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Year Round Feed and Fodder Availability in Smallholder Dairy Farms across High and Low Altitude Areas in Eastern Africa

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Feed-year strategies involve matching the cycles of dairy production with the changing availabilities of all sources of nutrients over time. Therefore, an understanding of seasonal variation in availability of forage resources is important in future planning and development of appropriate technologies to assure resilience of smallholder dairy systems to seasonal changes. This study was carried out to: 1) evaluate the current pattern of seasonal variation in forage availability in smallholder dairy farms, and 2) assess seasonal variation in year-round forage based feeding strategies in smallholder dairy farms in Eastern Africa. Data was collected from a purposive representative sample of 400 smallholder dairy farmers through cross-sectional and observational

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studies. The Feed Assessment Tool (FEAST) was used to capture the season's effect (wet and dry) across high and low altitude areas in Kenya and Tanzania from 2016-2018. Data were analyzed using the generalized linear model (GLMM) procedure of SPSS 21.0 (Chicago, IL, USA), using models that included the fixed effects and random effects; and FEAST Version 2.21. Results showed that location (country), agro-ecological zone and season had a significant influence ($p \leq 0.05$) on year-round rainfall variability. Availability and utilization of concentrate feeds, green and dry crop residues, improved fodder, pasture and legume forage throughout the year, were significantly influenced ($p \leq 0.05$) by location, agro-ecological zone, seasons and production systems. Correlation between the forage resources revealed highly significant ($p \leq 0.001$) and positive relationships in availability and usage across the two countries. From this study, rainfall variability was crucial in determining sources and year-round variation in availability and utilization of forages. Therefore, different seasonality driven site, region or country specific year-round feeding interventions and strategies could be applied depending upon type, source, quantity (availability) and quality of feeds to overcome seasonal milk fluctuations in smallholder dairy farms in Eastern Africa.

Keywords: Agro-ecology; feeds and fodder; seasonal variation; utilization; year-round.

1. INTRODUCTION

A recent assessment of the major technical constraints to smallholder dairy cattle production, and the opportunities for increasing productivity and more efficient performance from dairy animals showed that nutrition and genetics are the most important factors [1]. Nutrition is the main factor driving sustained productivity in the short-run [1,2]. Therefore, to increase the productivity of dairy cattle, it is especially important to improve the availability of local feed resources [3,4]. The principal determinants of the types of food-feed crops grown in any particular locations are the prevailing agro-ecological conditions [5]. Climate and soils affects the natural vegetation and influence farmers' choice of food-feed crops [6,7]. These determines the feed resources, its quantity, quality and distribution [8–11]. Feed resources provide a direct link between crops and animals. The interaction between the two, together with other environmental challenges, largely dictate the development of smallholder crop-livestock systems [12]. Feed resources in smallholder dairy farms may be divided into five categories, namely: permanent natural pastures, crop residues, cultivated (improved) fodder, legume forages and energy feeds–grains, concentrates or agro industrial by-products [13]. Feed-year strategies involve matching the cycles of dairy production with the changing availabilities of all sources of feed nutrients over time [8,14,15]. Locally available feed resources must be consistent with the diverse production objectives of farmers and with the feasibility of achieving the nutritional support for dairy cattle required [13,16]. These vary seasonally with farmers' bio-physical, socio-political, economic and environmental circumstances [6]. Effective utilization of locally available feed and appropriate supplementation of poor quality natural pasture and crop residue based diets appear to be the necessary steps to alleviate the nutritional problems of dairy animals [14]. However, different feeding and supplementation strategies could be applied depending upon the season, type, accessibility and price of supplementary feeds in a given area. Therefore, understanding seasonal variation in feed resource availability and utilization is important in future planning and development of appropriate technologies or strategies that can ensure resilience of smallholder dairy systems to seasonality driven milk shortages. It is against this context that, the objectives of this study were to: 1) evaluate the current pattern of seasonal variation in feed availability in smallholder dairy farms across high and low altitude areas in Kenya and Tanzania; and 2) assess seasonal variation in year-round feed utilization in smallholder dairy farms across high and low altitude areas in Kenya and Tanzania in Eastern Africa.

2. MATERIALS AND METHODS

2.1 Location

The study was carried out at highlands and lowlands agro-ecological zones in Kenya and Tanzania in Eastern Africa. A general overview was conducted out to have an understanding of the study areas in the two countries and to select representative agro-ecologies before proceeding to formal survey. The two countries were stratified into highlands agro-ecology (greater than 1,500 meters above sea level) and lowlands agro-ecology (less than 1,500 meters above sea level) based on the Kenyan and Tanzanian agro-ecological classification [17] and secondary data obtained from government livestock offices. Four distinct locations representing the highlands and lowlands agro-ecologies were selected, namely: Mbulu (highlands) and Karatu (lowlands) in Manyara region of Northern Tanzania; and Kakamega (highlands) and Siaya (lowlands) in Western region of Kenya. Karatu lies in Latitude 3.3454ºS and Longitude 35.6697ºE. Mbulu lies in Latitude 4.0805ºS and Longitude 35.5466ºE. Siaya lies in Latitudes 0.0998ºN and Longitude 34.2747ºE, while Kakamega lies within Latitude 0.2827ºN and Longitude 34.7519ºE. The four study areas have a bimodal rainfall pattern, which is unevenly distributed throughout the year with maize as the main food crop and dairy cattle as main livestock.

2.2 Data Collection

Data was collected using the Feed Assessment Tool (FEAST), which is a systematic method to assess local feed resource availability and usage (www.ilri.org/feast). FEAST offers a systematic and rapid methodology to assess feed resources at site level with a view to developing site-specific strategies to improve and optimize feed supply, utilization and animal production, through technical or organizational interventions [18,19]. FEAST differs from conventional feed assessment approaches that focus on the feeds, their nutritive value, and ways to improve them. FEAST broadens this assessment to account for the importance of livestock in local livelihoods, the relative importance of feed problems locally, and the local situation related to feed availability, seasonality, and utilization [1]. Qualitative data collection using FEAST was through focus group discussions (FGD) handled by a facilitator, interpreter, two notes takers and one observer in each session. The farmers (FGD participants) were selected based on information from the interaction of key informants with the community members through which smallholder crop and livestock farmers were identified and classified into four categories, namely: wet and dry seasons in highlands agro-ecology and wet and dry seasons in lowlands agroecology in both Kenya and Tanzania. In each agroecology (highlands and lowlands), 18 farmers (12 men and 6 women) were selected for the FEAST exercises, giving a total of 108 farmers in all the two countries.

