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Research Article

# An Assessment on the Feeding Practices and other Factors Influencing Dairy Production Under Smallholder Systems of Kilimanjaro Region in Tanzania

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## Abstract

A survey study was conducted to assess the influence of altitude and socioeconomic characteristics of smallholder dairy farmers in adaptation to feeding practices (FPs) and their ultimate effect on the nutrition of dairy cattle and milk production. One hundred and twenty dairy farmers from highland (60) and lowland (60) zones of Hai district, Tanzania were interviewed. Feed samples were collected for evaluation of proximate and Van Soest composition, in vitro dry matter (INVDMD) and organic matter (INVOMD) digestibility for three FPs, namely zero grazing (FP1), grazing with supplementation (FP2) and extensive grazing (FP3). Data on milk yield was obtained from the farmer record books and database of African Asian Dairy Genetic Gain program. Most respondents from both highland (88%) and lowland (53%) zones were practicing zero grazing (FP1) than grazing plus supplementation. High level of education, farming experience of >10 years, and dairying plus other sources of livelihood showed positive likelihood of influencing adaptation of zero grazing practice (FP1). Forage diets offered to cows under FP1 had lower mean values of crude protein (6.9%, CP) and metabolisable energy (5.01 MJ ME/kgDM) compared to other practices**.** Concentrate diets used in FP1 practice had higher CP (13.7%) compared to those in FP2 (10.9%). There was higher average milk yield from cows under FP1 in the highland (11.6 kg) compared to their counterparts. Cows under FP1 on the lowland had similar ($P>0.05$) average milk yield (8.7 kg) to those under FP2 in the highland zone (9.47 kg). Cows under FP3 in the lowland produced the lowest ($P<0.05$) milk yield of 4.61 kg. The study concluded that differences in socioeconomic characteristics of farmers and altitude zones have influence on the adaptation and domination of a specific feeding practice, which ultimately determines the level of performance of the dairy cattle. It is recommended that more studies are required to assess the influence of feeding and other management practices of dairy cows on the environmental effects.

## Keywords

Altitude Zones, Dairy Cattle, Feed Resources, Feeding Values, Milk Yield, Socioeconomic Characteristics

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# 1. Introduction

In Sub-Saharan African (SSA) countries the demand of milk is projected to increase considerably during the next few decades due to population growth and rising of income. In Tanzania for instance, consumption of milk and milk products was projected in the Livestock Master Plan (TLMP) 2017/18 – 2021/22 to increase by 77 percent from 45 litres per capita [1]. Inconsistently, the gap is expected to continue increasing because production is constrained by a number of factors including poor management of animals and the negative impact of climate [2]. In fact, Tanzania is lagging behind in East Africa with respect to dairy production and thus different interventions need to be planned and implemented.

Smallholder dairy farms (SDFs) are the primary source of milk production for human consumption [3] in many developing countries including Tanzania. Several feeding practices have been adapted by smallholder dairy farmers to ensure availability of nutrients to animals, which ultimately enhance milk production. These include, zero grazing/stall feeding with or without supplementation of concentrates, extensive grazing in which animals are grazing for at least 8 hours, and mixed grazing where by animals are grazed for some hours and supplemented with forage or concentrates in their shades [4]. The SDFs normally adapt and implement feeding practice of choice. There are factors which influence adaptation of a certain feeding practice among small smallholder dairy farmers including socio-economic factors such as source of livelihood, level of education, size of the land, and types of breeds [5]. These factors are important and influence decision making and resources allocation. For instance, before 1970s the adapted feeding practices of dairy animals were extensive grazing because there was enough land for grazing [6]. In recent times, adaptation of feeding practice is mainly influenced by increased human population and the negative effect of climate. For example, farmers in urban and peri-urban areas have no choice other than practicing zero grazing due to limited sizes of land as well as the need for recycling nutrients in the small urban farms (gardens) using manure. Therefore, it is important to understand the influence of socio-economic characteristics of farmers on the adaptation of feeding practices when promoting dairy production.

Quality of diet offered under different feeding practices is affected by types of feeds, forage species, season, and management of grazing land. It has been hypothesised that dairy animals in the zero grazing and grazing with supplementation receive more nutrients than those on extensive grazing.

Feeding practices in SDFs have been studied extensively [7]. However, information linking the feeding practices, nutritional quality of the diets offered to cows and milk production is less documented. Another factor, which could have influence on the availability and quality of the diet for dairy cows under different feeding practices is altitude. The effect is mainly due to variation in temperature, rainfall, and soil fertility, ultimately affecting forage quality [8]. Temperature variation between altitudes e.g. high temperatures reduce quality of forage due to early lignification of plants [9]. In addition, altitude influences adaptation of certain feeding practice among smallholder dairy farmers due to land limitation in high-altitude areas of Kilimanjaro for instance. This situation forces them to adapt intensive feeding practices which accompanied with production of improved forages, forage conservation including hay and silage making as well as supplementation to improve nutrition of animals. From such perspectives, it is necessary to evaluate the nutritional quality of diets and feeding practices adapted by the smallhoder dairy farmers based on the altitude zones for making proper recommendations on animal management practices. Therefore, this study aimed to assess the influence of altitudes and socioeconomic characteristics of smallholder dairy farmers on the adaptation of feeding practices of dairy cows and their ultimate effect on the performance of dairy cows.

# 2. Materials and Methods

This study was approved by the Research Ethical Committee (REC) of Sokoine University of Agriculture (Ref: SUA/DPRTC/R/186/25) on behalf of the Commission for Science and Technology of Tanzania (COSTECH).

## 2.1. Description of Study Area

The study was carried out in Hai district, Kilimanjaro region in Tanzania. The district is located between latitudes 2°50’ - 3°29’ S and longitudes 30°30’ - 37°10’ E (Figure 1). Characteristically, the district is divided into two altitudinal zones, namely highland and lowland, respectively >1100 and ≤1100 m above sea level (masl). The district receives bimodal rainfall with a long season running from March to June and a short rain season starting from November to December. Annual precipitation is between 1000 and 1500 mm in the highland and 500 and 900 mm in the lowland. The average annual temperature is 15 $^{o}$C and between 26 to 31 ℃ in the in the highland and lowland zones respectively. The soils of Hai district are clay and characteristically volcanic due to the influence of volcanoes of Mount Kilimanjaro, being dark brown to brownish-red in colour and fertile, in the highland zone, whereas in the lowland zone, the soils are light and less fertile. The geographic characteristics and climatic condition of Hai district, especially in the highland favours intensive dairy cattle production, which is among the major economic activities.

