Increased Productivity in Tanzanian Cattle is the Main Approach to Reduce Methane Emission per Unit of Product

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Abstract

Reduction in emission of the greenhouse gas methane is a major global goal, and ruminants are major contributors to methane emission. It is well known that increased productivity will reduce the methane emission per unit of product, but its immense quantitative importance under Tanzanian conditions may not be realised. The aim of this study was to compare the present situation (M0, F0) with two improved scenarios, one where weight gain until maturity is improved by 100 g/day for both male and female (M100-F100), and one where male gain is improved by 200 g/day and female by 100 g/day (M200-F100). Scenario calculations were based on 2003 statistics for Tanzanian cattle number and herd composition, on IPCC (2006) equations for feed energy requirements and methane emission, and on several assumptions to simplify scenario calculations, e.g. that all cattle are Tanzania Short Horn Zebu (TSHZ). Present weight gain was assumed to be 115 g/day for both males and females, and mature weight to be 280 kg for female and 300 kg for male. Increased growth rate reduced total stock number as slaughter weight was reached earlier, but birth of a similar number of calves per year in all scenarios was assured by number of female breeding stock. For scenario M0-F0, M100-F100 and M200-F100, total number of cattle were 17.0 (based on 2003 statistics), 14.6 and 13.7 million, total feed requirement in NE were 312, 351 and 354 million MJ/day, total kg of carcass meat harvested were 163, 246 and 264 million kg/year, and total methane emission were 588, 561 and 520 million kg/year. NE requirement was 699, 522 and 488 MJ/kg carcass, and methane emission was 3.61, 2.28 and 1.96 kg/kg carcass for scenario M0-F0, M100-F100 and M200-F100, respectively, equivalent to a reduction of 37% and 46% of the two scenarios compared to the present situation. In conclusion, the potential for improving productivity and reducing methane emission at the same time in Tanzanian cattle production is immense.

Introduction

Enteric fermentation from livestock is on top three of the largest sources of global methane production. Livestock account for 35 – 40 % of the global anthropogenic methane emission via enteric fermentation and manure (Steinfeld *et al.,* 2006). Developing countries are responsible for three-quarters of the global enteric methane emission (Aluwong *et al.,* 2011). Tanzania ranks third in Africa in terms of number of cattle after Ethiopia and Sudan, and is thereby one of the main contributors of methane emission in Africa. The high contribution to the total methane emission from developing countries is mainly due to the extensive production system and the high number of animals (Steinfeld *et al.,* 2006). Methane emission varies highly, and recent database analyses showed that g methane per kg dry matter (DM) intake (DMI) varies from 9.0 to 30.4 (Niu *et al.,* 2018). Nutrition of the Tanzanian cattle herd is far from optimal, and generally cattle are underfed in dry periods, where they might lose the gain obtained in the previous rainy seasons. Improved nutrition obtained by either grass/pasture conservation in end of the rainy season for feeding in the end of dry season, concentrate supplementation, rangeland/pasture improvements, feed/forage cultivation, or herd reduction could heavily improve growth and production efficiency.

Greater efficiency will direct a larger portion of the energy in the animals feed into useful products such as meat or milk, and methane emission per unit of product will be reduced. Increased production efficiency also leads to a significant reduction in the herd size required to produce a given level of product (Steinfeld *et al.,* 2006).

The aim of this study was to document and quantify the potential for reducing methane emission by increasing productivity in Tanzanian cattle.

Materials and Methods

The statistics on numbers of cattle used are based on NBS (2003). It is not a fully updated reference and the total number of cattle in Tanzania has increased since, but this reference is grouped (male and female calves, bulls, heifers and cows) satisfactorily for the scenario calculations. The numbers of male and female calves used were 1,700,000 and 2,047,617. The numbers of males, heifers and cows were 4,335,385, 2,996,525, and 5,920,781, respectively. No reliable statistic was found on the division between TSHZ and other indigenous cattle, therefore the numbers of cattle from NBS (2003) used in the calculations were all assumed to be TSHZ, as TSHZ is the dominant breed among the indigenous breeds (Njombe and Msanga, 2008; Chenyambuga *et al.,* 2008). Three calculation scenarios were performed; present conditions as zero scenario (M0-F0), and two improved scenarios (M100-F100 and M200-F100). Improved scenarios were based on an increasing daily weight gain of either 100 (male/female) or 200 (male) g per day compared to zero scenario, respectively.

All calculations were made from country perspective, which means that they are based on the number of cattle in Tanzania and then eventually scaled down to production per cattle. This is an overall approach showing the effects of increasing productivity on methane emission from the cattle population in Tanzania as a whole.

Calculations

The calculations were based on three scenarios for males (M0, M100, and M200) and two scenarios for females (F0, F100).

