Characterization of Chemical Composition and Availability of Pastures in Pastoral and Agro-Pastoral Production Systems of Uganda: Tackling Barriers to Enteric Methane Inventorying Using the Tier 2 Approach

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Abstract

In Uganda, there is still a lack of activity data (specifically on animal categories, performance, and feeding systems) that is used as inputs in the Tier 2 approach of estimating methane (CH_4) emissions. This study aimed to characterize the chemical composition and availability of pastures in pastoral and agro-pastoral systems of Uganda. The study was conducted in four districts (Nakasongola, Moroto, Gulu, and Mbarara, representing the Central, Karamoja, Northern, and Western regions, respectively). Pasture samples were collected (from grazing areas in agro-pastoral and pastoral systems) and analyzed for chemical composition. Pasture herbage mass was measured during the dry and wet seasons, and pasture availability during each month of the year was scored by participating farmers using a perceived availability scale from 1 to 10. Pasture botanical composition was also determined. The CP, NDF and ADL compositions of the pastures were similar ($P > 0.05$) across the four study regions (averaging 5.7, 67.8 and 6.0%, respectively). The CP composition tended ($P = 0.058$) to be lower in the pastoral system, while ADL composition was similar ($P > 0.05$) between the pastoral and agro pastoral except for the Northern region where the composition was higher ($P < 0.05$) with the pastoral system. DM yield was similar ($P < 0.05$) between the dry and wet seasons in both the agro-pastoral and pastoral systems (averaging 2.45 and 2.72 t/ha, respectively). However, the fresh yield tended ($P = 0.09$) to be higher during the wet season (for agro pastoral), and was higher ($P < 0.05$) during the wet season (for pastoral). Pasture availability score matched the rainfall pattern of the study areas. The better-quality pasture species (such as Brachiarria and *P. maximum*) were more abundant in the agro-pastoral system and during the wet season and vice versa. In conclusion, although no difference in DM yield was observed, there was a trend for higher CP content for agro-pastoral than pastoral pastures, and presence of better-quality pasture species in the agro-pastoral system, both suggesting that there is a higher likelihood for agro-pastoral systems making a lower contribution to the national enteric CH_4 inventory compared to the pastoral system.

Key words: Pastoral/agro-pastoral cattle, Pasture characterisation, Pasture availability, chemical composition

Introduction

The emission of methane (CH4) by ruminant livestock is a major environmental concern worldwide. Ruminants are major contributors to the global CH4 emissions directly through enteric fermentation and manure management (Herrero et al., 2016). In Uganda, enteric fermentation accounts for over 68% of key CH4 emission source categories (MWE, 2019), with the bulk coming from pastoral and agro-pastoral livestock. According to Uganda's First Biennial Update Report (FBUR) 2019, enteric fermentation contributed about 20% of total national greenhouse gases (GHG) emissions (MWE, 2019). In Uganda's FBUR, the Tier 1 approach was used to estimate enteric CH4 emissions, whereby the default IPCC emission factors of 46 and 31 kg CH4/head/year (for dairy and other cattle, respectively) were applied to the corresponding cattle populations. However, the IPCC (2006) guidelines recommend the use of the Tier 2 approach for source categories that make a significant contribution to a country's GHG inventory, whether in terms of the absolute level of emissions, the trend in emissions or both.

The IPCC Tier 2 approach (2019 refinement) for estimating enteric CH4 emissions requires country specific data on animal characteristics (i.e. identification of animal subcategories, breeds, average body weight, mature body weight, and average daily gain), performance (i.e. milk production, fat content, pregnancy), and feeding systems (i.e. feed intake and digestible energy (DE) as a percentage of gross energy in feed). Compared to the Tier 1 inventory, a Tier 2 inventory reflects a country's specific feeding management practices as well as animal productivity and animal categories (Ibidhi *et al*., 2021). Unfortunately, in Uganda, there is still a lack of appropriate activity data to allow the use of the much-needed Tier 2 approach. Thus, there is a need to generate Uganda-specific activity data (on animal categories, performance, and feeding systems) that is used as inputs in the Tier 2 approach. The objective of this study was therefore to characterize the chemical composition and availability of pastures in pastoral and agro-pastoral systems of Uganda.