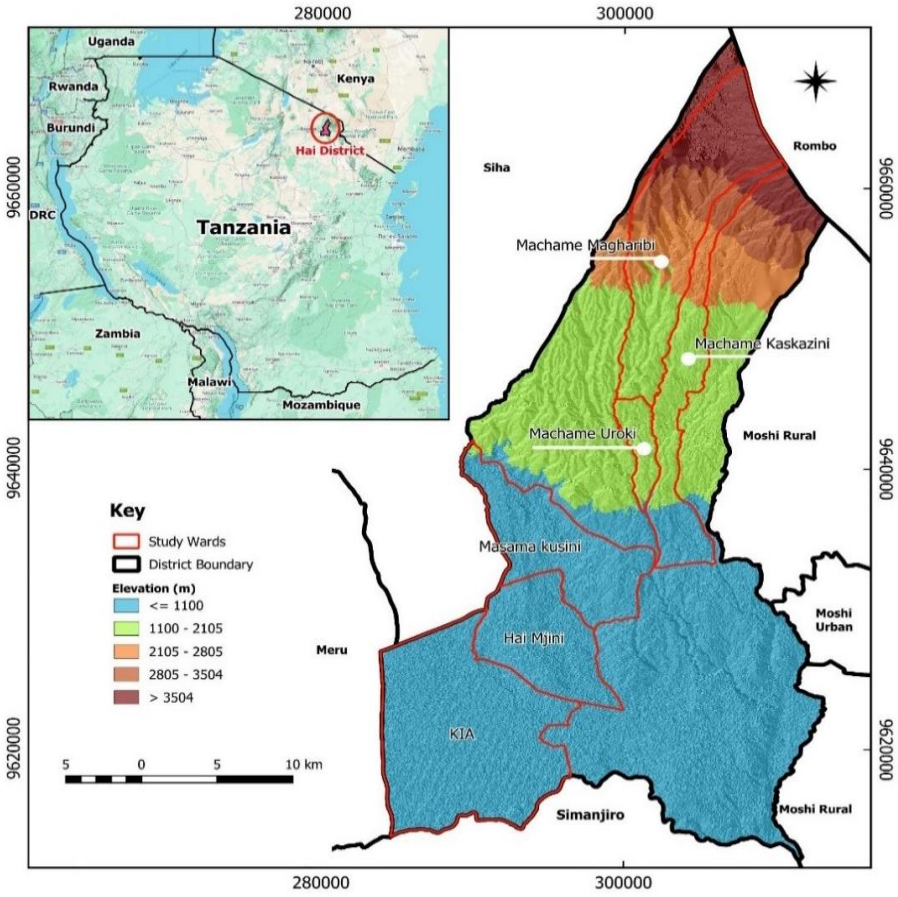


***Figure 1.*** *A map showing the highland and lowland areas of Hai district.*

## 2.2. Nature of the Study

This study comprised of diagnostic and household surveys, direct observation, and collection of data through secondary sources. The study was part of Enviro-Cow project, which was implemented in partnership between the International Livestock Research Institute (ILRI), Scotland's Rural College (SRUC) in Scotland, UK, and Tanzania Livestock Research Institute (TALIRI) in four Councils of Tanzania including Moshi Rural, Hai district, Arusha district, and Arusha City. The project was funded by Bill and Melinda Gates Foundation (BMGF) and its overall goal was to reduce greenhouse gas emission and production costs in smallholder dairy cattle enterprises.

## 2.3. Diagnostic and Household Surveys

A diagnostic survey was performed at the initial stages of the study, involving seven key informants including the Hai district livestock officer and ward extension officers. They were interviewed using checklist questions to obtain general useful information including number of dairy cows, existing feeding practices, and types of feed resources used for feeding dairy cows. Information provided was useful in the development of a questionnaire to be used in household interviews. The instrument organized an extensive list of variables, such as feed resources into categories. The categories involved (i) natural pastures including grass and legumes (mainly Desmodium) harvested from forest, uncultivated plots, road sides and river sides and crop residues (maize stover, bean straw, rice straw); (ii) improved pastures including elephant grass and setaria species; (iii) banana crop residues including banana leaves and stems; (iv) desirable weeds collected from the field, such as *Biden Pilosa, Commelina bangalenisis, Ageratum conyzoides, Galinsoga parviflora,* and *Tegetus minuta*; (v) feed supplements procured from the farm input shops; as well as (vi) kitchen by-products including carrots, green vegetables, and banana peels.

Multistage and purposive sampling designs were used to select the study area for the household survey, in which Hai district was selected based on higher number of dairy farmers and dairy cows relative to other districts of the Northern milk shed [10]. Within this district, highland and lowland zones were used during sampling. From each zone, three wards were purposely selected based on existing number of dairy cows. Thereafter, 20 households from each ward were purposely selected, making a total of 120 households. The selected households were having at least one lactating dairy cow. A cross-sectional design, was employed to collect

information from the household heads using a structured questionnaire. The questionnaire was embedded into open data kit (ODK), a tool that is installed in android devices to facilitate paperless collection of information from the field and sent directly to the server for storage. Prior to actual data collection, the questionnaire was pre-tested using 20 respondents from Arumeru district in Arusha region. The interviews were conducted in Swahili language. The information collected was demographic characteristics of households, dairy cattle breeds, herd size, and composition, feeding practices, and feed resources.

### 2.4. Direct Observations and Collection of Secondary Data

Direct observations were made by the interviewers and targeted checking of feeding troughs, fodder sheds, grazing areas, and other places in the farms such as road and river sides and uncultivated plots to assess types of feed resources used in feeding dairy cows. The supplementation strategies between highland and lowland zone farmers were investigated by observing the amount of concentrates offered animals. Secondary data, specifically milk yield by individual cows was obtained from record books of farmers and the database belonging to the African Asian Dairy Genetic Gain (AADGG) program, where the data for the Enviro-Cow Project were stored. Rainfall and temperature levels for 12 months (June 2023 - May 2024) were obtained from the Tanzania Meteorological Agency (TMA).

