.04 | 0.003 | NS |
| Taro production (t) | 0.04 | 0.03 | 0.03 | 0.03 | 0.003 | NS |
| Cassava production (t) | 0.10 | 0.12 | 0.12 | 0.12 | 0.011 | NS |
| Coffee production (t) | 0.02 | 0.02 | 0.03 | 0.02 | 0.003 | NS |
| Irrigated land (t) | 0.00[b] | 0.04[a] | 0.00[b] | 0.02 | 0.004 | *** |
| Fallow land (t) | 0.05 | 0.05 | 0.09 | 0.06 | 0.007 | NS |
| Permanent grazing land (t) | 0.39 | 0.55 | 0.45 | 0.48 | 0.032 | NS |
| Forest and wood land (t) | 0.00[b] | 0.02[a] | 0.00[b] | 0.01 | 0.003 | *** |
| Communal grazing land (t) | 0.00[c] | 0.42[a] | 0.21[b] | 0.26 | 0.029 | *** |
| Tree and shrubs (t) | 0.02[a] | 0.01[b] | 0.02[a] | 0.02 | 0.001 | *** |
| Roadside grazing (t) | 0.35[b] | 0.61[a] | 0.00[c] | 0.39 | 0.037 | *** |
| Riverside grazing (t) | 0.15 | 0.24 | 0.23 | 0.21 | 0.026 | NS |

[a,b,c] Means with different letters in the row are significantly different (P=0.05); SEM, standard error of means; *P=0.05; ** P=0.01; *** P=0.001.

**Table 6.** Average yearly difference in the balance between feed supply and requirement.

| Feed supply | Agro-ecology mean | | | Overall | | |
| --- | --- | --- | --- | --- | --- | --- |
| | *Dega* | *Woina-Dega* | *Kolla* | Mean | SEM | P |
| Available (tons) | 4.39 | 5.09 | 5.37 | 4.98 | 0.168 | NS |
| Required (tons) | 8.04[ab] | 8.20[a] | 6.77[b] | 7.80 | 0.195 | ** |
| Balance (tons) | -3.11[a] | -3.66[a] | -1.39[b] | -2.82 | 0.211 | *** |

[a,b,c] Means with different letters in the row are significantly different (P=0.05); SEM, standard error of means; *P=0.05; ** P=0.01; *** *P*=0.001

requires owed attention in the study area.

## CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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# Phenotypic characterization of pigs and their production system in Liberia

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**Native pig farming is an important component of rural farming systems in Liberia but the population has recently stagnated, due to the absence of a comprehensive improvement and conservation program. A survey was conducted to measure the phenotypic morphometric parameters and production system of native and exotic pigs of Liberia. The survey was carried out in 15 Counties of Liberia and covered 545 animals from 264 farms. A pre-tested structured questionnaire, group discussion and in-depth interviews were the tools used in data collection. Phenotypic descriptors were directly measured using a measuring tape. The main pig breeds encountered were Landrace, Large White/Yorkshire and native pigs. The sampled pigs had predominantly smooth skin (91%), solid/uniform coat color pattern (80%) and straight head profile (82%). Mean adult body weight was 55.1±1.2 kg, body length 88.9±0.74 cm and chest girth 91.4± cm. The ears are prick (52%) or droopy (38%) and more pigs have long and thin snouts (74%). The pig farmers were mostly male (71%), literate (72%) and did not belong to any farmer's association and their main motivation for raising pigs is income (92%). The production system is mainly commercial (51%) and subsistence (46%) based on backyard scavenging (71%) and use of local feeds (72%).**

**Key words:** Pig characterization, genetic resources, production systems.

## INTRODUCTION

Pig has a relatively high potential to contribute to increased productivity on account of their high fecundity, feed conversion efficiency, short generation interval and early maturity (Ouma et al., 2013; Mbuthia et al., 2015). Available statistics up to 2015 (USDA, 2016) indicates that pork accounted for 40% of world meat consumption followed by chicken (33%), cattle (22%) and mutton and goats (7%). Native pigs of Liberia make substantial contribution to human livelihoods, employment generation and food security as well as their superior adaptation to harsh environmental conditions and resistance to endemic diseases (MOA, 2008).

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Pigs (*Sus scrofa*) display enormous phenotypic diversity in terms of shape, colour, size, production and reproduction abilities (Osei-Amponsah et al., 2017). Although local pigs have small body sizes compared to exotic pigs, their genetic diversity could be exploited to improve on their productivity. Exploitation of genetic diversity among and within breeds of pigs will thus help identify the most productive and adapted animals for specific environments (Philipsson et al., 2011). There is a need to characterize and maintain local breeds of pigs which have variable traits suited to a particular ecological zone (FAO, 2015; Adjei et al., 2015).

Morphometric information has been used to evaluate the characteristics of various breeds of animals and could provide first-hand information on the suitability of animals for breeding (Nesamvuni et al., 2000; Mwacharo et al., 2006; Adeola et al., 2013, Adjei et al., 2015). FAO (2012) reported that information provided by phenotypic characterization studies is important for management of the animal genetic resources for conservation and food security. The swine genetic resources of Liberia need to be characterized as a basis for their genetic improvement and characterization. Adequate information on the phenotypic characteristics and production system of pigs is unknown and is essential in developing breeding, management and conservation programs. The objective of this study therefore was to carry out phenotypic characterization of native and exotic pigs of Liberia, along with their production systems in order to recommend appropriate strategies for their conservation and sustainable use.

## MATERIALS AND METHODS

### Scope of characterization

Liberia, a country located along the coast of West Africa covers a total area of 110,000 km$^2$ and has an estimated population of 4 million. Prudent planning and management of animal genetic resources (AnGR) require reliable data which are not available in Liberia. In order to overcome this challenge and help improve pig production, the Government of Liberia through a Technical Cooperation Project (TCP) with the FAO implemented by the Central Agricultural Research Institute (CARI) collected baseline data on Liberia's AnGR. This was undertaken through a survey and characterization of available AnGR and provided valuable inputs for the development of a national Strategic Action Plan on AnGR (NSAP-AnGR) for Liberia. This intervention has thus contributed to development of a medium to long-term strategy to ensure sustainable use of Liberia's AnGR and maximize their contribution to economic growth, food security and poverty reduction.

### Study sites and data collection

The survey was conducted in 15 counties of Liberia using on FAO's Guidelines for phenotypic characterization of AnGR (FAO, 2012). Training of supervisors and enumerators for the survey and characterization of Liberia's AnGR took place in February, 2016. The training helped to develop human resource capacity on AnGR in Liberia and also provided training and knowledge in the various aspects of phenotypic characterization. The methodology employed for sampling and data collection has been described by Karnuah et al. (2018). Data collected included general information on household characteristics, pig production and management practices, and phenotypic characteristics (FAO, 2012). Linear and morphological measurements including body measurements such as heart girth, whither height and body length were also taken using measuring tape. Livestock characterization and production system data was collected by the team of enumerators using an electronic data capture system with the EpiCollect software application (http://www.epicollect.net/).

### Data processing and analysis

Various analyses were carried out to determine the relative frequencies of various characterization parameters and the results summarized in Tables and Figures. All data analyses were done using the *Mosaic* and *Survey* Packages in R (R Core Team, 2016).

## RESULTS AND DISCUSSION

### Respondents and educational status

A total of 372 respondents that are pig farmers were randomly surveyed from the 15 counties of Liberia with the highest numbers coming from Monsterrado (95), Lofa (83), Nimba (47), and Bong (41) counties. The number of farmers visited and interviewed by gender, educational status and membership of livestock associations are shown in Table 1.

