ENTERIC METHANE EMISSION OF CATTLE GRAZING RANGELAND ECOSYSTEMS OF SOUTH EASTERN KENYA

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ABSTRACT
Large herds of ruminant cattle grazing degraded rangeland pastures in Kenya are associated with enteric methane (CH₄) emission, contributing to global warming potential (GWP). Yet the CH₄ emissions and associated GWP are hardly quantified to inform emerging threats to sustainable use of grassland ecosystems. This study estimated enteric CH₄ emission and the GWP from cattle grazing in Makueni County, a rangeland ecosystem in South Eastern Kenya. Estimation applied the intercontinental panel of climate change (IPCC) Tier I and Tier II approaches with Tier II incorporating seasonal differences in feed quality, dry matter intake and animal performance. Animal activity and production data for the year 2019 was obtained from the County livestock inventory reports while feed quality data was sourced from recently published literature. The resultant emission factors (EFs) (kg/year) were 47.1 for females >2 years; 27.2 for heifers 1-2 years; 46.5 for males > 2years; 32.9 for young males 1-2years; and 17.2 for calves <1year. These EFs were higher (7.7 to 14.9%) than those of Tier I for females >2years, young males 1-2years and for calves <1yr but lower (5.4 to 12.3%) for males > 2years and for heifers 1-2 years. The Tier II estimates were 4.4% higher than the estimates with Tier I approach for both total estimated enteric CH₄ emission (9,279,526.80 vs 8,889,997 kg CH₄/year) and GWP (259,826,750.4 vs. 248,919,916 kg CO₂ eq.). The results reflect uncertainty of EFs generated from Tier I approach, which necessitates development of region-specific EFs using data from local breeds of animals and feed resources. This will improve certainties of the enteric CH₄ emissions and accuracy in reporting the Nationally Determined Contributions (NDCs)

Key words: Rangelands, emission factor, dry matter intake, dry matter digestibility, feed quality

INTRODUCTION
Ruminant livestock account for most of methane (CH₄) emission that is human activity contributed. Of the global total enteric CH₄ emissions, livestock activities are estimated to account for 35% of the total emissions (Azizi et al., 2017). The global warming potential (GWP) due to CH₄ is 28 to 34 times per molecule greater over 100 years than carbon dioxide, and it has a lifetime of 9-15 years in the atmosphere (IPCC, 2013 ). The emission of CH₄ by ruminant animals comes from enteric fermentation of feeds in the rumen and from hindgut to a small extent (Haque, 2018; Yan et al., 2010). This is aided by microbes in the rumen (carbohydrate fermenters) that contribute to the breakdown of fibrous feeds through anaerobic fermentation to yield energy and products for incorporation and growth of microbial cells. The by products are volatile fatty acids (VFA), free hydrogen (H₂) and carbon dioxide (CO₂) molecules. Of these products, the free hydrogen molecule is reduced using CO₂ with the help of methanogenic archaea to CH₄

CO₂ +4H₂→CH₄+2H₂O (Moss et al., 2000)
The VFA constitutes the major source of energy for the ruminant. However, the enteric CH$_4$ production represents a loss of 5-10% of ruminant gross energy (GE) intake (Johnson and Johnson 1995; Madsen et al., 2010), a loss of dietary nutrients which could have been directed to production of meat and milk (Liu et al., 2017). The emissions of CH$_4$ from ruminants vary from one region to another (Goopy et al., 2018; Ndung’u et al., 2019). Further, these emissions from livestock vary with the animal class, animal live body weight, dry matter intake, quality and quantity of feed consumed, type of volatile fatty acid produced in the rumen and animal energy expenditure (Hegarty et al., 2010; Johnson and Johnson, 1995; Shrestha et al., 2013; Steinfeld et al., 2006). Emission factors (EFs), the average emission rate of a given source, relative to units of activity or processes (Mareddy, 2017), are important in estimating CH$_4$ emission levels in any production system. The IPCC guidelines provide three-level approaches (Tier I to III) for deriving the EFs and they advance in levels of complexity. Tier I uses default values provided in the literature, Tier II accounts for animal class, diet and productivity differences and animal activity while Tier III is a country-specific methodology and parameter estimates. Tier I is the least precise but remains a predominantly used approach in African countries where a lack of technical and financial capacity is a barrier to upgrading the method.