### 2.5. Collection and Preparation of Feed Samples

Samples of feed resources offered to dairy cows were collected from each farmstead under household surveys. Samples from zero grazing practice were obtained from the troughs/stalls comprising of mixture of different forages. Quartering method was used to obtain samples from the fields for extensive grazing and grazing with supplementation. Forages were cut by a sickle from different grazing sites, such as uncultivated plots, roadsides, riversides and reserved forests. The forages were hand chopped into sizes 2-3 inches, using garden scissors. The samples were then thoroughly mixed and divided into four quarters, then two opposite quarters were taken as representative samples. Samples of concentrate were collected from households practicing concentrate supplementation. Similar samples from different households on the same feeding practice were bulked and sub-sampled, making a total of 42 forage and 35 concentrate samples for zero grazing, 23 forage, 20 concentrate samples for grazing with supplementation, and 15 forage samples for extensive grazing. Since it was rare for the animals to consume one kind of forages per day, most of the collected feed samples contained mixtures of different forage species. All the samples were fresh weighed on site using a sensitive portable electronic weighing scale (WH A08, Mumbai, India). Then each sample was placed into a separate envelope, labeled, and dried under shade in a curing room at the National Artificial Insemination Centre (NAIC) in Arusha. Dried samples were reweighed to obtain air-dried sample weights. Thereafter the samples were transported to the Tanzania Veterinary laboratory Agency (TVLA) in Dar es Salaam for nutritive value evaluation.

### 2.6. Laboratory Analyses of Feed Samples

The feed samples were analysed at TVLA laboratory for chemical composition, which included Dry matter (DM), crude, protein (CP), crude fat (CF), ash, neutral detergent fiber (NDF) and acid detergent fiber (ADF), using the Near-Infrared Reflectance Spectrophotometer (NIRS) technology. Some samples were evaluated for the in vitro dry matter digestibility (IVDMD) and in vitro organic matter digestibility (INVOMD) following the procedure of [11] at the Nutrition Laboratory of Sokoine University of Agriculture (SUA), Morogoro. The matabolisable energy (ME MJ/kgDM) of feeds was estimated using mathematical equations for ruminants developed by [12] for both forage and concentrate.

### 2.7. Statistical Analysis

Household data were transferred from ODK to Excel sheet for encoding and cleaning. The data were analysed using descriptive statistics, binary regression for the influence of socio-economic characteristics on adaptation of feeding practices by IBM SPSS version 27 of 2023. In addition, Pearson Chi-square was employed to explain possible statistical differences between variables and were determined significant at ($P<0.05$). The procedure of General Linear Model (GLM) was used for statistical analysis of the effect of feeding practices, altitude zone, and their interaction on nutritive value of feed stuffs offered to dairy cows and milk yield. The model used type III sum of squares which allow adjustment for unbalanced data to ensure fair comparison among groups. Turkey's pairwise comparison was used to assess mean difference between feeding practices, zones and their interaction effects, whereby the difference was considered significant at $P<0.05$.

## 3. Results

### 3.1. Socioeconomic Characteristics of the Respondents

The results of socioeconomic characteristics of the respondents from the highland and lowland zones are presented in Table 1. There was higher number ($P<0.05$) of respondents with no formal education in the lowland zone compared with those in highland zone. The respondents dwelling in the highland zone showed to have smaller ($P<0.05$) land sizes

compared to those in the lowland zone. There were highly significant differences in farming experiences with majority of respondents in the lowland zone having lesser (P<0.05) years (1-10) of experience in dairying than those from the highland zone. Large number of respondents (90%) in the lowland zone relied mainly on the mixed farming as source of living, while those in the highland zone apart of mixed farming, had other sources of living, such as business, and paid labour.

***Table 1.*** *Socioeconomic characteristics of the respondents (n=120) as influenced by altitude zones.*

| Variable | Category | Highland | | Lowland | | χ2 | P-value |
|---|---|---|---|---|---|---|---|
| | | N | percent | N | percent | | |
| Household head sex | Female | 17 | 28.3 | 12 | 20 | 1.137 | 0.290 |
| | Male | 43 | 71.7 | 48 | 80 | | |
| Education level | No formal school | 1 | 1.7.7 | 14 | 23.3 | 12.876 | 0.000 |
| | Primary | 27 | 45 | 22 | 36.7 | 0.862 | 0.353 |
| | Secondary | 22 | 36.7 | 16 | 26.7 | 1.386 | 0.239 |
| | Tertiary | 10 | 16.7 | 8 | 13.3 | 0.261 | 0.609 |
| Size of land | less than one (<1) acre | 51 | 85 | 33 | 55 | 12.857 | 0.001 |
| | one to five (1 - 5) acre | 9 | 15 | 27 | 45 | | |
| Farming -experience | 1-10 yrs | 22 | 36.7 | 38 | 63.3 | 16.296 | 0.000 |
| | 11-20 yrs | 15 | 25 | 11 | 18.3 | 0.786 | 0.375 |
| | 21-30 yrs | 9 | 15 | 3 | 5 | 5.17 | 0.023 |
| | 31-40 yrs | 12 | 20 | 8 | 13.3 | 10.439 | 0.375 |
| | 41-50 yrs | 2 | 0.3 | 0 | 0 | 1.008 | 0.315 |
| Source of live-lihood | Dairying | 43 | 71.7 | 54 | 90 | 6.508 | 0.011 |
| | Dairying +others | 17 | 28.3 | 6 | 10 | | |

## 3.2. Types of Cattle Breeds and Herd Structure Kept by the Respondents

The responses on the types of breeds kept, herd size and composition of the dairy cows kept by the respondents in the highland and lowland zones are presented in Table 2. The types of breeds of dairy cattle and the composition of the herds kept by respondents in the highland and those in the lowlands were similar (P>0.05). Respondents in the highland zone had larger (P<0.05) herd sizes of dairy cattle compared with those in the lowland zones.