Material and methods

Study area

This study was conducted in the pastoral and agro-pastoral areas of Uganda (Nakasongola, Moroto, Gulu, and Mbarara to represent the Central, Karamoja, Northern, and Western regions). Four farms (two from the pastoral county and the other two from the agro-pastoral county) were purposively selected from each selected district. The criteria for selection of the study farms included farm owners' willingness to participate in the study, allow unconditional access to their cattle herd, not to cull the heads of cattle that would be selected for data collection until completion of the data collection exercise and also have access to a crush for restraint and handling of animals during data collection.

Data collection

Collection of feed samples

From each study farm, 10 forage quadrants (0.5 m x 0.5 m) were taken from the major designated grazing field. Pasture sampling was done by walking the major designated grazing field in a "W" shape, and the forage quadrants taken at each of the 5 points of the "W" shape. All the herbage within each quadrant was hand-clipped at about 2 cm above the ground and immediately placed in a pre-weighed plastic bag, sealed, weighed and labelled. A random 50% of the quadrants (i.e. 5 quadrants) was used for chemical composition analysis, while the other 50% was used for forage bulk mass and botanical composition analyses.

Chemical composition analysis

The forages were oven-dried at 60 °C for 48 hours for dry matter (DM) determination. The oven-dried samples were then bulked (a random of 3 and 2 forage quadrants) into two composite samples, and ground through a 1-mm screen. The ground samples were then analyzed for crude protein (CP), ether extract (EE), and Ash according to AOAC (1990), as well as neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) according to van Soest and Robertson (1985). Gross energy (GE) content was determined using a bomb calorimeter (Gallenkamp auto bomb, UK).

Forage mass estimation

The plot harvest technique (Sharrow, 1984) commonly used to measure phytomass in range and pasture studies was used, and the weights of the quadrants for forage mass and botanical composition analyses were extrapolated to the "per hectare" basis.

Forage botanical composition analysis

After weighing the quadrants for forage mass and botanical composition analyses, the herbage for each quadrant was separated by species with the participation of the farmers. Botanical composition was then determined on both dry and wet-weight basis.

Forage availability calendars

Feed availability calendars were developed using participatory methods. For each selected county, two people per study farm were constituted into a group of key resource persons. Strictly, only the key persons involved in the daily feeding of the cattle were selected. Through open group discussions and by way of consensus, the groups were guided to develop forage availability calendars for their respective counties. The groups were asked to assign feed availability scores (from 1 to 10) to each month of the year, and also to identify the most important forage species by month.

Statistical data analysis:

The chemical composition as well as forage mass and botanical composition data were analysed using the PROC MIXED procedure of SAS (2003) according to the following model:

$Y_{ij} = \mu + S_i + fm_{j(i)} + e_{ij}$

Where: Y_{ij} = the observation (DM, CP, NDF, ADF, ADL, Ash or GE); μ = overall mean effect; S_i = fixed effect of the season (dry or wet); $fm_{j(i)}$ = random effect of the study farm (sources of samples); and e_{ij} = effect of the residual error.

Results

Chemical composition

Table 1 summarizes the chemical composition of the natural pastures used in agro-pastoral and pastoral production systems of Uganda. The chemical composition was similar ($P > 0.05$) across the four geographical regions. The CP, NDF, ADF, ADL and ash compositions of the pastures averaged 5.7, 67.8, 37.5, 6.0 and 9.6%, respectively. The NDF and ash compositions of the pastures did not differ ($P > 0.05$) between the pastoral and agro-pastoral systems, and averaged 67.8 and 9.6%, respectively. There was a tendency for higher ($P = 0.058$) CP composition with the agro-pastoral system. There was no significant interaction effect ($P > 0.05$) between region and production system for CP, NDF and ash compositions. For ADF and ADL, the compositions were similar ($P > 0.05$) between the pastoral and agro-pastoral systems except for the Northern region where the compositions were higher ($P < 0.05$) with the pastoral system (Region × System interaction, $P < 0.05$).

Table 1: Effect of geographical region and production system on chemical composition of natural pastures

Region (R)	Central		Karamoja		Northern		Western			P-value		
System (S)	**Agro**	**Past**	**Agro**	**Past**	**Agro**	**Past**	**Agro**	**Past**	**SE**	**R**	**S**	**R x S**
CP, % DM	6.2	5.2	5.5	4.6	9.1	4.6	5.5	5.0	1.63	0.535	0.058	0.323
NDF, % DM	68.8	69.0	64.0	64.0	61.3	72.5	71.0	72.0	4.55	0.392	0.168	0.096
ADF, % DM	36.8[b]	38.5[ab]	37.0[bc]	35.0[bc]	32.0[c]	44.5[a]	37.0[b]	39.0[b]	3.05	0.845	0.030	0.003
ADL, %DM	5.0[bc]	6.0[bc]	7.0[ab]	6.0[bc]	3.25[c]	10.0[a]	5.0[bc]	6.0[bc]	1.61	0.650	0.030	0.006
Ash, % DM	9.0	9.4	11.4	11.1	10.0	9.2	8.9	7.9	0.99	0.070	0.400	0.700