Kenya is committed to developing and implementing strategies that improve livestock productivity while reducing greenhouse emissions. The largest proportion of greenhouse gas emissions that is of agricultural origin is by ruminant animals from both fibre digestion and from the manure they excrete to the environment (Moss et al., 2000). This is particularly an issue where cattle graze the rangeland pastures. This is the case in Kenya, where Tier I approach remains the method of estimating GHG from livestock, yet the method is known to yield high uncertainty levels. A move to Tier II is therefore desirable but the availability of farm-level animal and feed data on productivity and activity has limited the adoption of this approach.

For the rangelands of Makueni County in south eastern region of the country, large herds of cattle graze degraded poor pastures. The large cattle herds though support livelihoods and coping with drought risk, are likely to contribute substantial volumes of enteric CH$_4$ emissions and to Global Warming Potential. In Makueni County, some data on the livestock production has been collected over time and together with feed quality and animal performance that may be valuable for estimating enteric CH$_4$ emission for the cattle grazing the rangelands. This study used IPCC Tier I and II approaches to estimate EFs and GWP estimates for cattle grazing the rangelands of Makueni County. This approach would improve the certainties of enteric CH$_4$ emissions and accuracy in reporting the Nationally Determined Contribution (NDC) that each country has to report to the UN periodically.

**MATERIALS AND METHODS**

**Study site**
Makueni County, the study site, lies between Latitude 1° 35′ and 32 00′ South and Longitude 37° 10′ and 38° 30′ East. It is a rangeland in the south eastern part of Kenya, with average temperature being 15°C to 26°C and annual rainfall of 250mm to 400mm in the lower regions and 800mm to 900mm in higher regions. The dominant vegetation are indigenous grasses (Eragrostis Superba, Cenchrus Ciliaris, Enteropogon Macrosthachyus among others) and shrubs, being the basal diet for the ruminant livestock, which includes indigenous cattle - zebu, Boran and their crosses, sheep and goats.

**Estimation of enteric methane emission**
The study estimated the EFs using both IPCC Tier I and II approaches in order to compare the uncertainties. Data pertaining to cattle population, animal classes and their performance and animal activity was obtained from Makueni County livestock inventory reports for the year 2019 and published information from Arid and Rangelands Research Institute (ARLRI) located in the County. Additional data on feed quality in the County was sourced from recently published literature.
Estimation of enteric CH\textsubscript{4} applying IPCC Tier I approach was a stepwise process. Firstly, a description of cattle population of 253,175 heads (Table I) with a larger proportion (34\%) being mature female>2 years, calves < 1 year (24.3\%) and males > 2 years (23.8\%). Secondly, the livestock numbers were multiplied by the default EFs (Table I) of the IPCC2006 guidelines to derive the net enteric CH\textsubscript{4} emissions. This was implemented according to the description of Gibbs \textit{et al.} (2002):

\[ CH_4 \text{ Emissions} = MEF_t \times N_t \] (i)

where,

\[ CH_4 \text{ Emissions} = \text{Total } CH_4 \text{ emission from enteric fermentation per animal class} \]

\[ MEF_t = CH_4 \text{ emission factor per class of livestock defined in IPCC2006 guidelines} \]

\[ N_t = \text{Number of head of livestock species per category or class.} \]

The CH\textsubscript{4} emission levels obtained were then multiplied by CH\textsubscript{4} GWP of 28 (IPCC, 2013) to estimate the contribution to the greenhouse effect in CO\textsubscript{2} equivalent.