***Table 2.*** *Responses (n=120) on the types of breeds, herd size and composition as influenced by zones.*

| Variable | Category | Highland | | Lowland | | χ2 | P-value |
|---|---|---|---|---|---|---|---|
| | | N | percent | N | percent | | |
| Breed types | Local breeds | 0 | 0 | 3 | 5 | 3.185 | 0.364 |
| | Friesian crosses | 53 | 88.3 | 54 | 90 | 0.086 | 0.769 |
| | Ayrshire crosses | 15 | 25 | 19 | 31.7 | 1.459 | 0.482 |
| | Jersey crosses | 5 | 8.3 | 7 | 11.7 | 0.37 | 0.054 |

| Variable | Category | Highland | | Lowland | | χ2 | P-value |
|---|---|---|---|---|---|---|---|
| | | N | percent | N | percent | | |
| Herd size | <5 | 28 | 46.7 | 41 | 68.3 | 0.711 | 0.399 |
| | 06 -10 | 17 | 28.3 | 13 | 21.7 | 1.154 | 0.283 |
| | 11- 15 | 10 | 16.7 | 6 | 10 | 4.138 | 0.042 |
| | 16 - 20 | 4 | 6.7 | 0 | 0 | 1.008 | 0.315 |
| | <20 | 1 | 1.7 | 0 | 0 | - | - |
| Herd composition | Lactating dairy cows | 60 | 100 | 60 | 100 | - | - |
| | Heifers | 30 | 50 | 23 | 38.3 | 1.656 | 0.198 |
| | Bulls | 5 | 8.3 | 9 | 15 | 1.294 | 0.255 |
| | Yearling | 24 | 40 | 14 | 23.3 | 3.851 | 0.050 |
| | Calves | 50 | 83.3 | 48 | 80 | 0.223 | 0.769 |

## 3.3. Responses on the Distribution of Feeding Practices Across Zones

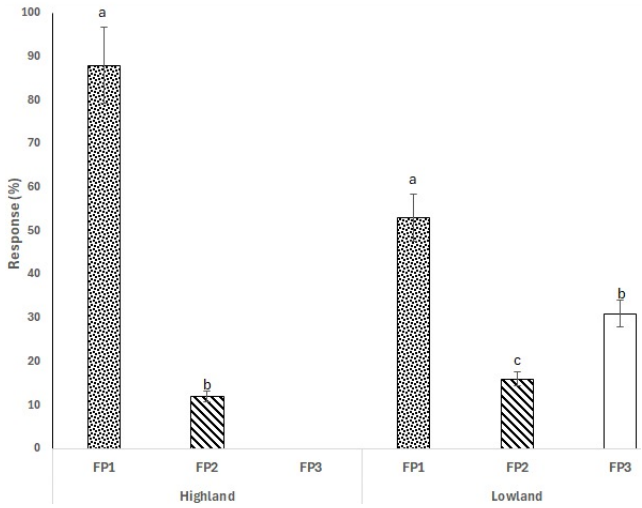


***Figure 2.*** *Responses on the feeding practices adapted by respondents in different zones of Hai district.*

Figure 2 presents the responses on the distribution of feeding practices across the zones. Three feeding practices, zero grazing (FP1), grazing with supplementation (FP2) and extensive grazing (FP3) were identified in the study area. These feeding practices were distributed differently across altitude zones with large (P<0.05) percent of respondents (88%) in the highland showed to practise FP1 compared to FP2. In the lowland zone, a larger (P<0.05) number of respondents (53%) were practising FP1, followed by FP3 (31%) with small number (16%) exhibiting FP2. Generally, respondents from both zones adapted FP1 compared to other feeding practices.

## 3.4. The Influence of Socioeconomic Characteristics on the Adaptation of Feeding Practices

Table 3 highlights the influence of socioeconomic characteristics on the adaptation of a certain feeding practice by the dairy producers. The female headed households had higher (P<0.05) likelihood of adapting FP2 practice compared to male headed households. As education level of respondent increases, the likelihood of adapting practices of FP1 and FP2 increases (P<0.05) compared with respondents with no formal education. Respondents with large land sizes ranging from 1-5 acres showed lesser (P<0.05) possibility of adapting FP1 practice and were likely (P<0.05) to adapt FP3 compared to those owned small land of less than one acre. Furthermore, the respondents with high experience in dairying of more than ten years showed likelihood (P<0.05) of adapting FP1 practice, followed by FP2 compared with those with less experience in dairying. The respondents depended on mixed farming plus other sources of income had higher (P<0.05) likelihood of adapting FP1 practice than other feeding practices. Results showed that respondents keeping Jersey and Ayrshire breeds had less (P<0.05) probability of adapting zero gazing and FP2 practices compared with respondents keeping Friesian breeds. Moreover, respondents dwelling in highland zone had twice as much chance of adapting FP1 practices compared with those dwelling in the lowland zone.

***Table 3.*** *The influence of socioeconomic characteristics on adaptation of different feeding practices.*

| | | 1FP1 | | FP2 | | FP3 | |
|---|---|---|---|---|---|---|---|
| **Variables** | | **[2]Coefficient** | **Odds Ratio** | **Coefficient** | **Odds Ratio** | **Coefficient** | **Odds Ratio** |
| Household head gender | Male | | 1 | | 1 | | 1 |
| | Female | -0.15 | 0.86 | 0.25* | 1.28 | 0.05 | 1.05 |
| Education level | No formal education | | 1 | | 1 | | 1 |
| | Primary | 0.65*** | 1.92 | 0.35** | 1.42 | 0.10 | 1.10 |
| | Secondary | 0.80*** | 2.22 | 0.45** | 1.57 | 0.12 | 1.13 |
| | Tertiary | 1.00*** | 2.72 | 0.60*** | 1.82 | 0.15 | 1.16 |
| Size of land | <1 acre | | 1 | | 1 | | 1 |
| | 1-5 acres | -0.20 | 0.82 | 0.10 | 1.10 | 0.45*** | 1.57 |
| Farming Exp. | 1-10 years | | 1 | | 1 | | 1 |
| | >10 years | 0.40** | 1.49 | 0.30** | 1.35 | -0.20* | 0.82 |
| Source of liveli-hood | Dairying | | 1 | | 1 | | 1 |
| | dairying+others | 0.75*** | 2.12 | -0.40*** | 0.67 | -0.30** | 0.74 |
| Breeds | Friesian | | 1 | | 1 | | 1 |
| | Jersey | -0.55*** | 0.58 | -0.50** | 0.61 | 0.10 | 1.11 |
| | Ayrshire | -0.40** | 0.67 | 0.30** | 1.35 | 0.05 | 1.05 |
| Zone | Lowland | | 1 | | 1 | | 1 |
| | Highland | 0.70*** | 2.01 | -0.40*** | 0.67 | -0.15* | 0.86 |

*In this and subsequent tables:*
*[1]FP 1 = zero grazing practice, FP2= grazing with supplementation, FP3= extensive grazing*
*`***` P < 0.001, `**`P < 0.01, `*`P < 0.05*

## 3.5. Responses on the Influence of Feeding Practices on the Type of Feed Resources Offered to Dairy Cows

The influence of feeding practices on the type of feed resources offered to dairy cows are presented in Table 4. There were significant associations between the feeding practices and the type of feeds offered to the dairy cows. A higher (P<0.05) frequency of respondents from FP1 used improved pastures, banana crop residues and weeds from crop fields in feeding dairy animals relative to those on the FP3 and FP2. A higher (P<0.05) number of respondents from FP1 used banana crop residues in feeding dairy animals followed by FP2 practice. The same trend on the usage of banana crop residues was also revealed during the dry season when the availability of forages was low. The FP3 practice relied on natural pasture and crop residues from harvested plots of crops. There was higher frequency (P<0.05) of respondents from FP1 supplemented dairy cows with home-made mixtures and other supplements, such as minerals and brewery waste as compared to those from FP2. The use of single ingredient specifically maize bran as supplement to dairy animals was higher (P<0.05) in FP2 practice compared to FP1 practice.