2.3 Quantitative Data Collection

Quantitative data collection was conducted after the qualitative FGDs through individual household interviews. A pre-tested structured questionnaire was used to collect information from a purposive representative sample of 400 smallholder dairy farmers (100 each for the highlands and lowlands agro-ecological zones in the two countries), by trained enumerators on visit interviews between October 2016 and May 2017, in order to capture the season's effect (wet and dry). The sample size was obtained by estimating the number of observations potentially needed to distinguish between the two (highlands and lowlands) agro-ecological zones by a difference of 7% in some of the important farm household variables. Therefore, assuming a desired confidence interval of 95% with a precision of 5%, and a coefficient of variation of 51%, the sample was estimated from the formula: $\mathrm{N} = 2(\mathrm{Zc}/\mathrm{d})^2$ [20]. Where, N=Minimum sample size, z=1.96 for 95% confidence interval, c=Coefficient of Variation, d=Level of difference. Accordingly, 400 HHs were selected. Multistage purposive sampling technique [21] and a single-visit multi subject formal survey method were used for the survey [22]. The cross sectional survey was followed by a purposive observational study covering two seasons (wet and dry) in the study locations between July 2017 and June 2018, to monitor and capture seasonal and year-round variations in feed and odder sources, including utilization.

2.4 Verification of Data Collection Method

Dependent variables were scored by farmers on a five point scale of 0-5 (where 0=none; 1=moderately low; 2=low; moderately high; 4=high and 5=very high) and validated during the wet and dry seasons of observational study. Verification of the method was achieved through comparison of farmer estimates of monthly rainfall, scored on a five point scale of 0-5 and actual meteorological measurement of monthly rainfall recorded at Kenya Agricultural and Livestock Research Organization, Kakamega. The actual rainfall data was then normalized on the five point scale scores. Plotted line graph (Fig. 1) for farmer estimates and normalized rainfall data were almost similar, an indicator that the method was valid and highly applicable for this study, as it was un-biased and non-subjective, as similarly reported by [1].

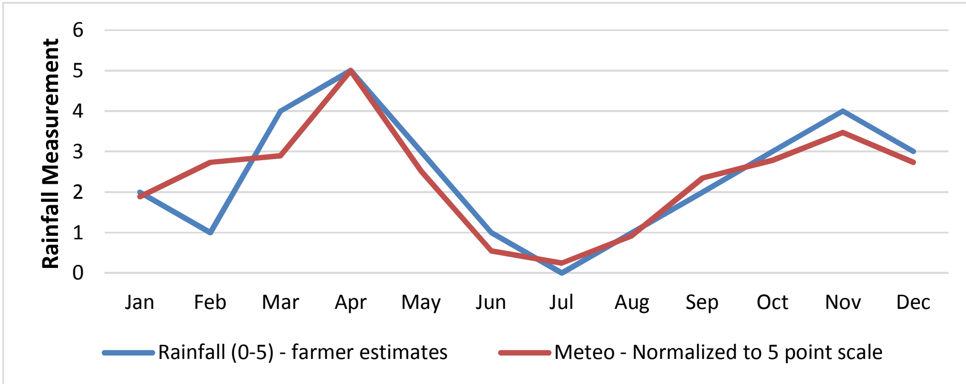

Fig. 1. Comparison of farmer estimates (5-point scale) and meteorological measurement of actual rainfall for method verification

2.5 Data Analysis

Independent variables consisted of location (country), seasons (wet and dry) and agro-ecological zones (highlands and lowlands). While, dependent variables comprised five (5) point scale farmer estimates of monthly rainfall, feeds and fodder sources that comprised: concentrates, green crop residues, dry crop residues, natural pasture, improved fodder, legume forage and fodder trees/shrubs. Analysis was done using the generalized linear mixed model (GLMM) procedure of SPSS 21.0 (Chicago, IL, USA) using models that included fixed effects and dependent variables. This was achieved using MANOVA (Multivariate analysis of variance) at 95% Confidence Interval (Significance level, $p \leq 0.05$). Means were compared using least significant difference (LSD). Further, Pearson's correlation was done to find the relationship between the different feeds and fodder sources. The statistical model for this study was represented as:

$$Y = \beta_0 + \sum_{i=1}^{p} \beta_i X_i + \varepsilon$$

Where: Y= Response (dependent) variable; β_0= the value of Y when all independent variables equal zero; β_i = the coefficient associated with explanatory variable X_i; and X_i = are independent variables described above.

3. RESULTS

3.1 Rainfall Variability/Seasonality

Country was significant ($p \leq 0.001$) on rainfall received throughout the year in Kenya and Tanzania, but not agro-ecological zone ($p \geq 0.05$). There was a significant difference ($p \leq 0.001$) on rainfall received in Kenya and Tanzania most of the year, except during the months of March and November (Figs. 2 and 3). Tanzania received more rainfall from the months of November – March compared to Kenya (Figs. 2 and 3). On the other hand, Kenya received more rainfall during the months of April to October compared to Tanzania. However, based on farmer rainfall estimates (5-pont scale score, 0-5) and actual long-term mean monthly actual rainfall (mm), almost the same amount of rainfall was received within highlands and lowlands agro-ecological zones in the two countries (Figs. 2 and 3). Yearly rainfall variability across different months was a confirmation of seasonality of rainfall across two countries. Overall across both countries, wet season period peak long rains were received in April, while peak short rains were received in November (Fig. 2). The dry season period with very minimal or no rains was between June-September for Tanzania and December-February for Kenya (Figs. 2 and 3).

3.2 Concentrate Feeds/Homemade Ration

Country, feed and fodder type and their interaction had significant influence ($p \leq 0.001$) on year round availability and utilization of concentrate feeds/homemade rations in Kenya and Tanzania (Table 1 and Fig. 4). Concentrates feeds consisted of commercially mixed ration/dairy meal, cereal bran and grains, molasses and agro-industrial crop by products. However, agro-ecological zones had no significant influence ($p \geq 0.001$) on year-round availability and utilization of concentrates feeds. The mean difference between months in availability and utilization of concentrates feeds throughout the year within the two countries was significant at ($p \leq 0.05$) level (Table 2). This implies that throughout the year, more concentrates feeds were available and utilized in Tanzania compared to Kenya (Fig. 4). Overall, year-round availability and utilization of concentrates feeds, of whichever type as listed above, for supplementary feeding was almost similar across the highlands and lowlands agro-ecological zones of the two countries (Fig. 3).