The calculations were divided by sex (male and female). Adult males were assumed to be 50 % bulls and 50 % steers. Birth weight was assumed to be 30 kg for male calves and 28 kg for female calves (Reynolds *et al.,* 1980). Mature weight depends on many factors, including nutrition, sex, and breed, and many different estimates are given for TSHZ in the literature due to the great variation in the conditions cattle face before maturity. In this study the mature weight was assumed to be 300 kg for males and 280 kg for females (Mwilawa, 2011).

The weights in the different age groups were calculated from birth weight (males 30, female 28 kg), daily weight gain (115, 215 (+100) and 315 (+200) g/day) and 365 days/year. The estimated present daily weight gain (115 g/day) as average gain over the growth period was based on pasture fed cattle (Mwilawa, 2011), where live weight for 3.5 years old TSHZ was 177 kg and assuming birth weight was 30 kg.

The yearly death rate was assumed to be 25 % for calves and 10 % for older cattle (Mwilawa, 2011). The slaughter rate was rational guesstimates for different age groups, as proportions of number of cattle. For improved male scenarios, it was simply assumed that 50,000 slaughter cattle cover the cattle required yearly for celebrations like weddings, other important celebrations or other reasons to slaughter a few number of cattle. The slaughter rates were included because it was assumed that some animals are slaughtered before mature weight due to celebrations etc. At female scenarios the slaughter rates also reflected the non-fertility rate, as unfertile females are not useful for the herd.

The grouping according to sex, calves/adult and heifers/cows was based on the statistic information NBS (2003). Calves from NBS (2003) were defined as the number of animals less than one year. Heifers are females above one year until they reach mature weight where they become cows. Within scenario animals were divided, and calculations performed, into groups at one-year intervals.

It was assumed that the weight of the carcass is 50 % of the live weight of the slaughtered animals by the current productivity (M0, F0) (Mwilawa, 2011). This was expected to increase with increased productivity, at M100 and F100 the carcass percentage was assumed to 51 % and at M200 to 52 %, based on slaughter data from studies of un-supplemented and feedlot supplemented TSHZ (Asimwe *et al.,* 2015a; Asimwe *et al.,* 2015b).

Methane emission from cattle was estimated from required gross energy intake (GEI) as a conversion rate. To estimate GEI, the required net energy intake (NEI) is first estimated. The NEI specifies the requirements for maintenance, growth and lactation. The energy requirements for maintenance were estimated as a function of the weight of the animal. The energy requirements for growth were estimated as a function of the mature weight of the animal and the rate of weight gain. The energy requirements for pregnancy and the portion of cows that give birth each year are not included in the calculation of total NE, to simplify the calculations and due to the lack of reliable data. The possible energy requirements for milk production is neither included, but it was assumed that this energy requirement is covered in the calves requirements for energy for growth. Energy requirement calculations were based on IPCC (2006).

Equation 1: $NE_m = Cf_i \times (weight)^{0.75}$

where;
NEm = Net energy for maintenance, MJ/day
Cfi is a coefficient MJ/kg/day that varies for each animal category. Table 10.4 in IPCC (2006) is used for Cfi coefficients. For males (steers) the Cfi is 0.370, and 15 % higher for intact males, = 0.426. It was assumed that 50 % of the males are castrated and 50 % are intact males, then Cfi used in male groups was 0.398 (average of 0.370 and 0.426). Cfi used for the females was the coefficient for non-lactating cows 0.322.
Weight = live-weight of animal, kg (mean in group)

Equation 2: $NE_g = 22.02 \times \left(\frac{BW}{C \times MW} \right)^{0.75} \times WG^{1.097}$

where;
NEg = Net energy required for growth, MJ/day
BW = the average live body weight (BW) of the animals in the group, kg
C = a coefficient with the value of 0.8 for females, 1.0 for castrated males and 1.2 for bulls. The coefficient used in male groups in the scenarios was 1.1, mean of 1.0 and 1.2.
MW = 280 (female) and 300 (male). The mature live weight of an adult animal in moderate body condition, kg.
WG = the average daily weight gain of the animals in the group, kg/day

To calculate dry matter (DM) and gross energy (GE) intake the net energy per kg dry matter is required and are given in Table 1.

Table 1: NE/DM (MJ/kg DM) from table 10.8 in IPCC (2006)

	NE/ kg DM	Used factors
Scenario0	3.5 – 5.5	4.5
Scenario100	5.5 – 6.5	5.5
Scenario200	6.5 – 7.5	6.5

Intake of DM (DMI) in kg was calculated by the sum of the NE requirements from equation 1 and equation 2 and divided with energy concentration (NE/DM). GE/kg DM was assumed to be 17.9 (Schiemann *et al.,* 1972). GE/day/animal was calculated by multiplying DMI with GE/kg DM. The methane production was subsequently calculated on the basis of the total GE consumption.

The total methane emission in the group of calves up to one year was reduced to half assuming calves the first 6 month only consumes milk without rumen fermentation.

Using equation 3 and estimating the Ym factor

(IPCC, 2006) the methane emission per animal per year was calculated.