***Table 4.*** *Responses (%) by respondents (n=120) on the influence of feeding practices on the types of feeds given to the dairy cows.*

| Feed resource | Feeding practice | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | FP1 | | FP 2 | | FP 3 | | | |
| | Frequency | Percent | Frequency | Percent | Frequency | Percent | χ2 | p-value |
| Forage resources | | | | | | | | |
| Natural pastures | 85 | 100 | 16 | 100 | 19 | 100 | . | . |
| Improved pastures | 43 | 50.6 | 3 | 18.8 | 0 | 0 | 19.81 | 0.000 |
| Crop residues | 76 | 89.4 | 15 | 93.8 | 19 | 100 | 2.38 | 0.304 |
| Banana residues | 35 | 41.2 | 1 | 6.25 | 0 | 0 | 17.49 | 0.000 |
| Weeds | 68 | 80 | 1 | 6.25 | 0 | 0 | 54.7 | 0.000 |
| MKB | 12 | 14.1 | 2 | 12.5 | 1 | 5.3 | 1.11 | 0.573 |
| Dry season feeds; | | | | | | | | |
| Crop residues | 84 | 98.8 | 15 | 93.8 | 19 | 100 | 2.5 | 0.287 |
| Banana residues | 45 | 52.9 | 4 | 21.1 | 1 | 6.25 | 16.63 | 0.000 |
| Concentrates | | | | | | | | |
| Maize bran | 17 | 20 | 10 | 57.5 | 10 | 0 | 34.54 | 0.000 |
| Homemade mixture | 65 | 76.5 | 7 | 43.8 | 0 | 0 | 29.53 | 0.000 |
| Compound meals | 15 | 17.65 | 1 | 6.3 | 0 | 0 | 5.47 | 0.065 |
| BB and pellets | 18 | 21.2 | 0 | 0 | 0 | 0 | 8.72 | 0.013 |

*MKB=market and kitchen by-products, BB=brewery by-products*

## 3.6. Nutritive Values of the Diets Offered to Cows in Different Feeding Practices and Zones

Table 5 presents the means of the nutrient composition and in vitro digestibility of the forage diets offered to dairy cows by the different feeding practices and zones. Forage diets used in FP1 had lower (P<0.05) mean CP content than those from FP2 and was highest (P<0.05) in FP3 practice. In addition, higher mean ash content was obtained in forage diets from FP3 practice. Forage diets used by the cows on FP1 contained higher (P<0.05) mean neutral detergent fiber (NDF) than those used in other practices, whereas the means acid detergent fibre (ADF) contents were similar (P>0.05) for all the feeding practices. Lowest (P<0.05) mean values of the in vitro dry matter (INVDMD) and organic matter (INVOMD) digestibility and metabolisable energy (ME) were observed on the forage samples collected from FP1 practice compared with those from the other feeding practices. Forage diets collected from the lowland zone contained higher (P<0.05) mean values of CP and ash contents and were less fibrous than those collected from the highland zone. The mean values of the in vitro digestibility and metabolisable energy contents of the forages were, however not different (P>0.05) between the two zones. There was a significant (P<0.05) interaction effect between feeding practices and altitude zone on CP and ME. Forage diets in highland zone had lower CP and ME in all feeding practices than those in the lowland zone.

***Table 5.*** *Lsmeans ±SEM of the influence of feeding practices and altitude zones on the nutritive values of forage diets offered to dairy cows in Hai district.*

| | Feeding practices | | | | | Altitude zones | | | | FP*Zone |
|---|---|---|---|---|---|---|---|---|---|---|
| **Variable (%)** | **FP1** | **FP2** | **FP3** | **SE** | **P-value** | **Highland** | **Lowland** | **SE** | **P-value** | **P-value** |
| n | 42 | 23 | 15 | | | 40 | 40 | | | |
| DM | 49.54 | 47.14 | 40.01 | 6.36 | 0.52 | 46.14 | 47.11 | 5.53 | 0.91 | 0.68 |
| CP | 6.90$^{c}$ | 8.58$^{ab}$ | 10.15$^{a}$ | 0.72 | 0.001 | 6.58$^{b}$ | 9.21$^{a}$ | 0.45 | 0.0003 | 0.001 |
| C. Fat | 1.49 | 1.12 | 1.38 | 0.10 | 0.049 | 1.45 | 1.46 | 0.05 | 0.849 | 0.049 |
| Ash | 6.32$^{b}$ | 7.06$^{a}$ | 7.39$^{a}$ | 0.23 | 0.020 | 6.15 | 7.26 | 0.35 | 0.032 | 0.020 |
| NDF | 57.60$^{a}$ | 52.54c | 54.81$^{b}$ | 1.08 | 0.010 | 58.37 | 53.86 | 0.89 | 0.013 | 0.010 |
| ADF | 34.64 | 32.68 | 32.95 | 0.93 | 0.061 | 35.16 | 32.48 | 0.77 | 0.058 | 0.061 |
| IVDMD | 40.1$^{b}$ | 47.33$^{ab}$ | 53.17$^{a}$ | 3.416 | 0.048 | 44.99 | 48.68 | 2.87 | 0.404 | 0.048 |
| INVOMD | 32.32$^{b}$ | 46.1$^{a}$ | 47.11$^{a}$ | 5.824 | 0.019 | 41.75 | 41.28 | 3.26 | 0.924 | 0.019 |
| ME MJ/kgDM | 5.01$^{a}$ | 7.38$^{a}$ | 7.54$^{b}$ | 0.93 | 0.019 | 6.68 | 6.6 | 0.52 | 0.924 | 0.019 |