Male pig farmers (71%) were more than the females (29%). About 20% of the pig farmers were illiterate and the high level of literacy among farmers (82%) could have positive effects on adoption of innovative animal husbandry practices. Male farmers were relatively more educated than their female counterparts. Education helps farmers in making informed decisions, solving problems and learning new technologies (IFPRI, 2010). Most pig farmers (80%) did not belong to any pig farmers associations. The absence of well-organized farmer/breeder associations to support governmental initiatives has hindered the effort to develop an appropriate and integrated livestock monitoring and recording systems for Liberia's AnGR (MOA, 2008). It will be advisable to encourage pig farmers to come together in associations particularly in counties where pig farming is popular such as Monsterrado, Lofa, Nimba and Bong. These associations will help to safe-guard breed utilization and conservation of swine genetic resources.

### Phenotypic characterization

A total 594 adult pigs were characterized of which 38% were identify as Landrace, 21% as Large White/Yorkshire, 17% as native pigs, 10% and Hampshire (Table 2). In Liberia, the Landrace is also referred to locally as long mouth and white pig. Local names for the Large White/Yorkshire include white pig, Boaygui and

**Table 1.** Characteristics of pig farmers.

| Parameter | Male | Female | Total |
|---|---|---|---|
| Gender of farmers | 264 (71%) | 108 (29%) | 372(100%) |
| | | | |
| **Educational status** | | | |
| Illiterate | 26 (10%) | 40 (37%) | 66(18%) |
| Basic (Read and write) | 68 (26%) | 21 (19%) | 89(24%) |
| Secondary | 121 (46%) | 37 (34%) | 158(42%) |
| Tertiary | 49 (19%) | 10 (9%) | 59(16%) |
| Total | 264(71%) | 108(29%) | 372(100%) |
| Chi Square value = 39.81 | df = 4 | P<0.001 | |
| | | | |
| **Membership of Livestock Association** | | | |
| Yes | 49 (19%) | 25 (23%) | 74(20%) |
| No | 215 (81%) | 82 (77%) | 297(80%) |
| | 264(71%) | 107(29%) | 371(100%) |
| Chi Square value = 39.81 | df = 4 | P<0.001 | |

**Table 2.** Number of pigs sampled by breed.

| Breed | Number | Percentage |
|---|---|---|
| Crossbred | 48 | 8 |
| Exotic | 33 | 6 |
| Hampshire | 61 | 10 |
| Landrace | 229 | 38 |
| Large White/Yolkshire | 125 | 21 |
| Native pig | 99 | 17 |
| Total | 596 | 100.0 |

**Table 3.** Statistics of selected quantitative variables of sampled pigs.

| Variable | Mean ± SE | n | CV% | Range |
|---|---|---|---|---|
| Body weight (kg) | 56.9 ± 1.3 | 595 | 55 | 10.0 - 250.4 |
| Body length (cm) | 89.7 ± 0.7 | 595 | 19 | 40.6 - 149.9 |
| Chest girth (cm) | 92.3± 0.7 | 595 | 19 | 48.3 - 149.9 |
| Tail length (cm) | 26.3 ± 0.3 | 595 | 25 | 7.6 - 58.4 |
| Ear length (cm) | 19.6 ± 0.2 | 594 | 31 | 10.2 - 38.1 |

Mapuka whist the Hampshire is also known locally as Boaygui. The native pig referred to as West African Dwarf pig is also known as Mba, Saynee, Gbocho, Que Bayee, Black pig and Pepee in various part of Liberia.

Table 3 shows summary statistics of some key phenotypic characterization parameters of sampled pigs in Liberia. The mean body weight of pigs was about 57 kg with a chest girth of 92 cm.

Variation in mean phenotypic characterization para-meters are as shown in Table 4 with sampled Landrace being superior in most of the parameters measured.

These variations could be attributed to both breed and age effects.

The dominant body coat colour pattern of pigs in Liberia (Table 5) is solid/uniform/plain (80%), spotted (11%) and patchy/pied (8%). In fact, 82% of Landrace, 96% of Large White and 59% of local pigs had solid/uniform/plain coat colour patterns with the rest being patchy (21%) and spotted (18%). In terms of coat colour, the pigs were predominantly white (79%) with some pigs being fawn (9%) or black (7%).

The dominant ear types of pigs in Liberia were prick

**Table 4.** Variation in mean phenotypic characterization parameters (±SE) of sampled pigs by breed.

| Breed | Body weight (kg) | Body length (cm) | Chest girth (cm) | Sample size (n) |
|---|---|---|---|---|
| Crossbred | $53.8 \pm 4.6^b$ | $87.2 \pm 2.8^b$ | $89.4 \pm 2.8^b$ | 48 |
| Exotic | $59.9 \pm 5.3^b$ | $88.9 \pm 3.7^{ab}$ | $92.8 \pm 3.5^a$ | 33 |
| Hampshire | $41.6 \pm 1.9^c$ | $80.7 \pm 1.3^c$ | $83.3 \pm 1.4^c$ | 61 |
| Landrace | $63.3 \pm 2.3^a$ | $93.6 \pm 1.1^a$ | $96.1 \pm 1.2^a$ | 229 |
| Large White/Yorkshire | $49.3 \pm 2.3^c$ | $85.5 \pm 1.4^b$ | $88.1 \pm 1.4^{bc}$ | 125 |
| Native pig | $62.1 \pm 3.2^{ab}$ | $92.9 \pm 1.8^a$ | $95.3 \pm 1.9a$ | 99 |

Within columns means followed by different subscripts are significantly different (P < 0.05).

**Table 5.** Frequency of coat colour pattern of pigs in Liberia.

| Coat colour pattern | Number | Percentage |
|---|---|---|
| Patchy/pied | 48 | 8 |
| Solid/Uniform | 476 | 80 |
| Spotted | 67 | 11 |
| Pigmented | 3 | 1 |
| Total | 594 | 100 |

**Table 6.** Frequency of ear type of pigs in Liberia.

| Ear type | Number | Percentage |
|---|---|---|
| Droopy | 277 | 38 |
| Prick | 308 | 52 |
| Lop | 17 | 3 |
| Semi-lop | 42 | 7 |
| Total | 594 | 100 |

**Table 7.** Frequency of head profile of pigs in Liberia.

| Head profile | Number | Percentage |
|---|---|---|
| Concave | 96 | 16 |
| Convex | 6 | 1 |
| Straight | 491 | 83 |
| Total | 593 | 100 |

(52%), droopy (38%) and semi-lop (7%) (Table 6). Landrace shows 48% droopy and 47% prick ears, while Large Whites recorded 50% droopy and 41% prick ears. Native pigs had mostly prick (69%) and droopy ear (19%). In terms of orientation, ears of pigs projected forwards (46%) or upwards (46%).

The head profile of pigs in Liberia (Table 7) are mostly straight (83%) or concave (16%). Large White demonstrated straight head profile (95%), followed by Landrace 89% and Hampshire 84%. The native pigs exhibited straight (80%) and concave (17%) head profiles.

Liberian pigs were characterized as having straight (66%) or curly/kinked (34%) tails. Landrace exhibited 88% straight and 25% curly/kinked tails, followed by Hampshire with 64% straight and 32% curly/kinked tails. The native pigs showed 59% straight and 42% curly/kinked tails. The backline of pigs in Liberia is either straight (81%) or swayed back (19%) as shown in Table 8. Large White shows 100% straight backline, Hampshire with 97% and Landrace with 65% straight and 22% swaybacked. Native pigs demonstrated straight backline