3.3 Green Farming by/Waste Products or Residues

Country, feeds and fodder type and interaction were significant ($p \leq 0.05$) on year round availability and utilization of green crop residues (Table 1). The green crop residues consisted of cereal crops thinning's, i.e. maize, sorghum, millet, rice, wheat, cut natural grass/weeds, sugarcane tops, banana pseudo stems, kales (*Brassica oleracea*), assorted vegetables (home use leftovers), banana pseudo stems, sugar cane tops. The mean difference in availability and utilization of green crop residues was significant ($p \leq 0.05$) throughout the year (Fig. 5) between the two countries, except during the month of June ($p \geq 0.05$) as shown in Table 2. There were much green crop residues available and utilized in Tanzania from December to May (Table 2). This period in Tanzania coincided with the long rains and cropping period. However, much green crop residues were available and utilized in Kenya from July to November (Table 2), a period that coincided with harvesting and short rains cropping season. This implies that availability and usage of green crop residues was closely related to the cropping season in both countries.

3.4 Dry Farming by/Waste Products or Residues

Country and agro-ecological zone, feeds and fodder type and interaction between country and feeds and fodder type were significant ($p \leq 0.05$) on year round availability and utilization dry crop residue (Table 1). The dry crop residues consisted of cereal crops residues i.e. maize stover, sorghum/millet stover, rice straw, wheat straw; legume crops residues i.e. beans and pigeon pea haulms, groundnuts hulls, sunflower husks; sugar cane bagasse. Agro-ecological zone was also significant ($p \leq 0.05$) on availability and utilization of dry crop residues from May to July (Fig. 6). This implies that much dry crop residues were available and utilized in the highlands of the two countries as opposed to the lowlands (Fig. 6). The mean difference in availability and utilization of dry crop residues was significant ($p \leq 0.05$) throughout the year within the two countries, except during the month of December (Table 2). Much drier crop residues

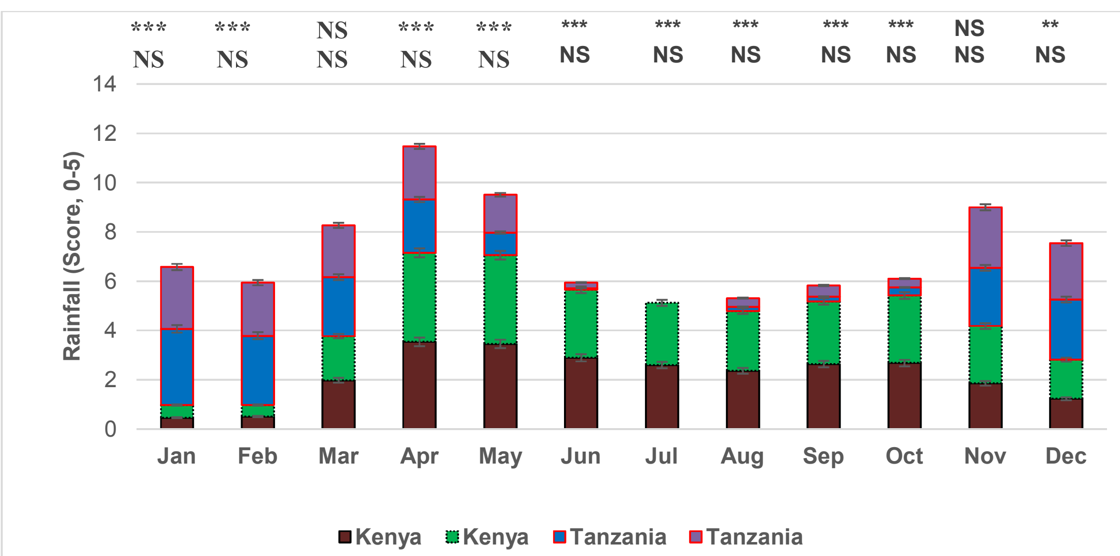

Fig. 2. Farmer monthly rainfall estimates (5-point scale score, 0-5) in highlands and lowlands areas in Kenya and Tanzania (95% CI) from 2016 to 2018
*NS=Not Significant; *** Significance level (p ≤ 0.001); **Significance level (P ≤ 0.01)*

Table 1. ANOVA for the influence of country, agro-ecological zone, feed and fodder type and interaction of year round availability and utilization in highlands and lowlands areas of Kenya and Tanzania

Months	AEZ			Country			Feed and fodder			Country*feed and fodder		
	MS	F	Sig.	MS	F	Sig.	MS	F	Sig.	MS	F	Sig.
January	0.009	0.010	0.919	1.917	9.272	0.005	2.348	11.358	0.000	5.569	26.942	0.000
February	0.010	0.009	0.923	18.948	100.389	0.000	4.185	22.174	0.000	7.321	38.789	0.000
March	0.000	0.000	0.998	25.795	164.497	0.000	6.643	42.360	0.000	8.855	56.471	0.000
April	0.028	0.019	0.892	19.917	114.788	0.000	9.184	52.932	0.000	10.814	62.323	0.000
May	0.007	0.004	0.949	10.513	49.190	0.000	2.659	12.441	0.000	11.767	55.060	0.000
June	0.000	0.000	0.992	0.398	1.775	0.194	1.102	4.917	0.002	11.937	53.258	0.000
July	0.002	0.001	0.970	1.485	8.130	0.008	1.867	10.225	0.000	10.691	58.537	0.000
August	0.016	0.012	0.915	10.756	73.616	0.000	5.508	37.693	0.000	9.747	66.707	0.000
September	0.016	0.015	0.904	8.170	58.935	0.000	5.948	42.908	0.000	7.827	56.466	0.000
October	0.003	0.002	0.963	3.042	16.351	0.000	8.564	46.035	0.000	9.662	51.939	0.000
November	0.001	0.001	0.973	2.844	21.036	0.000	5.598	41.418	0.000	7.090	52.450	0.000
December	0.000	0.001	0.980	0.408	2.510	0.124	3.080	18.958	0.000	3.667	22.566	0.000

MS-Mean Squares; Sig. Significance level ($p \leq 0.01$)

Table 2. Least square means for year round availability and utilization of feeds and fodder in the highlands and lowlands areas of Kenya and Tanzania