*In this and subsequent tables:*
*a-c Means with different superscript letters within a row differ significantly ($p<0.05$). SEM= standard error of the mean*
*CP=crude protein, C. Fat=crude fat, NDF=neutral detergent fiber, ADF=acid detergent fiber, IVOMD=invitro dry matter digestibility, INVOMD=invitro organic matter digestibility, ME=matabolisable energy.*

Table 6 presents the nutritive values of concentrate diets offered to dairy cows for the different feeding practices and zones. The concentrates mixtures used by cows from FP1 had higher (P<0.05) mean values of CP and ash contents compared to those offered to cows on FP2 practice. However, there were no significant differences on the mean values of in INDMD and ME contents of the concentrates offered to cows in the two feeding practices. The mean values of CP contents of the concentrate mixtures were not different (P>0.05) between the highland and lowland zones. The mean values of the crude fat, NDF and ADF contents were higher (P<0.05) in the concentrate mixtures collected from the lowland zone than those from the highland zone. The mean values of the INVDMD, INVOMD and ME contents of the concentrate mixtures from the highland and lowland zones were similar (P>0.05). A significant interaction effects between feeding practices and altitude zones were observed for CP and Ash contents of the concentrates. The concentrate diets in the highland zone had higher (P>0.05) means of CP and Ash contents in all feeding practices than those in the lowland zones.

***Table 6.*** *Lsmeans ±SEM of the influence of feeding practices and altitude zones on the nutritional values of concentrate diets offered to dairy cows.*

| | Feeding practices | | | | Altitude zones | | | | FP*Zone |
|---|---|---|---|---|---|---|---|---|---|
| **Variable (%)** | **FP1** | **FP2** | **SE** | **P-value** | **Highland** | **Lowland** | **SE** | **P-value** | **P-value** |
| n | 35 | 20 | | | 30 | 25 | | | |
| DM | 88.86 | 90.76 | 0.27 | 0.052 | 88.86 | 89.3 | 0.19 | 0.94 | 0.081 |
| CP | 13.68$^{a}$ | 10.90$^{b}$ | 0.92 | 0.003 | 14.41 | 13.80 | 0.22 | 0.067 | 0.003 |
| C. Fat | 7.35 | 9.20 | 0.64 | 0.040 | 6.23$^{b}$ | 9.02$^{a}$ | 0.49 | 0.001 | 0.040 |
| Ash | 7.99 | 5.80 | 0.55 | 0.010 | 8.21$^{a}$ | 7.38$^{b}$ | 0.42 | 0.026 | 0.010 |
| NDF | 28.98 | 26.90 | 0.96 | 0.202 | 28.33$^{b}$ | 32.31$^{a}$ | 0.72 | 0.004 | 0.202 |

| | Feeding practices | | | | Altitude zones | | | | FP*Zone |
|---|---|---|---|---|---|---|---|---|---|
| **Variable (%)** | **FP1** | **FP2** | **SE** | **P-value** | **Highland** | **Lowland** | **SE** | **P-value** | **P-value** |
| ADF | 11.90[b] | 14.97[a] | 0.89 | 0.030 | 14.08[b] | 17.74[a] | 0.85 | 0.007 | 0.030 |
| INVDMD | 81.69 | 83.11 | 4.05 | 0.06 | 85.83 | 78.73 | 3.55 | 0.203 | 0.060 |
| INVOMD | 80.45 | 83.47 | 3.65 | 0.68 | 85.78 | 77.58 | 4.4 | 0.242 | 0.680 |
| ME MJ/kgDM | 12.1 | 12.5 | 0.545 | 0.68 | 12.87 | 11.63 | 0.65 | 0.242 | 0.680 |

### 3.7. The Influences of Feeding Practices and Zones on the Average Milk Yield

Cows under FP1 from the highland zone produced the highest (P<0.05) average milk yield of 11.6 kg (Figure 3), whereas their counterparts from the lowland had similar (P>0.05) average milk yield to those under FP2 in the highland zone (8.7 kg and 9.47 kg). Cows under FP3 in the lowland produced the lowest (P<0.05) milk yield of 4.61 kg. However, the FP3 system was not practiced in the highland zone.

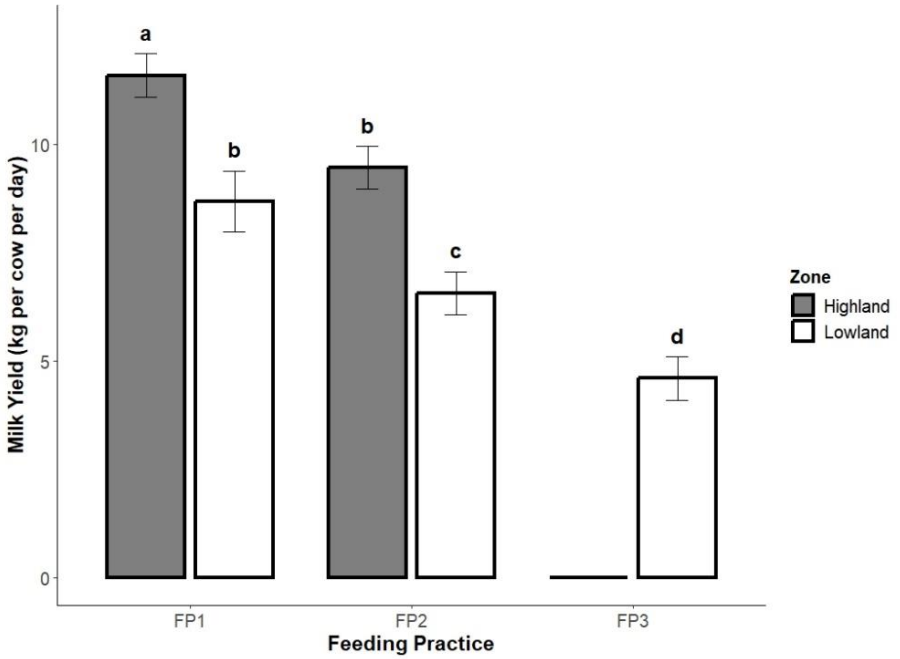


***Figure 3.*** *Trends of average milk yield (kg/cow/d) as influenced by the feeding practices and altitudes in the study area.*

## 4. Discussion

It is affirmed in this study that the majority of livestock keepers have the basic primary and secondary education, a normal undertaking in many animal farming communities as also reported by [13]. However, the observed higher percentage of respondents with no formal education in the lowland relative to highland zone could be due to the fact that farmers in this zone, were still transforming slowly from traditional to modern livestock keeping, which denied their access to school. In addition, small land sizes (less than one-acre) was a common feature of SDFs in this study sites due to population pressure. In the area land is normally divided between sons in the family, in agreement with report of [14]. In the highland zone the problem of less land size is more pronounced due geographical features such as hills and valleys which limit expansion of the plots. Small land size in the highland zone of this district relative to other highlands was also reported by [15].