**Table 8.** Frequency of backline profile of pigs in Liberia.

| Backline profile | Number | Percentage |
|---|---|---|
| Straight | 481 | 81 |
| Swayed back | 112 | 19 |
| Slopes towards rump | 1 | 0 |
| Total | 594 | 100 |
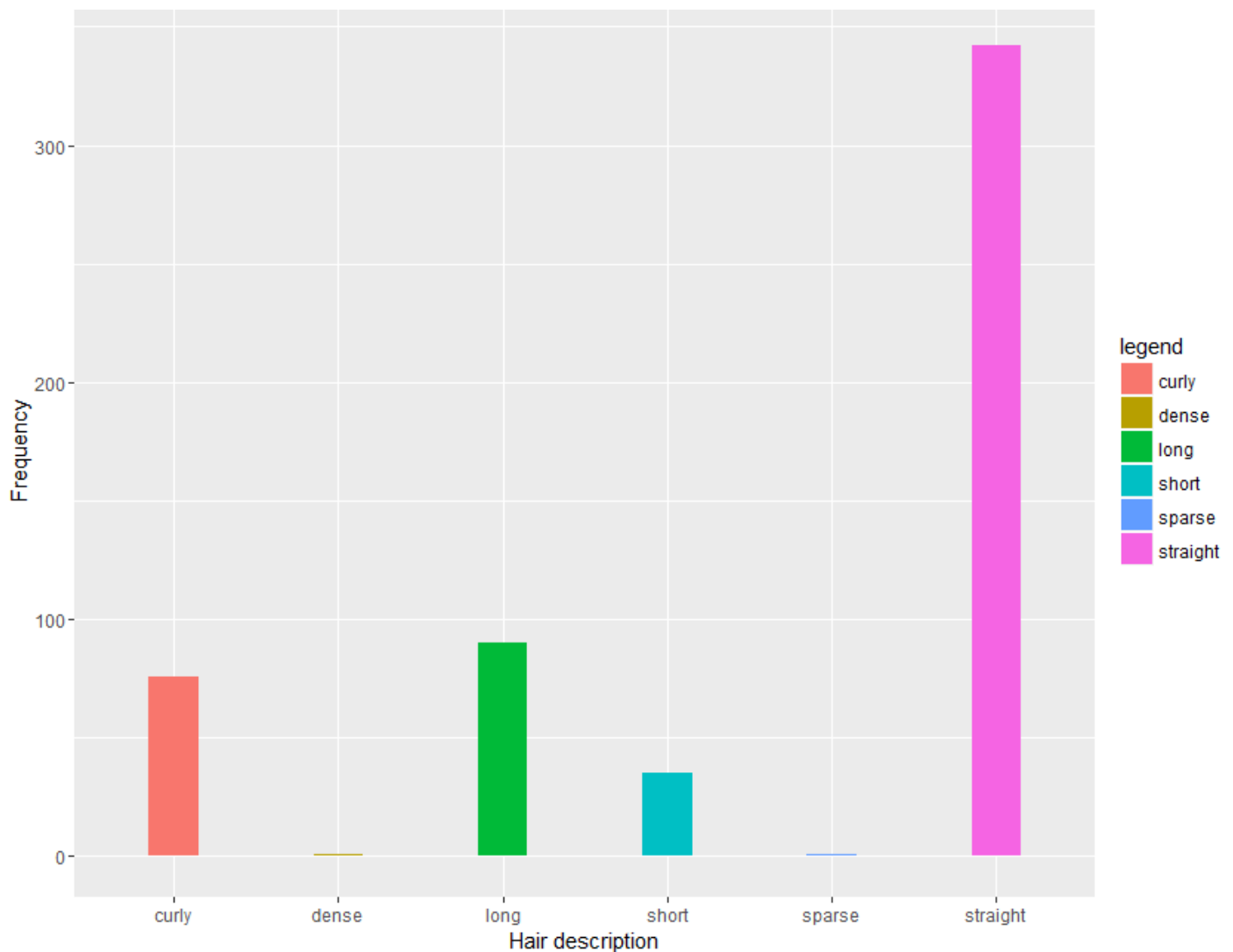


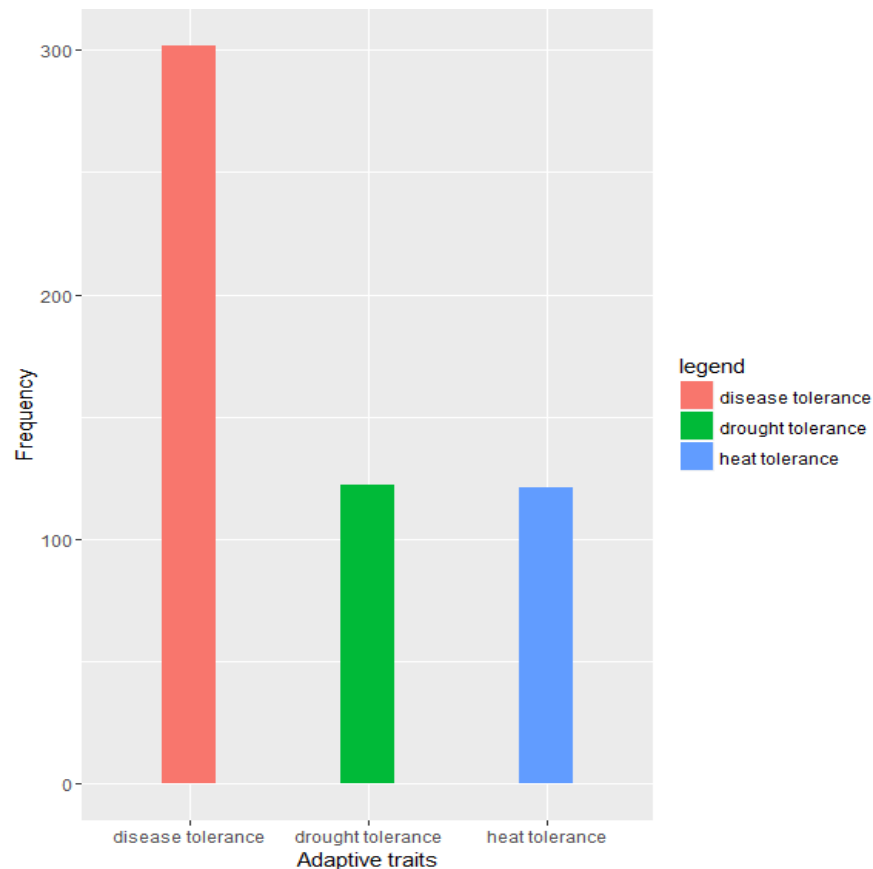**Figure 1.** Bar graph showing frequency of hair description of sampled pigs.

(72%) or swaybacked (28%).

These variations can be attributed to breed and age effects (Adjei et al., 2015).

Irrespective of breed, sampled pigs showed predominantly smooth skin (91%) with a few wrinkled types (9%). The pigs were characterized mostly as having long and thin snout (74%) or short and cylindrical snout (23%). Native pigs had mostly long and thin snouts (72%) with a few having short and cylindrical snouts (28%). Hairs of pigs in Liberia can be described as straight (63%), long (17%) and curly (14%) as shown in Figure 1.

Most of the pigs were described as being moderate in temperament or friendly as shown in Figure 3. Landrace

**Figure 2.** Bar graph showing frequency of adaptive traits of pigs in Liberia.

exhibited mostly and moderately tractable (61%) and placid/friendly temperaments (33%), while Large White exhibited moderately tractable (72%) and placid/friendly temperaments (25%). On the other hand, native pigs, exhibited aggressive/wild (32%), moderately tractable (30%), and placid/friendly temperaments (38%). The various levels of temperament observed among the Native pigs could be due the level of domestication. Some of the native pigs are kept in piggeries with daily human interactions, while others are scavengers and roam around freely in the villages and towns.

Pig farmers in Liberia indicated that disease, drought and heat tolerance as the major adaptive traits. The farmers stressed the importance of disease tolerance, but also giving attention to heat and drought tolerance. In Large White 71% showed disease tolerance, followed by native pigs 68% and Landrace 50% as shown in Figure 2. Native pigs are normally known for disease and heat tolerance to their adaptability of the ecosystem (Osei-Amponsah et al., 2017).