### TABLE I - THE MAKUENI COUNTY CATTLE POPULATION BY ANIMAL CLASSES AND IPCC2006 EMISSION FACTORS (EF) USED FOR TIER I APPROACH

<table>
<thead>
<tr>
<th>Animal classes</th>
<th>EF (IPCC2006)</th>
<th>Cattle Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Females &gt;2yrs</td>
<td>41</td>
<td>87,803</td>
</tr>
<tr>
<td>Males &gt;2yrs</td>
<td>49</td>
<td>60,304</td>
</tr>
<tr>
<td>Heifer (1-2yrs)</td>
<td>31</td>
<td>26,617</td>
</tr>
<tr>
<td>Males (1-2yrs)</td>
<td>31</td>
<td>16,989</td>
</tr>
<tr>
<td>Calves &lt;1yr</td>
<td>16</td>
<td>61,462</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>253,175</td>
</tr>
</tbody>
</table>

Application of IPCC Tier II approach involved use of detailed data on animal classes, animal performance, feed quality, dry matter intake and animal energy expenditure. The animals were grouped into five classes based on age and sex: females (>2yrs), males (> 2years), heifer (1-2yrs), young male (1-2yrs) and calves (<1 year). Animal data on live weight and live weight gain, milk production, lactation status and estimated distance travelled by the animals from grazing fields to watering points and back to holding bomas were obtained from the County livestock inventory. The computational approach of Goopy \textit{et al.}, (2018) was followed for determining feed and animal variables needed to estimate the EF.

#### Determination of feed quality

Wet season mixed feed quality (total N and ADF) were those determined in wet chemistry procedure according to AOAC methods (AOAC method no.988.05 and 6.5.1, respectively). A factor of 6.25 was used to convert N to CP.

The nutritive value of average feed available for the animals in the County varied between the seasons with animals having access to better feed during the wet than during the dry season (Table II). Weight gain by the animals was season-dependent with animals gaining higher weight gains during the wet season than in the dry season.

### TABLE II - FEED NUTRITIVE COMPOSITION AND DRY MATTER DIGESTIBILITY OF DIETS GRAZED BY ANIMALS IN MAKUENI COUNTY FOR BOTH THE DRY AND WET SEASONS.

<table>
<thead>
<tr>
<th>Season</th>
<th>Feedstuff</th>
<th>DM</th>
<th>OM</th>
<th>%DMD</th>
<th>ADF</th>
<th>NDF</th>
<th>CP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry</td>
<td>Mixed range standing hay\textsuperscript{1}</td>
<td>93.7</td>
<td>-</td>
<td>49.07</td>
<td>44.7</td>
<td>58.3</td>
<td>5.54</td>
</tr>
<tr>
<td>wet</td>
<td>Mixed range grasses</td>
<td>97.4</td>
<td>91.85</td>
<td>53.36</td>
<td>40.57</td>
<td>70.98</td>
<td>6.08</td>
</tr>
</tbody>
</table>

\textsuperscript{1}Korir \textit{et al.}, (2020).
The dry season feed nutritional quality was obtained from published sources (Korir et al., 2020) while dry matter digestibility (DMD) was estimated using the equation of Oddy et al. (1983):

\[ \text{DMD} = 83.58 - 0.824 \times \text{ADF} + 2.626 \times \text{N} \]

\[ \text{DMD} = 83.58 - 0.824 \times \text{ADF} + 2.626 \times \text{N} \] (ii)

where,
ADF = Acid Detergent fibre, N = Nitrogen

Estimation of cattle energy expenditure
Total energy expenditure for each class was calculated based on maintenance energy requirements, distance walked and lactation status using equations previously used in several publications: CSIRO (2007), Goopy et al. (2018) and Ndung’u et al. (2019).