Feed and Fodder	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Concentrate feeds	1.78^{de}	2.09^{cd}	2.10^{c}	1.93^{bc}	2.03^{abc}	2.09^{ab}	2.08^{bc}	2.12^{c}	1.97^{c}	2.08^{c}	1.84^{d}	1.81^{de}
Dry crop residues	1.05^{abc}	0.70^{a}	0.48^{a}	0.47^{a}	1.96^{ab}	2.06^{ab}	2.82^{d}	3.42^{d}	3.18^{d}	3.26^{d}	2.68^{e}	1.84^{de}
Green crop residues	2.12^{e}	2.60^{d}	2.94^{d}	3.32^{e}	2.65^{cd}	2.29^{abc}	2.30^{cd}	1.31^{ab}	1.06^{ab}	0.80^{ab}	0.79^{bc}	2.03^{e}
Improved fodder	0.84^{ab}	0.78^{a}	1.08^{b}	1.42b	1.78^{a}	1.83^{a}	1.77^{ab}	1.56^{b}	1.41^{b}	1.35^{b}	1.16^{c}	1.00^{bc}
Legume forage	1.40^{dcd}	1.22^{ab}	1.90^{c}	2.52^{d}	2.81^{d}	2.84^{c}	1.88^{bc}	0.91^{a}	0.67^{a}	0.48^{a}	0.46^{ab}	0.39^{a}
Natural grass	1.62^{cde}	2.14^{cd}	2.98^{d}	3.56^{e}	3.42^{e}	2.46^{bc}	1.73^{ab}	1.53^{b}	1.48^{b}	1.34^{b}	1.17^{c}	1.37^{cd}
Fodder Trees/shrubs	0.61^{a}	1.53^{bc}	1.94^{c}	2.29^{cd}	2.57^{bcd}	1.77^{a}	1.30^{a}	1.29^{ab}	0.77^{a}	0.27^{a}	0.26^{a}	0.75^{ab}
SEM	0.33	0.36	0.39	0.43	0.45	0.46	0.43	0.41	0.37	0.41	0.35	0.27

SEM-Standard Error of Mean; ^{abcde} -Means with different superscript letters were significantly different ($p \leq 0.05$)

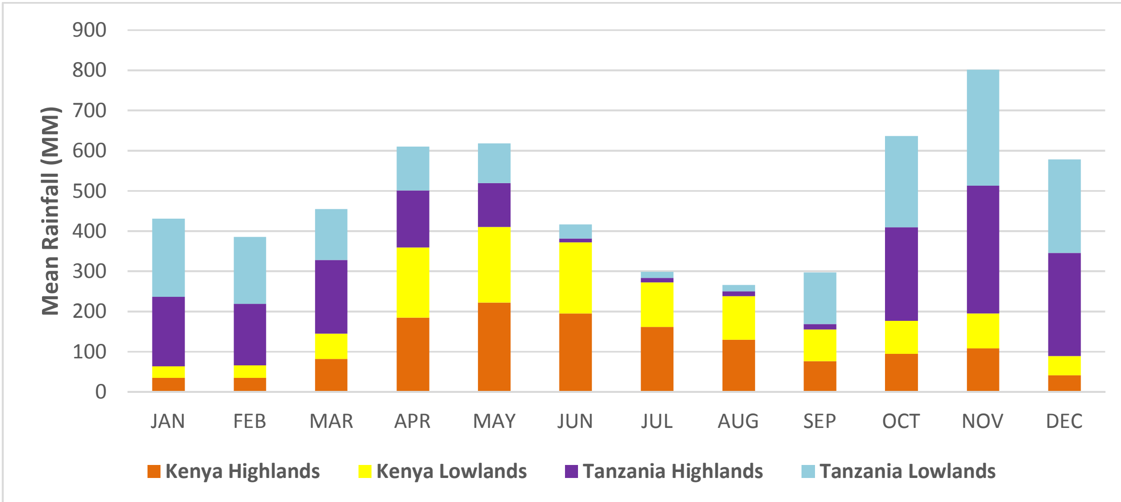

Fig. 3. Actual mean monthly rainfall (mm) in highlands and lowlands areas in Kenya and Tanzania from 2016 to 2018

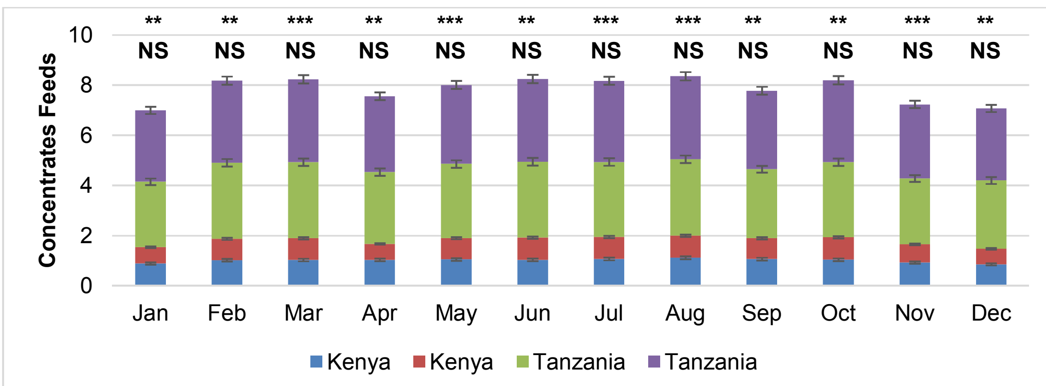

Fig. 4. Seasonal changes in year round availability and utilization of concentrates feeds in highlands and lowlands in Kenya and Tanzania

*NB: NS=Not Significant; *** Significance level ($p \leq 0.001$); ** Significance level ($p \leq 0.01$)*

were available and utilized in Kenya from January to April compared to Tanzania (Table 2). Similarly, much drier crop residues were available and utilized in Tanzania from May to November compared to Kenya (Table 2). Therefore, though dry crop residues were year-round, abundant availability and utilization was after the end of the cropping season after harvesting and during the dry season period across both countries (Fig. 6).