**Production system characterization**

Pig farming in Liberia is a predominantly commercial activity with over 75% of farmers in commercial production systems with peasant farming comprising about 20% and breeding and multiplication making up of only 4%. These data indicate very weak infrastructure for animal breeding in the Liberia livestock system. Pigs in Liberia are kept mostly housed with 71% of pig farmers providing permanent structures and 24% providing sheds. Only 5% of pig farmers provided no housing for their stock. The main reason for the high level of housing provision is the fact that most farmers are keeping exotic breeds such as the Landrace, Large White, and Hampshire in intensive systems. As expected therefore, most pigs in Liberia are continuously confined (82%), with a little over a tenth of pig farmers (11%) never confining their animals.

In Liberia, the main motivating factor for raising pigs is to generate income to take care of themselves and their families (MOA, 2008). About 92% of pig farmers reported income as their main motivation for pig farming. Others reasons given included pork (food) and socio-cultural factors. There are some commercial pig farms whose main motive is income and profit, but farms dedicated to training and research are very few. In general, pig farmers interviewed indicated that price of animal sold depends on either market value when it is ready for
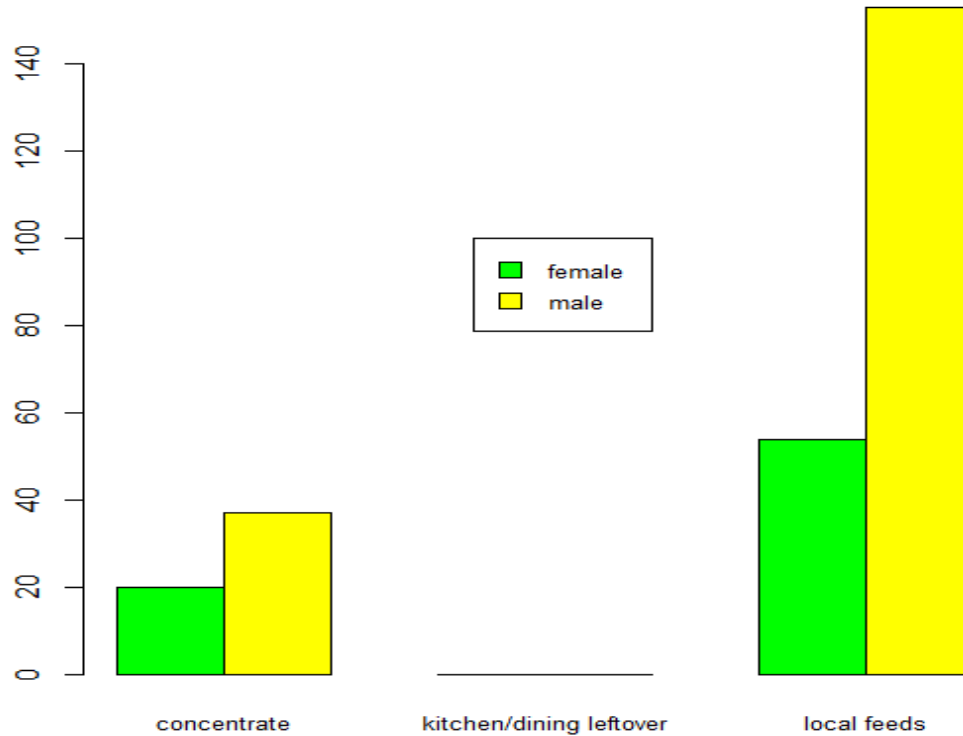
**Figure 3.** Proportion of type of feed given to pigs by gender of farmers.

market or when they are in financial need.

Trait of preference and economic importance for the overall pig farmers of Liberia were fast growth and overall meat production. Most farmers preferred fast growth and meat production (51%), whereas others preferred either fast growth (36%) or meat production (13%). The main sources of water for pig farming in Liberia are deep well, river/lake and pipe-born. Deep well accounted for 63%, river/lake 29% and pipe-born 8%. It is interesting to note that pipe-borne water is not the major source of watering pigs in Liberia even though there are commercial pig entities.

As shown in Figure 3, most pigs are kept in intensive and semi-intensive system and fed mostly local feeds (78%) with a small percentage of farmers providing concentrates (22%) for their pigs. In terms of availability of the feed, majority of pig farmers (65%) normally restrict their animals' access to feed, 24% usually do not restrict access to feed, while 12% occasionally do so. Therefore, pigs access to feeds in Liberia is restricted and can be explained by intensive and semi-intensive management systems, and availability of feeds.

The mating system for the livestock observed was uncontrolled, non-seasonal, natural mating involving the use of multiple sires. This is a common feature of traditional livestock systems in Africa. Although pig farming is predominantly intensive and semi-intensive, it is done with no or little monitoring of the mating system as controlled mating was just about 5% and there is a

need check this particularly in the breeding herd. This lack of controlled mating has created a high level of inbreeding among pigs in Liberia. The degree of phenotypic variations among the native pigs of Liberia is reflected in body size and colour pattern as shown in their natural environment (Figure 4).

Pig farmers indicated feed cost and availability (72%), cost of veterinary medicines (12%) and poor housing (10%) as the major challenges in their operations (Table 9). The main challenges in pig farming include cost and availability of feed, housing, and endemic diseases (MOA, 2008; Mbuthia et al., 2015), Being non-ruminants, the problem of feed availability and costs is even more acute in than with ruminant species and these challenges need to be addressed not only increase productivity but motivate more to go into pig production in Liberia. The cost of accessibility to veterinary services and medicines is a huge challenge to pig farming. There is little information available on major diseases of pigs such as African swine fever, hog cholera, parasites, brucellosis and pneumonia. There is no formal research program on animal diseases and the lack of veterinarians and veterinarian medicine needs to be addressed urgently (MOA, 2008).

The Liberian pig industry is also beset with the poor infrastructure and housing facilities resulting to low productivity on one hand and a shortage of feeds and local feed ingredients necessary for profitable pig production. Record keeping is also a challenge as most

**Figure 4.** Native pigs in foraging for feed in their production environment.

**Table 9.** Challenges of pig farming in Liberia.

| Challenge | Number of farmers | Percentage |
|---|---|---|
| Feed cost and availability | 246 | 68 |
| Cost of medicines | 47 | 13 |
| Poor Housing | 46 | 13 |
| Damage to property | 12 | 3 |
| Lack of medicines | 4 | 1 |
| Disease | 3 | 1 |
| Financial | 3 | 1 |
| Total | 361 | 100.0 |

of the respondents could not supply most of the required productivity data and this may require building up their capacity through training workshops and regular monitoring of such farmers by the Ministry of Agriculture.

**Conclusion**

The pigs of Liberia are mainly made up of the Landrace, Large White/Yorkshire, native pigs (West African Dwarf pigs), Hampshire and the Duroc. Pigs in Liberia are kept in intensive and semi-intensive systems, although often with insufficient investment in housing and feeding of the stock. Pigs were characterized as primarily having smooth skin, solid/uniform coat colour pattern and white body coat colours. Their ears are prick and droopy and oriented forwards or upwards. The pigs also have straight tails, head and backline profiles with mostly long and thin snouts. The key challenges hampering the development of pig production in Liberia include feed costs and unavailability, poor housing, diseases and the high cost of veterinary medicines. The relatively low proportion of native pigs suggests a need to undertake a program to improve the sustainable use and conservation of native pigs in Liberia. The Liberian pig sector is largely dominated by exotic pig breeds requiring intensive husbandry systems and thus greater investment. However, there is need to encourage the raising of the

local pig breed which does not require much inputs in terms of housing, feeding and veterinary care and to improve the productivity through improved management, record keeping and simple genetic selection. For an important regional transboundary breed like the local West African Dwarf pig, there is a need to have national breeding and conservation centres to ensure that the breed is maintained locally, as well as cooperation across borders to ensure management of the breed population as a whole. An Open Nucleus Breeding program can be set up by CARI to breed and supply superior breeding stock to local pig farmers. Participating farmers could be supported to form an association and periodically trained on basic husbandry practices such as record keeping, herd management, feed formulation, disease prevention, value addition and market access.

## CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

## ACKNOWLEDGEMENTS

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*Full Length Research Paper*

# Comparative analysis of climate change impact on livestock in relation to biomass base feed availability using standardized precipitation index in south-western Ethiopia

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The standardized precipitation index and normalized difference vegetation index on event incidences (at different time scale) and biomass feed dry matter production, were used to assess climate change influences on feed availability. A significant decline (p<0.05) in feed dry matter availability indices across years was observed. The deviation from normality shows that the biomass feed production could vary significantly during drought occurrence years and this accelerates profoundly over time as drought frequency is expected to increase over time. The highest significant decline was observed in 2015 followed by 2006 and 2014. The results of analysis of the impact of climate change on livestock in relation to biomass dry matter production discretely subdivide different agro-ecological zones into land use land cover classes in southwestern Ethiopia. As represented by temporal scale drought, flooding and landslides were incidences considered as the major climatic risks in the study area. The risks threaten the livelihoods and even the security of the socio-ecological systems in general and such marginalized segments of the farming society in particular. The future needs effective action on environment management, devising adaptive and mitigation mechanism and change should aim at managing the occurrence and effects of extremes.

**Key words:** Biomass base feed, climate extreme event, livestock feed risk, temporal scale.

## INTRODUCTION

Livestock systems in developing countries are changing rapidly in response to a variety of drivers (Thornton et al., 2009); population growth and the gradual emergence of peri-urban centres are creating potential market opportunities for livestock producers (Markakis, 2004), in many developing countries. However, the dire effects of climate change have plagued the livelihoods of rural communities in East Africa for generations (Berhe et al., 2017). The four main agricultural communities including pastorals, semi-pastorals, agro-pastorals and mixed-

farming are increasingly threatened by drought and climate factors. The impact of climate change on food security and poverty depends on multiple interacting drivers especially the timing of extreme events which are expected to become more frequent (IPCC, 2007). Climate change manifests itself through increasing variation in the weather, including temperature, precipitation, and wind (Ali and Erenstein, 2017).

The variability and change in these factors also affect the availability of water and feed for livestock; thereby, affecting livestock reproductive cycles and reducing the quantity of milk and meat produced by livestock and by increasing their vulnerability to disease. The growing period length varies with rainfall patterns and reduced, resulting in negative impacts on food production and income levels. Extreme temperature events are rare in the highlands but tend to be more frequent in the lowlands and severely affect crop and livestock production. The other extreme event is high rainfall that increases the incidence of flooding. Flooding damages crops and may even result in livestock losses. The global impact of El Niño event is apparent on drought, whereas some areas like the Horn of Africa show a significant effect on rainfall like large-scale floods (WFP, 2015).

Drought may be the most devastating (Edwards, 1997), yet wet stress, floods and landslides are important events that undermine the food security of a large number of people in Ethiopia. Mitigating these impacts requires understanding how current drought impacts measure up with the impacts of other droughts in terms of intensity, areal coverage and duration. Currently, a number of studies have employed climatic factor as an explicit event indicator to measure the severity of a wet or dry period.

The standardized precipitation index (SPI) is normalized so that wetter and drier climate is represented in a similar way (Mckee et al., 1993). Rainfall is the primary drivers of meteorological drought (Naresh et al., 2009). The value of SPI is expressed in standard deviations in which positive value indicates higher median precipitation and negative value vice-versa (Edwards, 1997). In the arid and semi-arid areas of northern Kenya and southern Ethiopia, some measures such as index-based insurance are taken as a mitigation strategy against the risk of drought-related livestock mortality (Njeri, 2016).

This paper aimed to evaluate the impact of climate change on livestock in relation to biomass base dry matter production discretely subdividing in different agro-ecological zones into land use land cover class using climatic factors and vegetation greenness in both a component and comparative analysis in southwestern Ethiopia.

## MATERIALS AND METHODS

### Description of the study area

Fourteen administrative zones constitute the South Nations Nationalities Peoples' (SNNP) regional state. The study was conducted in two of the zones, namely Gamo Gofa and Dawuro zones. The total area of the zones is about 16 530.49 km$^2$. The two zones lie between 5° 34′ 16.31″ N and 7°20′ 58.01″ N of latitude and 36° 22′ 13.04″ E and 37° 51′ 26.31″ E of longitude (Amejo et al., 2018). The zones are divided broadly into dry upper highland, wet highland, wet humid, wet sub-humid, wet upper lowland, wet lower lowland and wet and dry lowland agro-ecological zones (AEZs). The selected subregions in the zones belonged to wet highland, wet sub-humid, wet upper lowland, wet and dry lowland AEZ. The altitude in the zones varies from about 500 m.a.s.l (meter above sea level) in lower Omo valley basin to about 3600 m.a.s.l on the highland mountain in Dita. The terrain surface coverage in the zones remarkably reflects silvopasture agricultural system despite complex heterogeneous mixtures of the crop-livestock systems.

### Agricultural production system

The dominant agricultural production system in the study area is smallholder mixed crop-livestock systems. In this system, the livelihood activities of the farm population are interdependently tuned to the natural environment, land use the land cover, off-farm activities, though crop and livestock productions are a significantly vital source of food, income, fiber, medicine, production power and has various social and cultural roles. The bushes and woody trees such as acacia in lower altitudes and trees such as bamboo at higher locations are abundant. These resources can promote basic livelihoods and generate incentives for farmers through investment alternatives. The reallocation of rangeland biomass conditions can accelerate quite development opportunities.

### Sampling and data collection procedure

#### Sampling procedure

The two study zones in the SNNP region were selected purposively based on the diversity of the farming systems and AEZs. In each zone, the districts were stratified into three AEZs as highland, midland and lowland based on area proportion in the location. In each AEZ, the districts were randomly selected, followed by the Peasant administrations (PAs), designated for their production potential in discussion with local authorities. Later using the baseline information data tracked by geographical position systems, four distinct AEZs (the wet highland, wet upper lowland to the sub-humid, and wet and dry lowland) were identified which differ significantly. There were 13 PAs, in the two zones selected for the study. In the Gamo Gofa administrative zone, there was a total of seven PAs; one at wet highland (Losha), two at wet upper lowland to sub-humid (Fishto and Grss Zala) and four at dry lowland (Alga, Ancover, Furra and Para Gossa). In Dawuro, six Pas, one at wet highland (Gmra Qema), two at wet upper lowland to sub-humid (Guzza and Myla) and three at wet lowland (Qcheme Kessi, Tarcha Zuri, and Yallo Worbati) were selected.

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The households were selected randomly.

## Data collection procedure

Data were collected using structured questionnaire, which was prepared and used to collect data from the sampled household. The enumerators were under the close supervision of researcher andr esearch assistants. The data collection included demographic characteristics, household socioeconomic factors, land holdings, the livestock species kept, herd structure of cattle, sheep, goats, and equine, and production and reproduction performance of the livestock. The crops type grown, land use, land cover area by crop and seasons of growing, feed type and grazing pattern, were together gathered. Livestock feed supply from crop production, pastureland and communal grazing was determined. The data collection took place between February and December, 2016.

The land use land cover of the private ownership was gathered together with geographical information at the household level. Rangeland biomass in the respective site was the proportion of average farm holdings, population, and total area coverage was classified according to interview data, field experience, and other literature for the study zones. The feed availability from food production, pastureland and rangeland biomass was quantified in relation to maintenance and productivity performance of female breeding animal and livestock herd population in each farming system according to the interview result. Biomass productivity potential was determined using soil, slope, land use type and livestock utilizable factors.

### Rainfall and normalized difference vegetation index (NDVI) data

The rainfall and NDVI data used in this study are processed data obtained from livelihood early assessment and protection (LEAP) software version 2.7 for Ethiopia (Hoefsloot and Calmanti, 2012) which is available in pixel based on each district of the zones. There were decadal values of actual rainfall (RF1, RF2, and ARC2), available over some years. In a series of actual rainfall available from 1983-1994 (ARC2), 1995-2000 (RF1) and 2000-2016 (RF2), a total of 34 years were processed. The actual NDVI value of MODIS (FAO) from 2008-2016 and USGS from 1983-2007 were processed together.