The energy required for maintenance (MER) was estimated from the expression:

\[ \text{MER}_M = K \times S \times M \times (0.26 + MLW^{0.675}) \times \exp(-0.03 \times A) / (0.02 \times M/D + 0.5) \]

\[ \text{MER}_M = K \times S \times M \times (0.26 + MLW^{0.675}) \times \exp(-0.03 \times A) / (0.02 \times M/D + 0.5) \] (iii)

where:
K = 1.3 (the intermediate value for Bos taurus and Bos indicus), S = 1 for females and 1.15 for males, M = 1 (0% milk in diet of zebu cattle), MLW = mean live weight, A = age in years and M/D = Metabolizable energy content (ME MJ/DM kg) which was calculated as:

\[ M/D = 0.172 \times \text{DMD} - 1.707 \]

\[ M/D = 0.172 \times \text{DMD} - 1.707 \] (iv)

where:
DMD = % DM digestibility of feed.

i. Energy requirement for growth
All animal classes except for calves were found to gain an average of 200 g/day during the wet season and an averagely of 50 g/day in the dry season. For the lactating animals, an average milk yield of 2.5-3.0 L/day was used inclusive of what the calf sucked (1 litre). Calves on milk were assumed to gain an average of 50 g/day across all the seasons.

\[ \text{MER}_G = (ADWG \times 0.92 \times \text{EC} \times (M/D) + 0.04 \times \text{M/D}) \]

\[ \text{MER}_G = (ADWG \times 0.92 \times \text{EC} \times (M/D) + 0.04 \times \text{M/D}) \] (v)

where:
ADWG or ADWL (kg) = average daily weight gains or loss; EC (MJ/kg) = energy content of the tissue taken as 18 MJ/kg

ii. Energy requirement for lactation
The energy required for lactation, was derived from daily milk (litres) consumption by pre-ruminant calves (calves between 0-3.5 months) using calves live weight and average calves’ growth rates according to Radostits and Bell (1970) equation assuming the calves’ growth rate (LWG) to be 50 g/day:

\[ \text{Daily milk consumption} = \text{LW calf} \times 0.107 + 0.143 \]

\[ \text{Daily milk consumption} = \text{LW calf} \times 0.107 + 0.143 \] (vii)

Where:
LW calf = live weight of calf in kg, 0.107 = Energy required by calves for maintenance.

Daily Milk Yield (DMY) was calculated as:

\[ \text{DMY} = \text{Mean daily milk production} \times \text{N of days in milk} \]

\[ \text{DMY} = \text{Mean daily milk production} \times \text{N of days in milk} \] (viii)

The computation assumed 70% of mature female herd to be lactating. Energy requirements for lactation were calculated using the equation given in NRODR (CSIRO, 2007) as:

\[ \text{MERL} = \text{DMY} \times \text{EC} / (0.02 \times \text{M/D}) + 0.04 \]

\[ \text{MERL} = \text{DMY} \times \text{EC} / (0.02 \times \text{M/D}) + 0.04 \] (ix)
where:

$DMY (kg) = \text{daily milk yield}$, $ECM (MJ/kg) = \text{energy content of milk (taken as 3.054 MJ/kg (CSIRO, 2007) due to a lack of data regarding milk constituents)}$, $M/D = \text{Metabolizable energy content.}$

The energy requirement for locomotion assumed energy expended for locomotion as an estimate of:

$$MER_{(MJ/day)} = DIST (km) + MLW (kg) + 0.0026 (MJ)$$

Where:

$DIST = \text{average distance travelled (km)} - \text{average estimated distance from grazing field to watering point; }$

$MLW = \text{mean LW and 0.0026 is the energy expended (MJ/(kg LW/km).}$

The daily total energy expenditure ($MER_{\text{TOTAL}}$) for each animal class in each Sub County and the season was then calculated using the formulas below.

$$MER_{\text{TOTAL}} (MJ/day) = MER_M + MER_G + MER_R + MER_T$$

(Females) …………..(xi)

$$MER_{\text{TOTAL}} (MJ/day) = MER_M + MER_G + MER_L + MER_T$$

(Males, heifers and young males) ……… (xii)

$$MER_{\text{TOTAL}} (MJ/day) = MER_M + MER_G/L$$

(Calves) ……………………………….. (xiii)

Calculation of emission factors (EF)

In estimating the emission factors (EFs), dry matter intake (DMI) was calculated as a function of $MER_{\text{TOTAL}}$ and seasonal DMD of feed using the formulae by Goopy et al., 2018 below:

$$DMI (kg) = MER_{\text{TOTAL}} (MJ/day)/GE (MJ/day) * DMD/100))0.81$$

………………… (xiv)

where:

$MER_{\text{TOTAL}} = \text{The sum of all animal energy requirements (maintenance, locomotion, ploughing, growth, lactation, etc.); }$

$GE = \text{gross energy of the diet assumed to be 18.1MJ/kg DM, mid-range value for tissue and 0.81 is the factor to convert ME to digestible energy NRODR (CSIRO, 2007) }$

$DMD = \% \text{ Dry matter digestibility of the feed}$

The estimated DMI was used to calculate daily CH$_4$ production (DMP) using the equation developed by Charmley et al. (2016) as follows:

$$DMP (g) = 20.7 * DMI (kg/day) ................ (xv)$$

Mean annual CH$_4$ production per animal (emission factor: EF) for each class of animal in the County was calculated as:

$$EF (kg \ CH_4 \ per \ head \ per \ year) = \frac{DMP (dry \ season *91.25 \ days)+(DMP (Wet \ season *273.75 \ days))/(1000)}.........(xvi)$$

Statistical analysis

Data on EFs were analysed using R (R Core Team, 2021), ANOVA was run to assess the within animal class variations. A linear model was then fitted with County and animal class as fixed factors to estimate least square means. The differences between means were compared with Tukey’s method at p< 0.05.

RESULTS

Animal energy expenditure

Maintenance energy requirements, which was mainly a function of live weight, accounted for the highest amount of energy expenditure for all animal classes and in both seasons (Table III). The lowest expenditure was on locomotion. Total energy expenditure was higher during the wet season compared to the dry season for all animal classes except for calves, corresponding to higher weight gains during the wet season when the quality of the diet was better.
TABLE III- MAINTENANCE ENERGY (MER_M), LACTATION ENERGY (MER_L), GROWTH (LOSS OR GAIN) ENERGY (MER_L/G), MOVEMENTS’ ENERGY (MER_T) AND TOTAL ENERGY REQUIREMENTS (MER_TOTAL) FOR DIFFERENT CLASSES OF ANIMAL DURING THE WET AND DRY SEASON IN MAKUENI COUNTY

<table>
<thead>
<tr>
<th>Animal class</th>
<th>MER_M ±SE</th>
<th>MER_L ±SE</th>
<th>MER_L/G</th>
<th>MER_T ±SE</th>
<th>MER_TOTAL ±SE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wet season</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female &gt;2yrs</td>
<td>29.30±0.994</td>
<td>12.42±1.000</td>
<td>10.31</td>
<td>1.29±0.319</td>
<td>53.32±1.774</td>
</tr>
<tr>
<td>Males &gt;2yrs</td>
<td>39.46±0.994</td>
<td>-</td>
<td>10.31</td>
<td>1.59±0.319</td>
<td>51.36±1.774</td>
</tr>
<tr>
<td>Females (1-2 yrs)</td>
<td>21.81±0.994</td>
<td>-</td>
<td>10.31</td>
<td>0.84±0.319</td>
<td>32.96±1.774</td>
</tr>
<tr>
<td>Young males (1-2yrs)</td>
<td>27.29±0.994</td>
<td>-</td>
<td>10.31</td>
<td>0.94±0.319</td>
<td>38.54±1.774</td>
</tr>
<tr>
<td>Calves&lt;1yr</td>
<td>14.83±0.994</td>
<td>-</td>
<td>2.58</td>
<td>-</td>
<td>17.4±1.774</td>
</tr>
<tr>
<td><strong>Dry season</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female &gt;2yrs</td>
<td>28.70±0.994</td>
<td>11.99±1.000</td>
<td>2.86</td>
<td>1.22±0.319</td>
<td>44.76±1.774</td>
</tr>
<tr>
<td>Males &gt;2yrs</td>
<td>38.98±0.994</td>
<td>-</td>
<td>2.86</td>
<td>1.52±0.319</td>
<td>43.36±1.774</td>
</tr>
<tr>
<td>Females (1-2 yrs)</td>
<td>20.84±0.994</td>
<td>-</td>
<td>2.86</td>
<td>0.77±0.319</td>
<td>24.47±1.774</td>
</tr>
<tr>
<td>Young males (1-2yrs)</td>
<td>26.28±0.994</td>
<td>-</td>
<td>2.86</td>
<td>0.86±0.319</td>
<td>30.00±1.774</td>
</tr>
<tr>
<td>Calves&lt;1yr</td>
<td>13.64±0.994</td>
<td>-</td>
<td>2.86</td>
<td>-</td>
<td>16.5±1.774</td>
</tr>
</tbody>
</table>