Agro = Agro-pastoral system; Past = Pastoral system

Pasture herbage mass and availability

The pasture herbage mass is presented in Table 2. The interaction between season and production system was not significant (P > 0.05); thus, only tests on season effects are presented. The fresh yield tended (P = 0.09) to be higher during the wet season (for the agro-pastoral system) and was higher (P < 0.05) during the wet season (for the pastoral system). For DM yield, the dry and wet seasons did not differ (P > 0.05) in both the agro-pastoral and pastoral systems, and averaged 2.45 and 2.72 t/ha, respectively. The DM content was higher (P < 0.05) during the dry season in both the agro-pastoral and pastoral systems.

Table 2: DM yield of natural pastures during the dry and wet seasons

	Dry season	Wet season	SE	P-value
Agro-pastoral system				
Fresh yield, t/ha	4.65	7.28	1.10	0.090
DM yield, t/ha	2.75	2.15	0.37	0.252
DM, %	57.6[a]	34.4[b]	4.48	0.003
Pastoral system				
Fresh yield, t/ha	3.96[b]	7.28[a]	0.71	0.003
DM yield, t/ha	2.41	3.03	0.42	0.300
DM, %	59.2[a]	42.0[b]	3.70	<0.0001

The participating farmers were asked to score pasture availability during each month of the year using a perceived availability scale from 1 to 10 (1 = very low pasture availability, 10 = very high pasture availability). The pasture availability scores are summarized in Figure 1.