## Standardized precipitation index

The SPI was derived from the actual rainfall record in the districts within the sample PAs. A long-term data for 34 years (1983-2016) was used to quantify the SPI. McKee et al. (1993) described the standard procedure that was used first to fit the rainfall data into a probability distribution function. The series of three decadal (10 days) average rainfall aggregated to each month of the year was used in the present study. Before computing the SPI, the rainfall value was adjusted to mean 0 standard deviations 1.0 and skewness of the given precipitation was readjusted to zero as shown in Equations 1 to 3:

$$\bar{x} = \frac{\sum x}{n} \tag{1}$$

Where, $\bar{x}$ is the mean of the rainfall (mm), n is a number of observations and x is the rainfall amount (mm).

$$s = \frac{\sum (x - \bar{x})^2}{n} \tag{2}$$

Where, s is the standard deviation.

$$skewness = \frac{1}{(n-1)(n-2)} \frac{\sum (x - \bar{x})^2}{s} \tag{3}$$

Subsequently, converting the precipitation mean value to lognormal, the sample statistics U, scale parameters α and shape parameter β was computed as shown in Equations 4 to 6:

$$U = \bar{x} \ln - \frac{\sum \ln x}{n} \tag{4}$$

$$\beta = \frac{1 + \sqrt{1 + \frac{4U}{3}}}{4U} \tag{5}$$

$$\alpha = \frac{\bar{x}}{\beta} \tag{6}$$

The cumulative probability G(x) for a non-zero rainfall is computed as shown in Equation (7):

$$G(x) = \frac{\int_0^x x^{\alpha-1} e^{\frac{-x}{\beta}} dx}{\beta^\alpha \tau(\alpha)} \tag{7}$$

The gamma function is undefined for $x=0$ and a rainfall distribution may contain zeros, thus cumulative probability becomes computed as in Equation (8):

$$H(x) = q + (1-q)G(x) \tag{8}$$

Where, H(x) is the cumulative probability and q is the probability of zero rainfall. The cumulative probability was then transformed into a standard normal distribution provides mean zero and variance of one values of the SPI. This was carried out using an approximate transformation (Abramowitz and Stegun, 1964) as shown in Equations 9 to 12:

$$SPI = -(t - \frac{c_0 + c_1 t + c_2 t^2}{1 + d_1 t + d_2 t^2 + d_3 t^3}) \, for \, 0 < H(x) \le 0.5 \tag{9}$$

$$SPI = +(t - \frac{c_0 + c_1 t + c_2 t^2}{1 + d_1 t + d_2 t^2 + d_3 t^3}) \, for \, 0.5 < H(x) < 1 \tag{10}$$
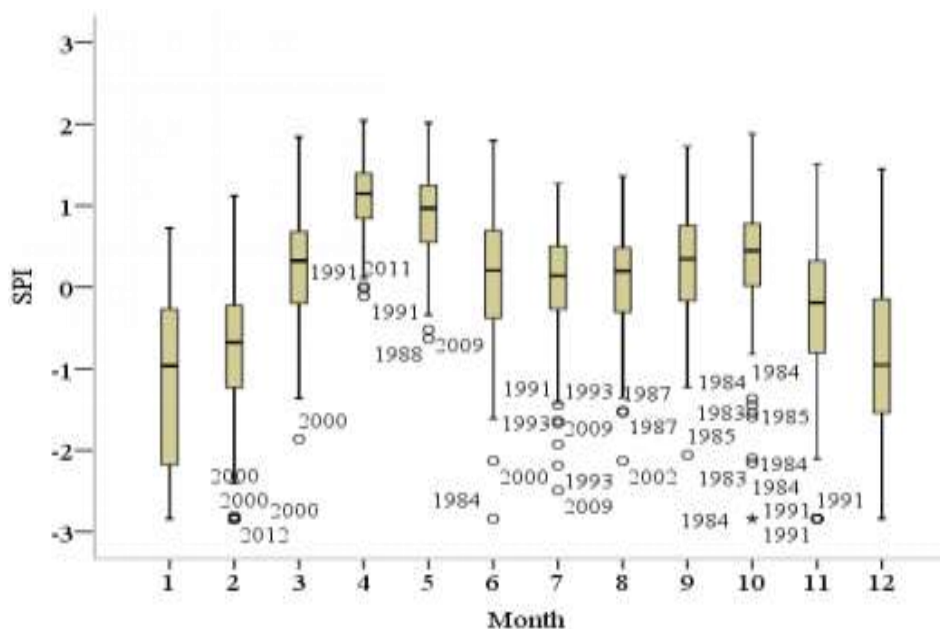
The t value was determined as:

$$t = \sqrt{\ln(\frac{1}{H(x)^2})} \, for \, 0 < H(x) \le 0.5 \tag{11}$$

$$t = \sqrt{\ln(\frac{1}{1 - H(x)^2})} \, for \, 0.5 < H(x) < 1 \tag{12}$$

Where, $c_0 = 2.515517$, $c_1 = 0.802583$, $c_2 = 0.010328$, $d_1 = 1.432788$, $d_2 = 0.189269$ and $d_3 = 0.001308$.

Equations 1 to 12 were computed in Excel using method given by Naresh et al. (2009) and Wambua et al. (2015). The monthly SPI value was computed in Excel, whereas standardization and further

**Figure 1.** Monthly scale SPI in district with peasant administration from January 1983 to December 2016, from statistical analysis (value in the box represents year of event occurrence).

analyze was carried out using the statistical software as described by Edwards (1997). The SPI extreme event classes were defined as SPI ≥ 2.0 extremely wet, 1.5 < SPI ≤ 2.0 severely wet, 1.0 < SPI ≤ 1.5 moderately wet, -1.0 < SPI ≤ 1.0 almost normal, -1.5 < SPI ≤-1.0 moderately dry, -2.0 < SPI ≤ -1.5 severely dry and SPI ≤ -2.0 extremely dry (McKee et al., 1993).

**Biomass base feed production index**

Livestock feed shortage risk related to climate change was assessed using the biomass base DM production derived from LULC class in the study area. The DM was derived from NDVI by determining goodness-of-fit independently in each selected site for consequent 34 years as equation given by Quiroz et al. (1999). The component analysis involved NDVI, and normal rainfall as the sensitivity factors, and SPI as an extreme event. The availability index (Deressa et al., 2008) measures the risk of livestock feed shortage in biomass base during drought occurrence as shown in Equation 13:

$$Index = 10^{-3}(Adaptive-(Sensitivity + Extreme)) \qquad (13)$$

The index is the amount of feed availability in month $i$ for the respective 34 years calculated as shown in Equation 14. The annual total was the sum of the respective month in a year processed in Excel which was further used in the statistical analysis.

$$Index(m_i) = 10^{-3}(DM - (NDVI + NRf) + (SPI))m_i \qquad (14)$$

Where, index is biomass dry matter for livestock adaptive capacity in climate event occurrences in month $i$; DM is dry matter consumable amount from biomass by livestock; NDVI is Normalized Difference Vegetation Index, and N Rf is normal rainfall, sensitivity

factors; and SPI is Standardized Precipitation Index, extreme factor.

**Statistical analysis**

The one sample run test was employed to define a possible effect of the event extremity. The deviation below and above the median was used in normality test. Three tests of normality, the Shapiro-Wilk statistic, p-values and the absolute value of the median was suggested (Wu et al., 2007). The analysis was done using Statistical Package for the Social Sciences (SPSS) version 20, and the significant difference was defined (p<0.05).

**RESULTS**

**Temporal scale of climate change extreme event**

Drought event with extended duration in 1988, 1991, 2000, 2009 and 2011/12 took place during the main rainy season (Figure 1). Although, the repeated occurrences were observed in the dry season. The drought of 1984/85, 1986/87, 1993, 2000 and 2002 lasted longer in the dry season with a short duration in a rainy month (Figure 1).