**Enteric methane emission estimates**

Table IV presents the enteric CH₄ EFs estimated with Tier I and Tier II for cattle population grazing the Makueni County rangelands. The EFs generated with Tier II were higher (7.7 to 14.9%) than those generated with Tier I for females>2yrs, young males 1-2yrs and for calves <1yr but lower (5.4 to 12.3%) for males>2yrs and for heifers 1-2 yrs. The EFs were closely associated with the animal body weights. The cattle in Makueni were on average heavier than the reference typical unspecified African cattle defined in the IPCC for Tier I.

**TABLE IV- ENTERIC METHANE EMISSION FACTORS (KG CH₄/HEAD/YEAR) AND MEAN LIVE WEIGHT (KG) FOR DIFFERENT CLASSES OF CATTLE ESTIMATED WITH IPCC TIER I AND TIER II FOR CATTLE GRAZING MAKUENI COUNTY RANGELANDS**

<table>
<thead>
<tr>
<th>Cattle class</th>
<th>Tier I EF estimates</th>
<th>Tier II EF estimates</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Live weight (kg)</td>
<td>Emission Factor</td>
</tr>
<tr>
<td>Females &gt;2yrs</td>
<td>200</td>
<td>41</td>
</tr>
<tr>
<td>Males &gt;2yrs</td>
<td>275</td>
<td>49</td>
</tr>
<tr>
<td>Heifer(1-2yrs)</td>
<td>-</td>
<td>31</td>
</tr>
<tr>
<td>Yong males(1-2yrs)</td>
<td>-</td>
<td>31</td>
</tr>
<tr>
<td>Calves&lt;1yr</td>
<td>75</td>
<td>16</td>
</tr>
</tbody>
</table>
TABLE V(TOTAL ENTERIC METHANE EMISSIONS AND GWP ESTIMATES WITH TIER I AND TIER II APPROACHES FOR CATTLE GRAZING MAKUENI COUNTY RANGELANDS

<table>
<thead>
<tr>
<th>Cattle class</th>
<th>Tier I total emissions (kg CH₄/year)</th>
<th>Tier II total emission (kg CH₄/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Females &gt;2yrs</td>
<td>3,599,923</td>
<td>4,135,521.30</td>
</tr>
<tr>
<td>Males &gt;2yrs</td>
<td>2,954,896</td>
<td>2,804,136.00</td>
</tr>
<tr>
<td>Heifer (1-2yrs)</td>
<td>825,127</td>
<td>723,982.40</td>
</tr>
<tr>
<td>Young males (1-2yrs)</td>
<td>526,659</td>
<td>558,741</td>
</tr>
<tr>
<td>Calves &lt;1yr</td>
<td>983,392</td>
<td>1,057,146.40</td>
</tr>
<tr>
<td>Total (kg CH₄/year)</td>
<td>8,889,997</td>
<td>9,279,527</td>
</tr>
<tr>
<td>GWP (kg CO₂ eq/year)</td>
<td>248,919,916</td>
<td>259,826,750.4</td>
</tr>
</tbody>
</table>

EF for Tier I(IPCC, 2006) EF using Tier II Current study, GWP used was 28 (IPCC 2013).