The present study established clearly that adaptation of zero grazing (FP1) for both highland and lowland zone could be due to small sizes of land caused by population growth.

Farmers in the lowland are less experienced in dairying due to previous existence of traditional livestock keeping including the Maasai pastoralists. On the contrary, the larger number of more experienced farmers in the highland could be a result of favourable dairying environment, including cool temperatures as reported elsewhere [16]. There is a historical evidence of dairy cattle farming in the highland zone of Hai district that started in the 1970's as stipulated by [17].

The zero grazing practice is termed as the modern way of keeping dairy cows and farmers are adapting the practice as means of increasing dairy production in the study area. The adaptation of feeding practices was found to be strongly influenced by the socioeconomic characteristics of farmers due to their different perception in making decision. The increased adaptation of FP1 feeding practices for male headed households could be due to their decision making power over resources needed to adapt this practice, the fact supported by [18]. The increased adaptation of FP1 practice with other socioeconomic characteristics, such as high level of education, longer farming experience and mixed farming could be due to exposure and access to technologies, training and extension services [19]. The FP3 was practiced more in lowland as farmers in this area had larger size of land than those in highland zone. Higher number of farmers owned crosses of Friesian breeds adapted FP1 practice than those with other breeds because the breed is known to be high milk producer but less resilient to hash environment. Friesian breed is prone to diseases, hence needs proper management specifically better feeding [20] which is achieved well under FP1 practice.

In this study, natural pastures were the main feed resources across all feeding practices. The observed higher use of improved pastures, banana crop residues and weeds from crop fields by farmers under FP1 than other feeding practices could be linked with the limited availability of feed resources due to limitation of land size. Therefore, farmers used all the available resources in their environment to ensure the animals are properly fed. These feed resources were supplemented by high-quality concentrates, such as homemade mixtures, compound dairy meal and brewery waste (Table 4).

The feeding practices and altitudes were found to have influence on the nutritive values of the feed sources offered, whereby the observed lower mean CP content of forage diets used under FP1 could be due to the type of forage mixtures collected for feeding the animals. The forage mixtures offered to cows in the highland zone during the study were dominated by crop residues and banana pseudo stems. The observed mean CP content of forages offered to cows under FP1 practice was similar to the CP content of 6.8 percent reported by [21] for forages offered to cows in the Eastern Tanzania. The observed higher mean values of NDF and ADF contents of forages obtained for forages offered to cows under FP1 practice were caused by mature plants with higher fiber contents and low digestibility values similarly reported by [22] for the cut and carry systems. As pointed out by [23], the forages of less than 7 percent CP as observed in forages offered to cows under FP1 cannot support production unless supplementation practise is adapted. Thus, the observed higher milk yield from cows under FP1 in the highland zone than lowland zone was influenced by the strategy followed by the farmers supplementing high amount of high quality concentrates such as homemade mixtures, compound dairy meal and brewery byproducts. Direct observation revealed that most dairy producers in highland zone supplemented dairy animals with 10 liters bucket of concentrates equivalent to 4 - 6 kg. In addition, most farmers in this zone supplemented dairy animals with brewery waste in which 8 - 10 kg of wet brewery by-products were fed alone or in combination with at least 2 kg of concentrates. Their counterparts in the lowland zone were supplementing dairy cows with 4 liters of concentrates equivalent to 1.5 - 2.3 kg. These supplementation strategies was also reported by [10] in the same agroecological zone. On the other hand, higher nutritional quality of forages obtained in the fields used by animals under FP3 and FP2 compared to those sampled from the feeding troughs for FP1 could be due to the effect of the above average short rains experienced in October and December 2023 according to the records by the Tanzania meteorological Agency (TMA) [24]. The rains promoted emergency of newly grown plants in the grazing fields, where samples were collected. It might be difficult for farmers to harvest such small plants for the FP1, hence conserved forages dominated by crop residues were mainly used. The present study emphasizes the importance of considering feeding practices and altitude zones in shaping the nutritional quality of feed resources offered to dairy animals to enhance sustainable dairy production.

## 5. Conclusion and Recommendation

The study concluded that high level of education, long experience in dairying and small size of land owned by farmers trigger the adaptation of zero grazing practice (FP1) to promote milk yield in both highland and lowland zones. Furthermore, the nutritional values of the available forage diets in the FP1 practice for the two zones were shown to be lower where those of concentrates were higher compared to other feeding practices. These results revealed that the socioeconomic characteristics of the farmers and location are necessary for interventions aiming at improving the performance of dairy cattle in Tanzania. Further studies on the influence of the feeding practices and altitude zones on the environment are recommended.

## Abbreviations

| | |
|---|---|
| $\chi 2$ | Chi-square |
| AADGG | African and Asian Dairy Genetics Gain Program |
| ADF | Acid Detergent Fibre |
| BB | Brewery By-products |

| | |
|---|---|
| BMGF | Bill and Melinda Gates Foundation |
| COSTECH | Commission for Science and Technology of Tanzania |
| CP | Crude Protein |
| DAARS | Department of Animal, Aquaculture and Range Sciences |
| DM | Dry Matter |
| FP1 | Zero Grazing Practice |
| FP2 | Grazing with Supplementation Practice |
| FP3 | Extensive Grazing Practice |
| GLM | General Linear Model |
| ILRI | International Livestock Research Institute |
| INVDMD | In Vitro Dry Matter Digestibility |
| INVOMD | In Vitro Organic Matter Digestibility |
| ME | Metabolizable Energy |
| MKB | Market and Kitchen By-products |
| NAIC | Artificial Insemination Centre |
| NDF | Neutral Detergent Fiber |
| NIRS | Near-Infrared Reflectance Spectrophotometer |
| ODK | Open Data Kit |
| REC | Research Ethical Committee |
| SDFs | Smallholder Dairy Farms |
| SEM | Standard Error of the Mean |
| SRUC | Scotland's Rural College |
| SSA | In Sub-Saharan African |
| SUA | Sokoine University of Agriculture |
| TALIRI | Tanzania Livestock Research Institute |
| TLMP | Livestock Master Plan |
| TMA | Tanzania Meteorological Agency |
| TVLA | Tanzania Veterinary Laboratory Agency |

## Author Contributions

**Anitha Carlos Ngesi:** Conceptualization, Data Curation, Formal Analysis, Investigation, Methodology, Validation, Visualization, Writing – Original Draft

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## Conflicts of Interest

The authors declare no conflicts of interest.