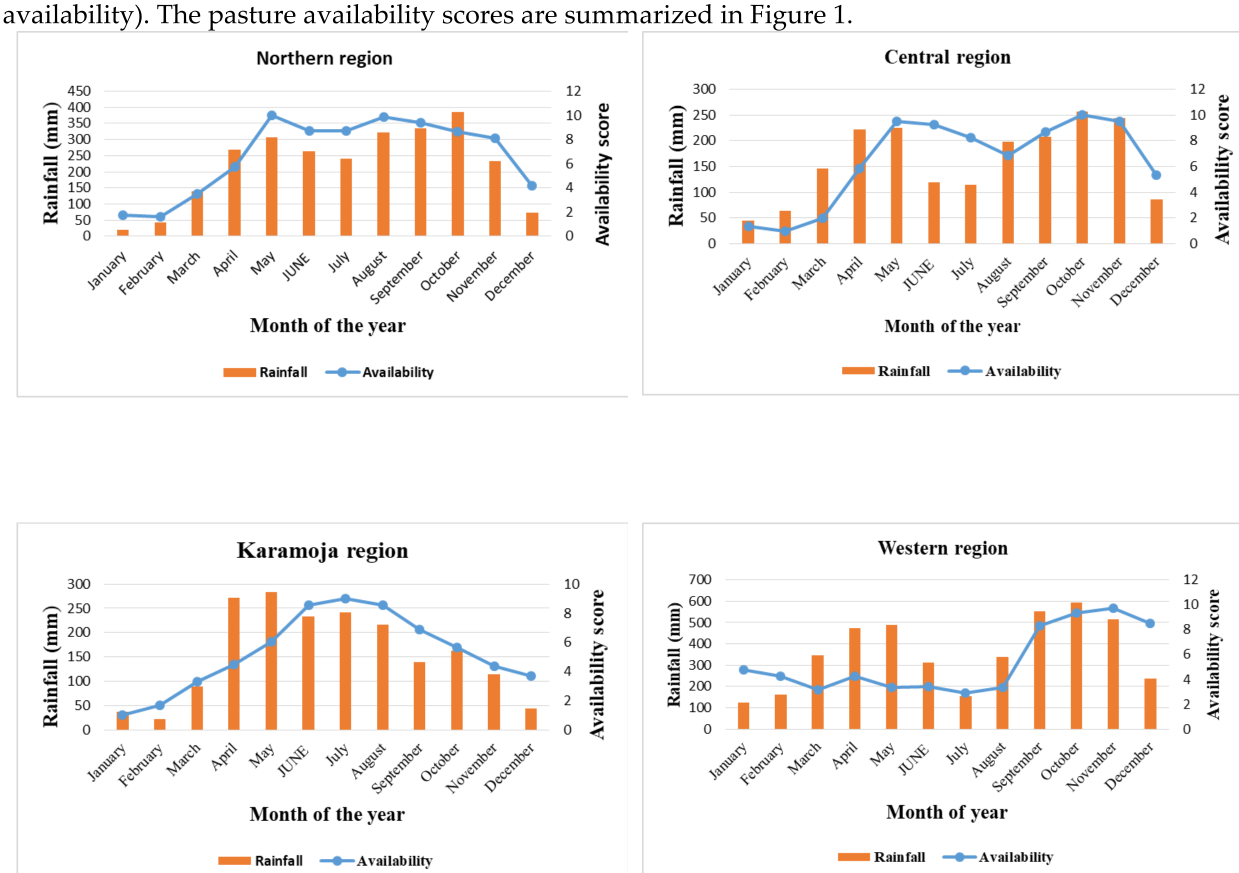

Figure 1: Farmer's pasture availability score in the study area during each month of the year
Rainfall figures used are for rainfall amounts received throughout the year 2019

Pasture botanical composition

Table 3 summarizes the botanical composition of the natural pastures used in agro-pastoral and pastoral production systems of Uganda. In the central region, pastures in the agro-pastoral system were dominated by Brachiarria species (38.5%) and *Panicum maximum* (20%) during the wet season, while *Cymbopogon afronandus* (50%) and *Hyperrhenia rufa* (18.5%) dominated during the dry season. For the pastoral system, *Digitaria abyssinica* (45.2%) and *Cymbopogon afronandus* (33.5%) dominated during the wet season, while *Imperata cylindrical* (76.7%) and *Hyperrhenia rufa* (23.3%) were the only available species during the dry season.

In the Karamoja sub-region, pastures in the agro-pastoral areas were dominated by a grass species locally known as *Ararabei* (42.1%) and *Panicum maximum* (39.4%) during the wet season, while *Setaria sphacelata* (49.7%) and *Cynodon dactylon* (30.5%) dominated during the dry season. The same species dominated pastures in the pastoral system during both the wet and dry seasons.

In the Northern region, pastures in the agro-pastoral system were dominated by Brachiarria species (32.6%) and *Themeda triandra* (21.6%) during the wet season, while *Cynodon dactylon* (56.9%) and *Panicum maximum* (35.3%) dominated during the dry season. For the pastoral system, *Hyperrhenia rufa* (37.0%) and *Imperata cylindrical* (30.0%) dominated during the wet season, while *Imperata cylindrical* (52.6%) and *Cynodon dactylon* (47.4%) were the only available species during the dry season.

In the Western region, pastures in the agro-pastoral system were dominated by *Hyperrhenia rufa* (66.0%) and Brachiarria species (18.0%) during the wet season, while *Sporobolus pyramidalis* (53.8%), *Hyperrhenia rufa* and Brachiarria species (23.1%) were the only available species during the dry season. For the pastoral system, *Hyperrhenia rufa* (66.0%) and Brachiarria species (18.0%) dominated during the wet season, while *Sporobolus pyramidalis* (61.2%) and *Themeda triandra* (21.1%) dominated during the dry season.

Table 3: Botanical composition (%) of natural pastures in pastoral and agro-pastoral cattle production systems during the wet and dry season

Region	Central[1]		Karamoja[2]		Northern[3]		Western[4]	
Season	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
Agro-pastoral								
Brachiarria species	-	38.5	-	-	20.3	32.6	23.1	18.0
Chloris gayana	-	5.0	-	-	29.8	-	-	-
Cymbopogon afronandus	50.0	10.5	-	-	-	-	-	-
Hyperrhenia rufa	18.5	9.5	-	-	-	-	23.1	66.0
Panicum maximum	14.0	20.0	-	39.4	35.3	20.9	-	-
Sporobolus pyramidalis	-	-	-	-	-	-	53.8	-
Themeda triandra	-	-	-	-	-	21.6	-	-
Cynodon dactylon	17.5	-	30.5	-	56.9	-	-	-
Digitaria abyssinica	-	-	19.8	-	12.9	-	-	-
Setaria sphacelata	-	-	49.7	-	-	-	-	-
Ararabei	-	-	-	42.1	-	-	-	-
Bidens pilosa	-	-	-	-	-	0.7	-	-
Achichilu	-	-	-	-	-	10.2	-	-