3.5 Improved (Planted) Fodder

Country, agro-ecological zone, feed and fodder type and interaction between country and agro-ecological zone were significant ($p \leq 0.05$) on availability and utilization of improved (planted) fodder (Table 1). Improved/planted fodder types consisted of Napier grass (*Pennisetum purpureum* Schumach), Rhodes grass (*Chloris gayana*), Giant Setaria grass (*Setaria sphacelata*), Bracharia, spp (*Bracharia ruziziensis*–Mulato) Congo signal (*Bracharia brizantha*), Pannicum *spp* (*Pannucum maximum*), Guatemala grass (*Tripsacum laxum*), Stylo (*Stylosanthes guiyanensis*), Italian rye grass (*Lolium multiflorum*), Bermuda grass (*Cynodon dactylon*), sweet potato vines (*Ipomea batatas*), Sunflower (*Helianthus anuus*), Sorghum (*Sorghum bicolor*), oats (*Avena sativa*), Maize (*Zea mays*) and fodder beat (*Beta vulgaris*). Mean differences between months were significant ($p \leq 0.05$) throughout the year for availability and utilization of improved fodder in the two countries (Table 2, Fig. 7). However, much improved fodder was available and utilized in the highlands and lowlands areas of Kenya, as opposed to Tanzania (Fig. 7), where it was very minimal or non-existent. The mean difference was significant (*p* ≤ *0.05*) on availability and utilization of improved fodder in Kenya from the months of December to February (Table 2). During the months of April to May, more improved fodder was available and utilized in the highlands areas of Kenya compared to the lowlands (Fig. 7). While, during the months of June to November, more improved fodder was available and utilized in the lowlands areas of Kenya compared to the highlands (Fig. 7). There was increased availability and utilization of improved fodder during the rainfall/cropping season in Kenya.

3.6 Pasture (Natural Grass)

Country alone had a highly significant influence (*p* ≤ *0.001*) on availability and utilization of pastures in Kenya and Tanzania, but not agro-ecological zone (*p* ≥ *0.05*) as shown in Fig. 8 and Table 1. Some of the natural pastures encountered in the two countries comprised Kikuyu grass (*Pennisetum clandestinum*), *Eragrostis superba*, Wire/themeda grass (*Themeda triandra*), *Cynodon dactylon*, Couch

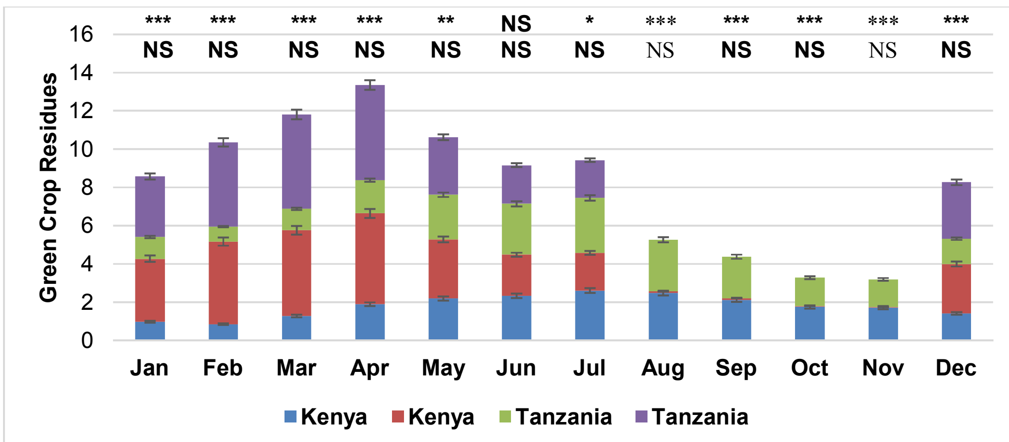

Fig. 5. Seasonal changes in year round availability and utilization of green crop residues in highlands and lowlands in Kenya and Tanzania

*NS=Not Significant; *** Significance level (p ≤ 0.001); ** Significance level (p ≤ 0.01);*
** Significance level (p ≤ 0.05)*

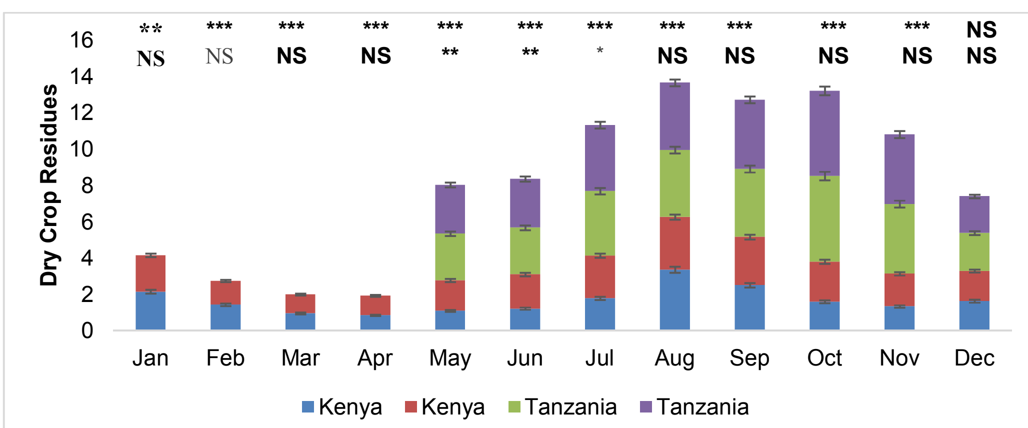

Fig. 6. Seasonal changes in year round availability and utilization of dry crop residues in highlands and lowlands in Kenya and Tanzania

*NS=Not Significant; *** Significance level (p ≤ 0.001); ** Significance level (p ≤ 0.01);*
** Significance level (P ≤ 0.05)*

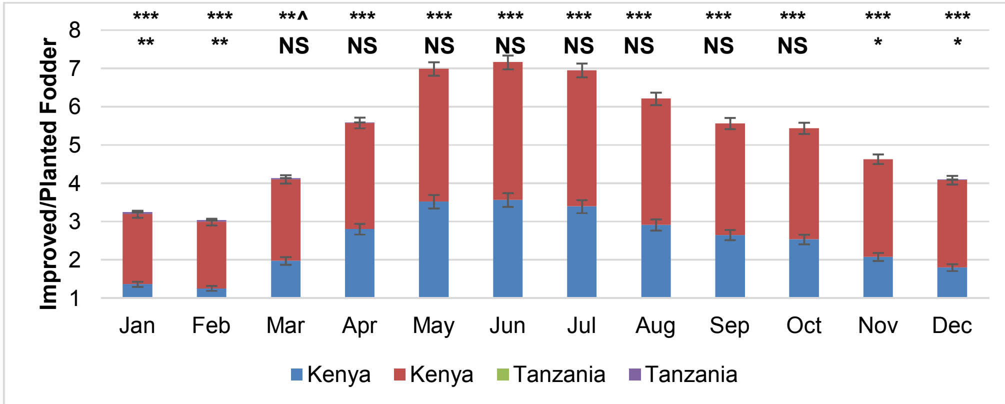

Fig. 7. Seasonal changes in year-round availability and utilization of improved fodder in highlands and lowlands in Kenya and Tanzania