## References

[1] Michael, S., Mbwambo, N., Mruttu, H. Tanzania Livestock Master Plan. International Livestock Research Institute (ILRI). 2018, 10-25.

[2] Häsler, B., Msalya, G., Roesel, K., Fornace, K, Eltholth, M., Kurwijila, L., Rushton, J., Grace, D. Using participatory rural ap-praisal to investigate food production, nutrition and safety in the Tanzanian dairy value chain. Global Food Security. 2019, 20(2), 122–131. https://doi.org/10.1016/j.gfs.2019.01.006

[3] Richards S., VanLeeuwen, J., Shepelo, G., Gitau, G. K., Kamunde, C., Uehlinger, F., Wichtel, J. Associations of farm manage-ment practices with annual milk sales on smallholder dairy farms in Kenya. Veterinary World. 2015, 8(1), 88-96.

[4] Waithaka, M. M., Nyangaga, J. N., Staal, S. J., Wokabi, A. W., Njubi, D., Muriuki, K. G., Njoroge, L. N., Wanjohi, P. N. Character-ization of dairy systems in the Western Kenya region. SDP Collaborative Research Report. International Livestock Research Institute (ILRI). 2002, 1-73.

[5] Nalunkuuma, J., Affognon, H., Kingori, S. W., Salifu, D., Njonge, F. K. Adoption of FP1 and impact on livestock keepers' knowledge of cattle reproductive parameters in Western Kenya. Age. 2013, 1, 0-32.

[6] Green, M. Dairying as development: Caring for modern cows in Tanzania. Human Organization 2017, 76(2), 109-120.

[7] Maleko, D., Msalya, G., Mwilawa, A., Pasape, L., Mtei, K. Smallholder dairy cattle feeding technologies and practices in Tanzania: failures, successes, challenges and prospects for sustainability. International Journal of Agricultural Sustainability. 2018, 16(2), 201-213.

[8] Melo, C. D., Maduro, D. C. S., Wallon S. Influence of climate variability and soil fertility on the forage quality and produc-tivity in Azorean pastures. Agriculture. 2022, 12(3), 358-367.

[9] Zhao, X., Li, P., Liu, X., Xu, T., Zhang, Y., Meng, H., Xia, T. High temperature increased lignin contents of poplar (Populus spp) stem via inducing the synthesis caffeate and conifer aldehyde. Frontiers in Genetics. 2022, 13, 1-14. https://doi.org/10.3389/fgene.2022.1007513

[10] Lyatuu, E. T., Komwihangilo, D., Msuta, G., Kelya, N., Okeyo, M., Ojango, J., Gebreyohanes, G. Unlocking Total Factor Productivity of Smallholder Dairy Farmers in Tanzania. Tanzania Journal of Agricultural Science. 2023, 22 (2), 338-345.

[11] Tilley, J. M. A., Terry D. R. A two - stage technique for the in vitro digestion of forage crops. Grass. Forage. Science. 1963, 18(2), 104-111.

[12] MAFF: Ministry of Agriculture, Fisheries and Food, Department of Agriculture and Fisheries for Scotland and Department Agriculture for Northern Ireland. Energy Allowances and Feeding Systems for Ruminants. Reference book. 1984, 433, 3-33.

[13] Mwaipopo, L. C., Mbaga, S. H. Assessment of preferable breeding method use and related limitations under smallholder dairy farmers' conditions: A case study in selected districts Southern Highland zone of Tanzania. European Journal of Agricul-ture and Food Sciences. 2022, 4(2), 78-85. https://doi.org/10.24018/ejfood.2022.4.2.484

[14] Alphonce, Eassessment of high human population density and its impacts on land resources in Moshi district council, Tan-zania. Ph. D Thesis, Mzumbe University. 2013.

[15] Swai, E. S., Mollel, P., Malima, A. Some factors associated with poor reproductive performance in smallholder dairy cows: the case of Hai and Meru districts, northern. Livestock Research for Rural Development. 2014, 26(6), 21-37.

[16] Adhikari, P., Sharma P., Sharma S. P. A Review on Effect of Climatic Zones on the Milk Production of Holstein Friesian and Jersey Cows. International Journal for Research in Applied Sciences and Biotechnology. 2021, 8(2), 45-51.

[17] Mdoe, N., Wiggins S. Returns to smallholder dairying in the Kilimanjaro region, Tanzania. Agricultural Economics. 1997, 17(1), 75-87.

[18] Omollo, E. O., Wasonga, O. V., Elhadi, M. Y., Mnene, W. N. Determinants of pastoral and agro-pastoral households' parti-ci-pation in fodder production in Makueni and Kajiado Counties, Kenya. Pastoralism. 2018 8, 1-10.

[19] Quddus, M. A. Adoption of dairy farming technologies by small farm holders: practices and constraints. Bangladesh. Jour-nal of Animal Science 2012, 41 (2), 124-135.

[20] Lukuyu, M. N., Gibson, J. P., Savage, D. B., Rao, E. J. O., Ndiwa, N., Duncan, A. J. Farmers' perceptions of dairy cattle breeds, breeding and feeding strategies: A case of smallholder dairy farmers in western Kenya. East African Agricultural and Forestry Journal. 2019, 83(4), 351-367. https://doi.org/10.1080/00128325.2019.1659215

[21] Kavana P. Y., Msangi B. S. J. On farm dairy cattle feeding experience in eastern zone of Tanzania. Livestock Research for Ru-ral Development. 2005, 18(2), 1–8.

[22] Pincay, F. P. E., López, G. F., Velarde, G. J. Cut and carry vs. grazing of cultivated pastures in small-scale dairy systems in the central highlands of Mexico. Journal of Agriculture and Environment for International Development 2016, 110(2), 349-363.

[23] Sampaio, C. B., Detmann, E., Paulino, M. F. Intake and digestibility in cattle fed low-quality tropical forage and supplemented with nitrogenous compounds. Tropical Animal Health and Production 2010, 42, 1471-1479.

[24] TMA: Tanzania Meteorological Agency. Available from: http://www.meteo.go.tz