**DISCUSSION**

All the animal classes had higher energy expenditure and dry matter intake during the wet season compared to the dry season. This is because of the higher productivity (weight gain and milk yield) during the wet season when diets were of better quality. Maintenance energy requirements accounted for the highest energy expenditure in both wet and dry seasons. The dry matter digestibility of the diets (49.07±0.91% in dry season and 53.36% in wet season), which is indicative of diet quality, was within the range of default estimate values of (50-55%) for mixed African forages reported by Dong et al., (2006) and slightly lower than 55% provided in IPCC 2006 used in Tier I estimation. Ndung’u et al. (2019) also reported a higher range of dry matter digestibility (53.1-67.9%) from a variety of diets in the feed basket of cattle in Nandi County, which is in the highlands with high agriculture potential. Feeds harvested in a highland county differ nutritional wise from the feeds in lowland rangeland with low agriculture potential. This can be due to the fact that feeds in the rangelands deposit more structural tissue that is more fibrous hence less digestible (Wilson et al., 1991).

The average live weights for the different animal classes were comparable to those of the reference typical African cattle defined in IPCC2006 but slightly lower than what Ndung’u et al. (2019) reported. The Ndung’u study was conducted in Nandi County in the Kenyan highlands with dairy cattle breeds supported with high biomass production sustained with high bimodal distributed rainfall pattern. In contrast, the cattle population dominant in the Makueni County rangelands are the Zebu (Bos indicus) that have a smaller body frame compared to dairy cattle breeds with larger body frames, which dominate in the highlands (Ndung’u et al., 2019). The live weights in the current study however were higher than what Goopy et al., (2018) reported from a study in the lowland lake basin of Nyando basin where the small East African Zebu cattle dominated.

The total enteric CH₄ emissions from cattle in Makueni County rangelands was only 4.4% higher when estimated using IPCC Tier II compared to using Tier I approach. The Kenyan inventory reporting used the IPCC Tier I approach estimates. Tier II approach uses dry matter in the computation of EF, which has a positive correlation with the amount of CH₄ emitted, from animal performance and activity data. These feed values and animal performance variables accounted for in Tier II can explain the 4.4% higher enteric CH₄ and GWP estimates made, when compared to Tier I estimates. This observation concurs with the findings of Kurihara et al. (1999) who concluded that the use of IPCC default EF in tropical context is likely to underestimate emissions due to the differences in animal breeds and diets between the tropics and temperate environments where Tier I estimation factors were developed.

The total enteric CH₄ emission of cattle in Makueni County using Tier I (8,916,225 kg/year) was 64% lower than the emissions estimate in Kajiado County (24,983,220 kg/year) as reported by Kimongo (2017). This can be explained by
larger herds kept by the dominant pastoral community of Kajiado County. In Makueni County rangelands, animals trekked for shorter distances in search of feed and water as compared to the case of Kimongo (2017) observed in the Kajiado County study. This is a further explanation of the lower energy expenditure in the current study hence lower estimated enteric CH$_4$ production.

Considering the current study used EF developed in a tropical environment (northern Australia), the Tier II figures could have been higher than when Tier I approach was used because tropical diets are more methanogenic than temperate grasses (Archimède et al., 2018). The tropical diets were what was used in the development of the Tier I EFs. The results reflect uncertainty of EFs generated from Tier I approach, therefore necessitating development of region-specific EFs using data from local breeds of animals and feed resources. This will improve certainties of the enteric CH$_4$ emissions and accuracy in reporting the Nationally Determined Contributions (NDCs). This would meet the requirement in reporting the NDCs, to which Kenya has declared commitment.

CONCLUSION

Enteric methane emission estimates using IPCC Tier II were higher compared to Tier I approach and marginally improved estimation of actual emissions, which is an indication that it is important to develop estimation factors under local production circumstances. This informs the need to develop locally generated estimation emission factors using local breeds and local feed resources not forgetting to factor in ecological conditions to improve inevitabilities of the enteric methane emissions. This approach would meet the requirements in reporting Nationally Determined Contribution (NDC) that each country has to report to the UN periodically.

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REFERENCES


Hegarty, R.S., Alcock, D., Robinson, D.L., Goopy,
Enteric Methane Emission of Cattle Grazing Rangeland Ecosystems of South Eastern Kenya