*NS=Not Significant; *** Significance level (p ≤0.001); ** Significance level (p ≤ 0.01); * Significance level (p ≤ 0.05)*

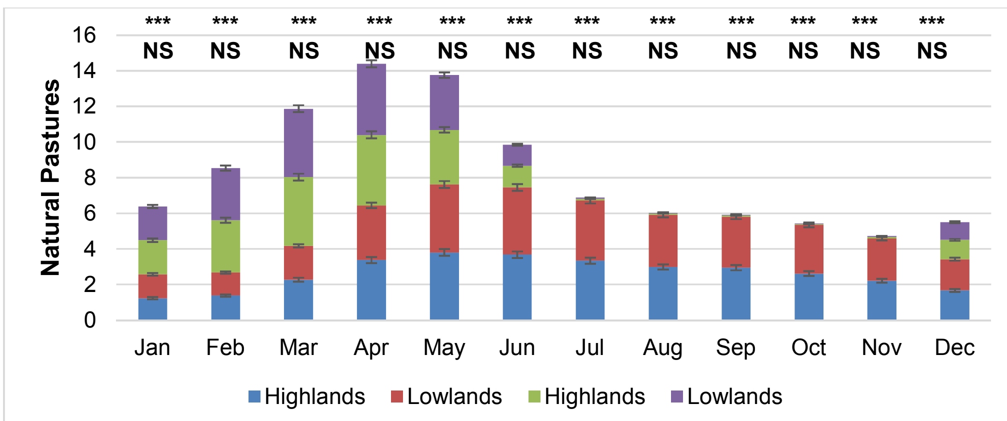

Fig. 8. Seasonal changes in year round availability and utilization of natural pastures in highlands and lowlands of Kenya and Tanzania

*NS=Not Significant; *** Significance level (p ≤ 0.001)*

grass (*Cenchrus cilliaris*), coloured guinea (*Panicum coloratum*), star grass (*Cynodon plectostachyus*), molasses grass (*Melinis minutiflora*), Columbus grass (*Sorghum almum*), edible cana (*Cana edulis*), *Sporobolus fimbriatus, Digitaria milanjiana, Digitaria abyssinica, Eragrostis cilianensis, Eustachyus paspaloides, Aristida adscensionis, Aristida kenyansis, Cynodon spp., Bothriochloa insculpta, Heteropogon contortus*. Mean differences between months were significant ($p \leq 0.05$) for year-round availability and utilization of natural grass in both Kenya and Tanzania (Table 2). Rainfall was a crucial factor in determining the availability and utilization of natural pastures in both highlands and lowlands agro-ecological zones in the two countries. There was more availability and utilization of natural pastures in highlands and lowlands areas in Tanzania from the months of January to April, a period that coincided with the long rains season (Figs. 2 and 8). The months of July to November were the dry season period in Tanzania, hence the absence of natural pastures. However, there were communal grazing areas in both the highlands and lowlands of Tanzania. The scenario was different in Kenya (Fig. 8), where despite absence of communal grazing areas in highlands and lowlands, natural pastures, though available and utilized year round, were more during the long rains season months from April to July.

3.7 Legume Forage

Country, feed and fodder type and their interaction had significant influence ($P \leq 0.01$) on availability and utilization of legume forage in Kenya and Tanzania (Table 1 and Fig. 9). Legume forages encountered consisted of *Macroptilium atropurpureum* (cv. Siratro), velvet or mucuna beans (Stizolobium spp.), Vetch (*Vicia vilosa*), Lablab (*Lablab purpureus*), Lucerne (*Medicago sativa*), White sweet clover (*Melilotus alba*), Desmodium (*Desmodium intortum/uncinatum*), Pigeon pea (*Cajanus cajan*), Soybean (*Glycine max*), beans (*Phaseola vulgaris*), Lupins (*Lupinus angustifolius*) and groundnuts (*Arachis hypogaea*). Mean differences between months were significant ($p \leq 0.05$) throughout the year on availability and utilization of legume forage in Kenya and Tanzania, except during the month of July (Fig. 9 and Table 1). There was more availability and utilization of legume forage in Tanzania from January to June in comparison to Kenya (Fig. 9). Similarly, there was more availability and utilization of forage legumes in Kenya from August to December compared to Tanzania (Fig. 9). Forage legumes in the two countries provided a feed reserve in the dry season, when the quantity and quality of the natural pasture was at minimum. The introduction of forage legumes into the crop rotation also served to break crop disease cycles, provide nitrogen through atmospheric nitrogen fixation, raise soil organic matter content and reduce soil erosion by providing more effective ground cover [23]. Therefore, availability and utilization of forage legumes in the two countries followed rainfall variability and cropping season (Figs. 2, 3 and 9).

3.8 Fodder Trees/Shrubs

Country, feed and fodder type, agro-ecological zones and interaction were significant on availability and utilization of fodder trees and shrubs in Kenya and Tanzania (Table 2 and Fig. 10). Fodder trees and shrubs encountered comprised Calliandra (*Calliandra carlorthysus)*, Gliricidia (*Gliricidia sepium*), Sesbania (*Sesbania sesban*), Leucaena (*Leucaena leuoccomponent),* Gravillea *(Gravillea robusta)*, Mulberry (*Morus alba*), Tegaste (*Chamacytisus prolifera*), Trichandra (*Leucaena trichandra*), Eucalyptus trees (*Eucalyptus spp*), European nettle tree (*Celtus australis*), Fig tree (*Ficus carica*), Accacia spp (*Acacia anguisstissima*). Mean differences between months were significant ($p \leq 0.05$) throughout the year on availability and utilization of fodder trees and shrubs in both Kenya and Tanzania (Table 2). There was high availability and utilization of fodder trees and shrubs in both highlands and lowlands in Tanzania from December to September compared to Kenya (Table 3). While, there was high availability and utilization of fodder trees and shrubs between October and November in Kenya compared to Tanzania (Table 3). Mean difference was also significant ($p \leq 0.05$) for availability and utilization of fodder trees and shrubs in both the highlands and lowlands areas of Kenya and Tanzania. In both countries more fodder trees and shrubs were available and utilized throughout the year in highlands compared to the lowlands agro-ecological zones. Fodder trees and shrubs have great potential as a source of protein and mineral nutrients, to supplement diets of dairy cattle normally fed nutritionally unbalanced and low digestibility roughage such as natural pasture, stubble and untreated crop residues [23]. Across the two countries, fodder trees/shrubs were available and utilized mostly during the rainfall and cropping season from February to August (Fig. 10).