Desmodium uncinatum	-	-	-	-	-	10.2	-	-
Ageratum conyzoides	-	-	-	-	-	16.5	-	-
Herbaceous weeds	-	-	-	-	-	26.4	-	-
Cyperus rotundas	-	-	-	-	9.6	-	-	-
Others#	-	17.0	-	18.5	-	3.45	-	16.0
Pastoral								
Brachiarria species	-	-	-	-	-	-	17.6	18.0
Cymbopogon afronandus	-	33.5	-	-	-	-	-	-
Hyperrhenia rufa	23.3	21.3	-	-	-	37.0	-	66.0
Panicum maximum	-	-	-	39.4	-	19.0	-	-
Sporobolus pyramidalis	-	-	-	-	-	-	61.3	-
Setaria sphacelata	-	-	49.7	-	-	-	-	-
Imperata cylindrica	76.7	-	-	-	52.6	30.0	-	-
Themeda triandra	-	-	-	-	-	-	21.1	-
Cynodon dactylon	-	-	30.5	-	47.4	14.0	-	-
Ararabei	-	-	-	42.1	-	-	-	-
Digitaria abyssinica	-	45.2	19.8	-	-	-	-	-
Others#	-	-	-	18.5	-	-	-	16.0

[1] Nakasongola district; [2] Moroto district; 3Greater Gulu area; 4Greater Mbarara area
#Combination of different species that could not be weighed individually

Discussion

Chemical composition

The low CP and high NDF compositions observed in this study corroborate previous studies that indicated low quality of the natural pasture in pastoral and agro-pastoral systems. The CP and NDF values reported in this study are within the range of the values reported by Johannson *et al*. (2013) for pastures in agro-pastoral production systems of Western Uganda. The tendency of agro-pastoral pastures (P=0.058) to have higher CP content, was partly attributed to poor pasture management under pastoral grazing systems, which is a key distinguishing feature of communally grazed pastures. The relatively high DM content reflected across the two systems in the dry season is in agreement with Johannson *et al*. (2013) who noted that in the semi-arid areas of Uganda, the grasses matured quickly and their nutritional value consequently decreased. DM content was higher in the dry season for both pastoral and agro-pastoral systems, ranging up to 50% in the dry season and 30%-40% in the wet season. The higher percentage in the dry season could be a result of the pastures advancement in their maturation and also high temperatures which are a common factor in the tropics, increasing lignification.

Pasture herbage mass and availability

The average DM yield values observed in this study (ranging from 2.15 to 3.03 t/ha) were in agreement with Roschinsky *et al*. (2011), who noted DM yield of 2 t/ha for the medium and high herbage yield. However, the herbage yield observed by Roschinsky *et al*. (2011) for the low yield pastures (1.88 - 1.99 t/ha) was lower compared to the values observed in this study. This could be attributable to the sampling procedures used. For pasture availability, the scores reported in this study matched the bimodal rainfall pattern of the study areas (March-May and September-November, being the rainy months). This was in agreement with Egeru *et al*. (2015) and Tibezinda *et al.* (2016) who also noted that the yield and nutritional quality of pastures in the tropics fluctuated with seasons, with the wet and dry seasons being characterized by abundant and low pasture availability, respectively.

Botanical composition

For the western region were Brachiarria species, *H. rufa*, *P. maximum*, *S. pyramidalis* and *T. triandra*. This observation was in agreement with Tibezinda *et al.* (2016) who also reported the same pasture species in Western Uganda. Some pasture species (such as *C. afronandus, H. rufa, I. cylindrica)* known to be of poor quality dominated in the dry season and were more evident in the pastoral production systems. This could be evidence of inappropriate pasture management and grazing systems, which lead to the replacement of good quality pasture species by poor quality species. The livestock selectively graze the palatable species, leaving the unpalatable species to dominate the grazing lands. It could also be noted that highly palatable and productive perennial pasture species can be replaced by unpalatable, low-quality annual species with associated loss of soil fertility (Atuhaire *et al*., 2018), which leads to further loss of good quality pastures.

Conclusion

Although no difference in DM yield was observed, there was a trend for higher CP content for agro-pastoral than pastoral pastures, and presence of better quality pasture species in the agro-pastoral system, both suggesting that there is a higher likelihood for agro-pastoral systems making a lower contribution to the national enteric CH_4 inventory compared to the pastoral system.

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