The drought incidence was mainly frequent in January, February, June, July, November and December (Figure 2). This also varied over the years in appearance. For example, before 1992, it commenced in June and November, whereas in later years, it was common in the above indicated months. The wetter event incidence was observed in April (in wet dry season) in 1989 and 2004 in different districts (Figure 2).

According to the study result, during 34 years period,
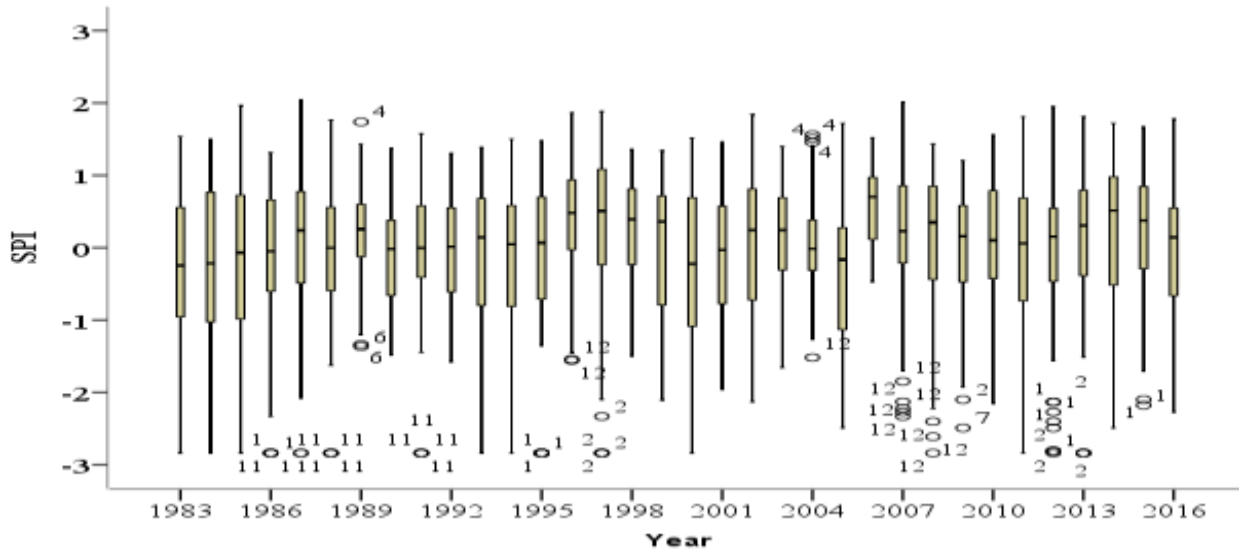
**Figure 2.** Yearly scale SPI in district with peasant administration from January 1983 to December 2016, from statistical analysis (value in the box represents month event start from January)

the extreme event incidence appeared in 19 different years (Figure 3). The drought was main rife in the districts of Chencha, Mirab Abaya and Bonke of Gamo Gofa zone where in Loma, Mareka, Issera and Tocha districts of Dawuro zone, both wet and drought incidences were frequent (Figure 3). The drought observed in the districts in the year 1987, 1988, 1991, 1993, 1994, 1995, 2011, 2012 and 2013 was found in extreme dry class with SPI ≤ -3.0 (Figure 3). Severely wet event with SPI ≥ 1.7 in Tocha in 1989, and similarly in 2004, in all districts of Dawuro zone within sample Pas, were ascertained (Figure 3).

During the progress of this study fieldwork, one of the study areas, Mirab Abaya, was visited by American Ambassador because of severe incidence of the very recent (2014/15) drought. However, the statistical analysis claimed that the extreme drought incidence (SPI ≤ -2.2) in that year was in Issara and Bonke districts which continued with SPI ≤ -2.4 in the latter year in 2016 in the same districts (Figure 3).

The magnitude, duration and occurrence of droughts varied highly and rapidly increased over time (Figure 4). The circumstances most probably dented environment responding capability and a spatial variability intra-seasonally. The extreme events in 2007/08 and 2009/10 appeared in February, July and December but very recent drought in 2012/13 and 2014/15 were in January and February (Figure 4).

**Livestock feed production risk**

Livestock feed shortage risk explained the highest

significant deviation in 2015 (-6.00) than the median (15,162.85), similar consequences occurred for ten different years (Table 1). The overall test effect was significantly different (Z=-2.61, p=0.01) between the years.

**DISCUSSION**

**Temporal scale of climate change extreme event**

Earlier studies in Ethiopia indicated that the infamous drought of the 1984/85 has significantly affected belg season (March, April and May) than the main rainy season (June, July, August), but the 1991 drought has targeted the main rain season while in 1994, there was a significant fluctuation between dry and wet extremes in southeastern Ethiopia (Awass, 2009). A more detailed view from two rainfall datasets analysis of the USGS, the central trends precipitation (1960-2014) by Florida State University, and Climate Hazards Group Infrared Precipitation with Station data, 1981-2015 indicated that the total rainfall deviation was averaged 480 mm across central/eastern Ethiopia between March and September 2015. Its outcome resulted in the worst drought in 50 years in Ethiopia (http://fews.net/Ethiopia; http://wfp.org).
The soil moisture is a closer proxy indicator of crop conditions than rainfall. The Land Data Assimilation System model run by NASA indicated the soil across most parts of Ethiopia, the driest in at least 30 years during the main cropping/rangeland regeneration period in 2015 (https://fews.net/Ethiopia)). Similarly, the highest negative deviation in the biomass base feed dry matter production was observed in the year 2015, followed by
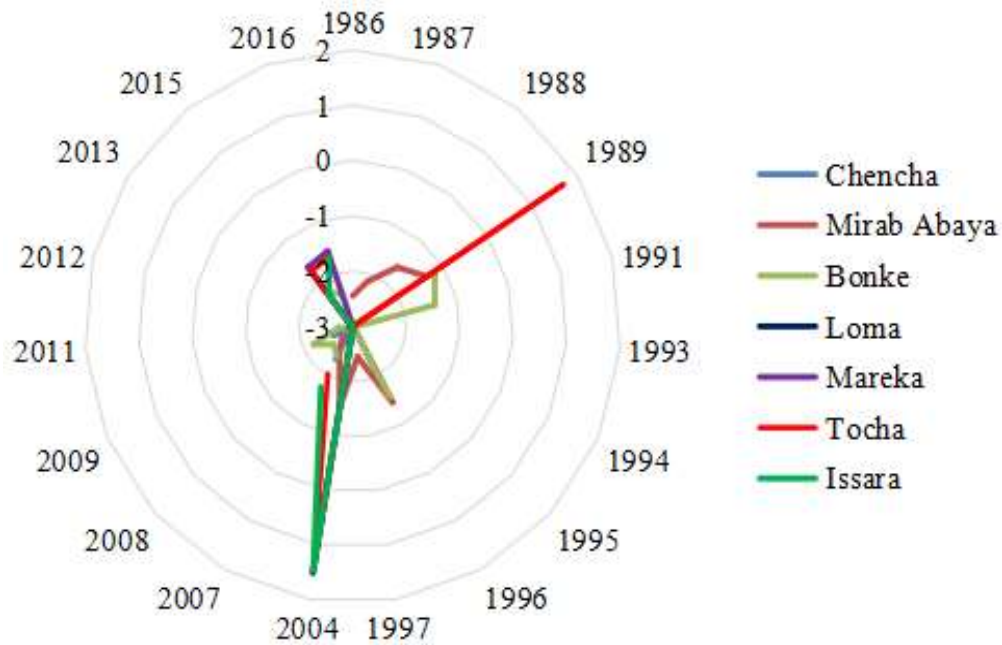
**Figure 3.** SPI for year in which extreme event was observed in districts with peasant administration from statistical analysis during the period of January 1983 to December 2016.
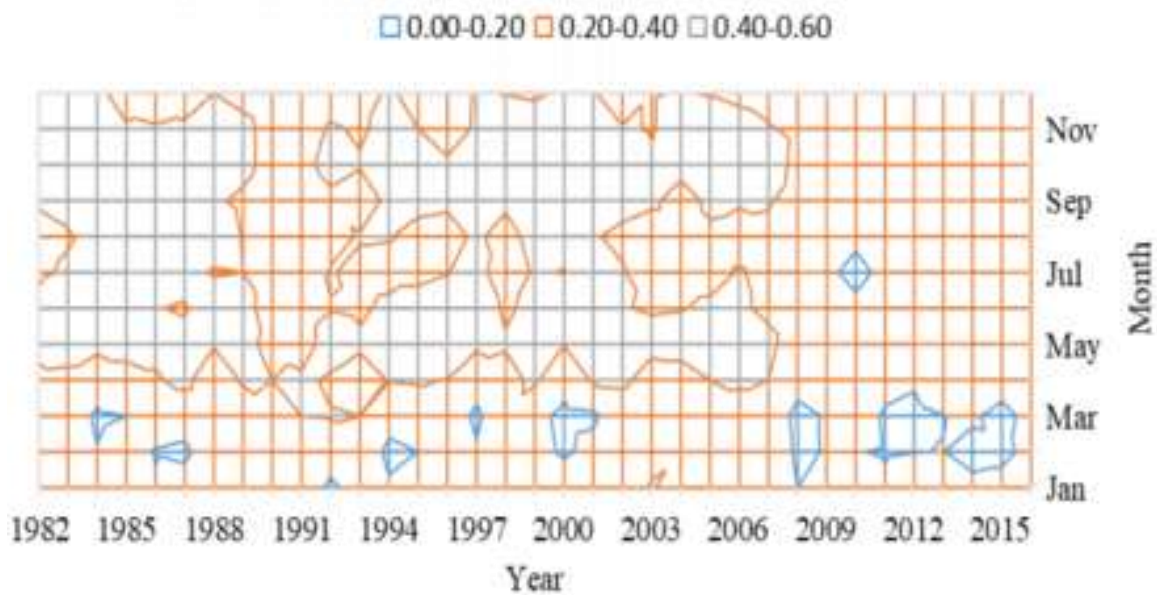