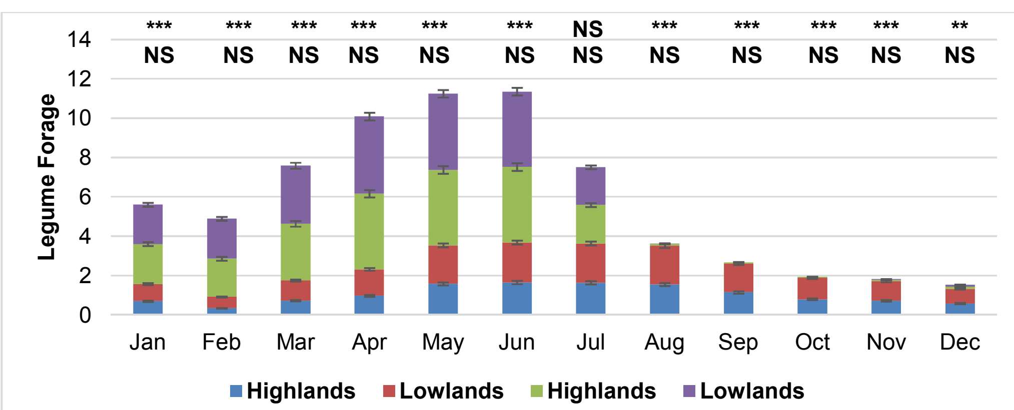

Fig. 9. Seasonal changes in year-round availability and utilization of legume forage in highlands and lowlands in Kenya and Tanzania

*NS=Not Significant; *** Significance level (P≤0.001); ** Significance level (P≤0.01)*

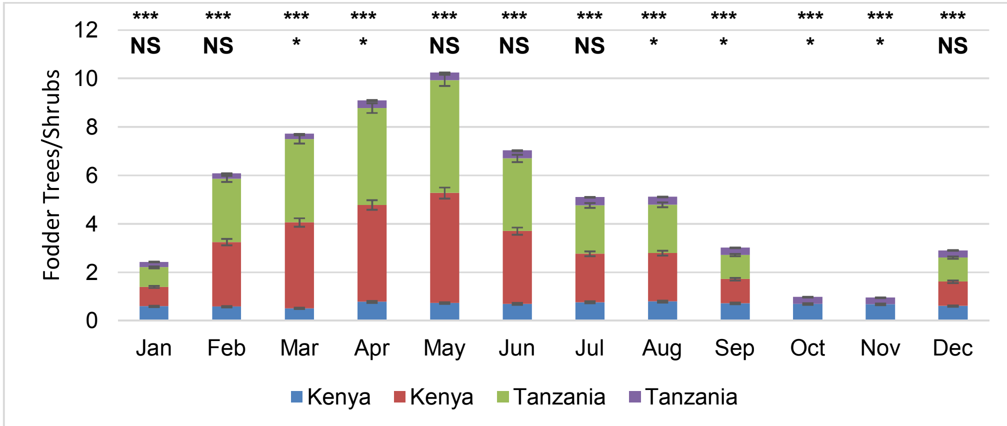

Fig. 10. Seasonal changes in year round availability and utilization of fodder trees/shrubs in highlands and lowlands of Kenya and Tanzania

*NS=Not Significant; *** Significance level (p ≤ 0.001); * Significance level (p ≤ 0.05)*

3.9 Overall Trends and Association in Year Round Feeds and Fodder Availability and Utilization in Eastern Africa

Effect of country, agro-ecological zone, feed and fodder type and interaction between country and feed and fodder type were significant (*p ≤ 0.05*) on overall availability and utilization of feeds and fodder in Kenya and Tanzania (Fig. 11 and Table 1). With exception of concentrates feeds, the other forage resources varied greatly by country and rainfall pattern (Fig. 11). Feeds and fodder availability was not significant (*p ≥ 0.05*) across the two countries for the months of June and December (Fig. 11). However, the mean difference significantly (*p ≤ 0.05*) showed that Tanzania had more feeds and fodder availability and utilization from January to May, while in Kenya from July to November (Fig. 11). The green feeds and fodder resources (as opposed to dry ones) were positively correlated in both the highlands and lowlands of Kenya and Tanzania (Table 3). There was a highly significant (*p ≤ 0.001*) relationship (coefficient of determination, $R^2 \geq 0.75$) between improved (planted) and natural pastures in both the highlands and lowlands in Kenya (Table 3). This implied that an increase in improved fodder resulted in a tandem increase in natural pastures and vice versa.

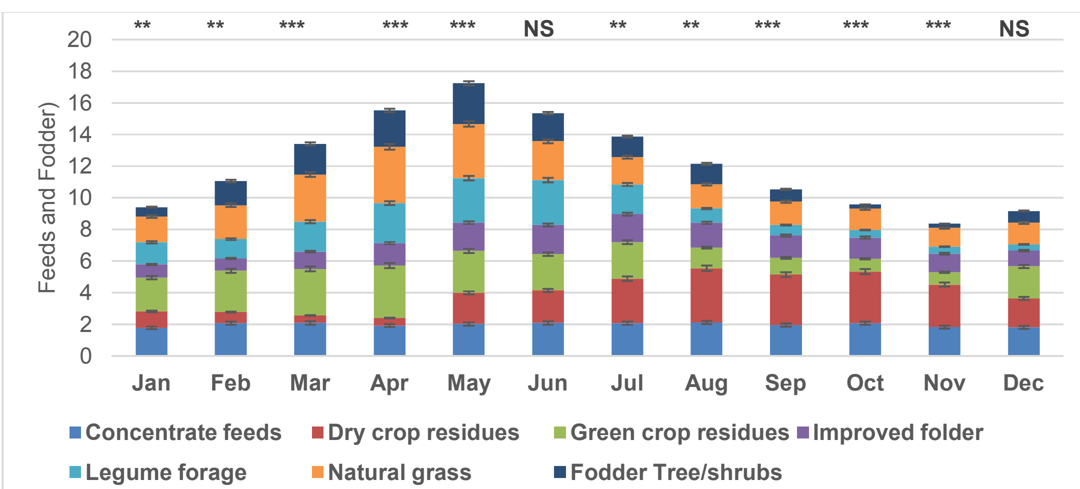

Fig. 10. Overall trend in year-round feeds and fodder availability and utilization (95% CI) in highlands and lowlands of Kenya and Tanzania