**Figure 4.** Temporal NDVI in district with peasant administration from January 1982 to December 2016

2006 and 2014, in the present study.

**Livestock feed production risk**

Drought occurs in virtually all climate zones, is attributed to deficiency in precipitation over extended periods of time such as a season or year which results in water shortage, causing adverse impacts on vegetation, livestock and human beings (Mishara and Singh, 2010). Currently, the economic costs involved (Hewitt, 1997; Belal et al., 2014), countries and organizations are

**Table 1.** One sample test for overall annual biomass dry matter production indices with median difference in the district with peasant administration.

| Year | Index (Dif.) | Year | Index (Dif.) | Year | Index (Dif.) |
|------|-------------|------|-------------|------|-------------|
| 1983 | 15167.48(4.63) | 1995 | 15163.61(0.76) | 2007 | 15160.55(-2.3)* |
| 1984 | 15167.24(4.39) | 1996 | 15160.64(-2.21)* | 2008 | 15161.11(-1.74) |
| 1985 | 15165.73(2.88) | 1997 | 15159.49(-3.36)* | 2009 | 15162.88(0.03) |
| 1986 | 15166.49(3.64) | 1998 | 15161.56(-1.29) | 2010 | 15160.53(-2.32)* |
| 1987 | 15162.65(-0.2) | 1999 | 15163.35(0.5) | 2011 | 15160.94(-1.91) |
| 1988 | 15163.88(1.03) | 2000 | 15164.51(1.66) | 2012 | 15159.62(-3.23)* |
| 1989 | 15164.08(1.23) | 2001 | 15164.33(1.48) | 2013 | 15158.00(-4.85)* |
| 1990 | 15166.28(3.43) | 2002 | 15162.79(-0.06) | 2014 | 15157.26(-5.59)* |
| 1991 | 15164.31(1.46) | 2003 | 15162.1(-0.75) | 2015 | 15156.85(-6.00)* |
| 1992 | 15165.26(2.41) | 2004 | 15162.83(-0.02) | 2016 | 15158.22(-4.63)* |
| 1993 | 15164.81(1.96) | 2005 | 15164.17(1.32) | | |
| 1994 | 15164.23(1.38) | 2006 | 15157.21(-5.64)* | | |

*Differences in index value is significantly different between years (p<0.05).

increasingly pursuing strategies aimed at mitigating the negative impacts of drought.

Njeni et al. (2016) found a positive correlation with a higher percentage and strong coefficients (r>0.75) in the inter-annual relationship between indices in seasonal forage scarcity and drought in the short rains seasons than the long one. The significant difference revealed for extreme event in the current study coincided with other several findings, which is described in this paper in a different section. A similar change was also reflected in the temporal scale comparisons between the study parameters of SPI and NDVI independently, as well as in the component analysis in the combination.

In another study, more than 94% of pastoral, semi-pastoral, agropastoral and mixed-farming communities perceived that lack of animal feed was their critical challenge during drought periods (Berhe et al., 2017). Drought severely harms the ecosystem and worsens human crises (Masih et al., 2014).

On the other hand, Tsegaye et al. (2013) described crop failure that directly causes scarcity of animal feed to be also associated with lack of rain and drying of water sources. As a result, semi-pastoral (86.5%), agro-pastoral (95.1%) and mixed-farming (83.3%) communities perceived that climate change, manifesting as drought, significantly destroyed crops that described by the households, they experienced crop failure twice or more times within five years (Berhe et al., 2017). Similarly, SPI analysis from 34 years long-term rainfall data, in 19 different years extreme events were obtained in the current study area. Moreover, the drought event of 2014-2016 was the most heightened in history and had substantial focus on the international diplomats in Ethiopia. Such a striking shock observed was high in Mirab Abaya district with the complete failure of field crops, particularly maize before maturity and harvested for livestock. This was even extremely highest in Bonke

and Issara districts in 2015 and 2016 as compared to Mirab Abaya which is evident in this statistical analysis.

Currently, focus has been given to drought; however, in the current study, both extreme drought and wet event was observed in all smallholder rural production systems. The result is also in support of respondent farmers claim as well as the field observation that households in the wet event reflected areas were less anticipation for *belg* season cropping activities is common for other PAs which is usual throughout the country in bi-modal rainfall receiving regions.

Moreover, the land area change computed in relation to the total population, the land area, and average holdings per sampled household indicated a negative balance in the magnitude of change in the wet highland PAs. This is probably associated with the extreme event (such as landslide, flood, etc.), and will be another aggression in peasant holdings and potential production, so it should be taken into consideration. The climatic extreme event seems like removing alternative means of farming practice although a combination of agricultural production performance for improved land productivity as well as livestock production in both wet stress and drought-prone area largely capitalize on household income and production input, supply, resilience and response of capability to most common supply-side difficulties.

## Conclusions

According to the result of the study, during the years of drought occurrences, the biomass DM production intrusively declined, and significant difference appeared later in 1990's in the current study area. The continuous dry condition could be seen in 2007 which continued as the recent severe drought. The negative impact of climate change on biomass dry matter production is increasing

much more rapidly, which might shift to the southwestern part of the country over time. The responding capability of rangeland/vegetation condition is weak and completely dry, manifesting even longer after the drought in southwestern Ethiopia was reported. Wet and dry events typical in the region can adversely affect both human and livestock production in such a less reachable area. Thus, future of livestock production in terms of feed supply could not be standard during the drought occurrence period. The risk which increasingly manifest, needs devising adaptive and mitigation mechanism in the area, taking into account, the increasing trend in the progress of extreme events.

## CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

## ACKNOWLEDGEMENTS

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