*NS=Not Significant; *** Significance level (P≤0.001); ** Significance level (P≤0.01)*

Table 3. Regression equations predicting farmer estimates of feeds and fodder availability in highlands and lowlands areas of Kenya and Tanzania

Agro-Eco zone	Feeds and Fodder (Y)	Feeds and Fodder (X)	Regression Equation	R^2
Kenya Highlands	Improved fodder	Natural grass	y = 1,0237x	0.916
	Improved fodder	Green crop residue	y = 1.4136x	0.599
	Natural grass	Green crop residue	y = 1.4526x	0.617
	Forage legume	Green crop residue	y = 0.5893x	0.665
	Improved fodder	Legume forage	y = 0.4115x	0.739
	Natural grass	Legume forage	y = 0.3984x	0.687
Kenya Lowlands	Concentrate feed	Fodder trees/shrubs	y= 0.4488x	0.824
	Natural grass	Green crop residue	y = 1.3872x	0.582
	Legume forage	Green crop residue	y = 0.7278x	0.687
	Improved fodder	Natural grass	y = 0.9590x	0.760
	Improved fodder	Legume forage	y = 0.5007x	0.742
	Natural grass	Legume forage	y = 0.5186x	0.672
Tanzania Highlands	Green crop residue	Natural grass	y = 0.7154x	0.823
	Natural grass	Fodder trees/shrubs	y = 1.0479x	0.607
Tanzania Lowlands	Natural grass	Green crop residue	y = 0.6888x	0.825
	Legume forage	Fodder trees/shrubs	y = 0.6923x	0.690

This scenario was explained by their dependence on the rainfall pattern (Fig. 2). Similarly, there was highly significant ($p \leq 0.001$) positive relationship ($R^2 \geq 0.60$) between improved fodder and natural pastures with green crop residues, legume forage and fodder trees/shrubs in both the highlands and lowlands in Kenya (Table 3). Results also showed highly significant ($p \leq 0.001$) positive association ($R^2 \geq 0.60$) between natural pastures, green crop residues, forage legumes and fodder trees/shrubs in both highlands and lowlands in Tanzania (Table 3), in response to rainfall variability (Figs. 2 and 3).

4. DISCUSSION

The current study has clearly shown the effect of variations between countries, agro ecologies and agro-ecologies on seasonal changes in specific types of feeds and fodder available and utilized, their sources and degree of year round scarcity. However, as documented by [24], an adequate year round supply of livestock feed is crucial to improving the livelihoods of millions of smallholder dairy farmers across the developing world, where various types of feed resources exist, including fodder shrubs and legumes, pasture grasses, weeds gathered from cropping areas, crop by-products and residues, agro-industrial by-products and purchased concentrates. The quantity of feeds and fodder available and utilized shows seasonal fluctuation with rainfall variability, as similarly reported by [25]. Findings further showed variation in feed and fodder sources, availability and utilization during the dry and rainy season period and their correlation with year round rainfall variability. This agree with many authors who have reported acute shortage of feed supply during the dry season and the available feed during this period is of very poor quality [13]. This seasonal changes in nutrition (feed and fodder availability and utilization) results in low production and reproductive performance, slow growth rate, loss of body condition and increased susceptibility to diseases and parasites as similarly reported by [26]. Smallholder dairy farmers buy concentrates feeds as a baseline feed strategy and to overcome periods of low forage production [1,12,14], evidenced by the inverse relationship with rainfall, improved fodder and natural grass from this study.

Decline in the forage legume fraction affects the overall efficiency of fodder and forage utilization, hence mixed pastures of fodder/grasses and legumes improve voluntary intake, dry matter digestibility, live weight gain and overall milk yield and reproductive performance [4]. Crop residues from dual-purpose crops including maize, rice, wheat, sorghum, finger millet, oilseeds, etc., are by far the most important source of feed, and account for 40-60% of the total dairy cattle feed on a dry matter basis as pointed out by [3,11,12,27]. There was considerable variation in the availability and utilization of crop residues from dual-purpose food crops by type (green or dry) across highlands and lowlands in Eastern Africa. Similar findings were reported by [11], that the availability of feed on a dry matter basis from the above groups of crop residues has varied during the last two decades. Natural pastures, properly utilized, is the largest and cheapest basal feed for dairy cattle and other livestock [28]. However, due to a decline in area under fallow lands, pasture and common lands, the availability of natural grasses across the two countries has declined as shown in this study.

Increasing population pressure on existing arable lands has led to encroachment of the area under common property resources [12]. Therefore, from this study, the quantity (and quality) of natural grasses across the two countries also declined due to over-grazing, and lack of proper maintenance. Hence, the improvement of natural pastures by manipulation of grazing pressure, use of appropriate species (including mixed herds), controlled burning and clearing and control of woody weeds seems to be the basis for better yields. As with all natural pasture improvement, this can only be done effectively where the land and its management can be controlled [29], a scenario not common on smallholder dairy farms in Eastern Africa. Evidenced from this study (Fig. 6), year round feed planning and budgeting, coupled with effective utilization of the available feeds and fodder [14] based on site/region specific seasonal availability trends, appear to be the necessary steps to alleviate the nutritional problems of dairy animals. Different supplementation strategies [2] could be applied depending upon the season, type, accessibility and price of supplementary feeds and fodder [30] in specific sites/regions [31] to overcome seasonality driven dairy cow milk fluctuations in Eastern Africa.

5. CONCLUSION

Seasonal availability and utilization of feeds clearly observed in Kenya and Tanzania could be overcome through strategic increase in shelf life of available feeds and fodder resources, in order to prevent seasonal milk fluctuations. Evaluation of the nutritive value of feeds, especially the dry season feed resources, would be important to enhance their proper utilization. In view of this situation, research should be directed towards the development of alternate feeding system which make better use of region specific local feed resource that are available throughout the year, based on the environment, rainfall pattern and prevailing climatic conditions. The new knowledge gained with this study on feeds and fodder variations in sources and responses to environment factors can be incorporated into a model of optimization of dairy cow feed rations and thereby be one among other tools for optimizing the production economy for the smallholder dairy farmers.

CONFERENCE DISCLAIMER

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DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

ETHICAL APPROVAL

All procedures performed in study involving human and animal participants were in accordance with the ethical standards of the researcher institutional (KALRO and NM-AIST) and/or national agricultural research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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