Equation 3: $$EF = \left(\frac{GE * (\frac{Ym}{100}) * 365}{55.65} \right)$$

where;

EF = emission factor, kg CH4/animal/year

GE = Gross energy intake, MJ/animal/day

Ym = Methane conversion factor, % of GE in feed converted to methane. Table 10.12 in IPCC (2006) shows percentages for different cattle categories. The factor used in these scenarios was from category 'Other cattle or Buffalo – grazing', however for M0 and F0 the factor was raised to 7.5 % due to the forage characteristics (fibre rich, low digestibility) often found in tropical Africa (USEPA, 1994). As the efficiency increase, this factor will decrease, and was assumed to be 7.0 for M100 and F100 and 6.5 % for M200. The factor 55.65 (MJ/kg CH4) is the energy content of methane.

Results and Discussion

Details on the impact of the alternative scenarios on herd size, herd composition, energy requirements, meat harvest and CH_4 emission are given in Table 2-6 for scenario M0, M100, M200, F0 and F100, respectively. With the improved scenarios (M0 to M200 and F0 to F100), number of males decrease from 6068 to 4007 thousand, and females decreased from 10922 to 9690 thousand. Carcass yield increased for males from 88883 to 155929 ton, and for females from 74115 to 108571 ton. Methane emission (kg) per kg carcass meat decreased for males from 2.19 to 0.77, and for females from 5.30 to 3.68.

Herd size and composition

Increasing daily weight gain severely affected the herd size and age composition using the present assumptions where the number of calvings per year was kept constant. The male part of the herd was considerably reduced in number and age by increased live weight gain, whereas the female part of the herd was less affected, as the fertile female herd had to be conserved to give birth to maintain the herd (Table 2, 3, 4, 5, 6). In Table 7 and Table 8 consequences for the total herd size are shown for sex specific scenarios, and for combined scenarios, respectively. For the combined scenarios the total herd was reduced by 3.3 million heads when moving from present situation (M0, F0) to the most improved (M200, F100) scenario (Table 8).

It is important to consider whether the herd can maintain itself, e.g. whether the number of fertile cows is high enough to give birth to the number of calves needed. In the scenarios a total of 3748 thousand calves were included yearly (sum of female and male, Table 2, 3, 4, 5, 6). From the number of heifers becoming cows (and giving birth to a calf), and from the remaining number of cows, and assuming an annual fertility rate for cows of 0.5 for F0 and 0.7 for F100, it can be calculated that 3108 and 3683 thousand calves were born per year in F0 and F100 scenarios, respectively (results not shown). It is reasonable to assume that fertility was improved considerably when nutrition was improved, although the rise from 0.5 to 0.7 was a qualified guess as no data for Tanzanian conditions were available. The calculated birth numbers shows that it is possible to maintain the herd with the reduced number of female stock in the improved scenario, due to earlier maturity and thereby earlier first calving, and improved fertility.

Feed consumption

The energy requirements only increased slightly, from 312 million MJ/year in the zero scenario (M0, F0) to 351 for the medium scenario (M100, F100) and 353 for the most improved (M200, F100) scenario (Table 8). The much higher gain with only a slight increase in NE requirement is possible as earlier slaughter age saves energy which alternatively would have been used for maintenance.

This indicates that the production efficiency in the improved scenario could be obtained with only a minor increase in feed resources due to better utilization. The basis is that improved scenarios result in reduced herd size, which will improve pasture availability and quality, and combined with conservation of forages in the wet season it is realistic that the improved scenario could be attained with only minor requirements for extra supplemental feed. Therefore, extra supplemental feed as e.g. by-products from the milling, oil or sugar industry would probably only be required for e.g. feedlot finishing of males for a short period before slaughter.

Often cattle gain weight in the wet season, and lose weight (mobilise) due to starvation in the dry period. Avoiding varying gain and mobilization will increase total energy efficiency; however, this is not taken into account in the scenarios. The increased supply and quality of feed in improved scenarios will reduce or eliminate the periods with mobilisation, and thereby the overall improvements in utilisation of feed energy are probably even greater than shown in these scenario calculations.

Meat production

Scenarios with increased live weight gain considerably increased the amount of carcass which could be harvested, from 163 to 264 thousand tons moving from the present (M0, F0) to the most improved (M200, F100) scenario (Table 8). As the same number of calves were born in all scenarios, the increase was a result of fewer dead animals, higher dressing percentage and higher slaughter weight although the final slaughter weight for males was kept constant. NE required to produce one kg of meat was reduced considerably, from 699 to 488 MJ/kg meat when moving from present situation (M0, F0) to the most improved (M200, F100) scenario (Table 8), as improved scenarios increased carcass output considerably whereas NE requirements were only slightly increased. The potential for increased and improved meat production has been studied extensively in both Tanzania and Uganda in recent years. Focus has been on finishing of cattle in the last period before slaughter, either in feedlot or by concentrate supplementation to pasture (Mwilawa *et al.,* 2010; Asizua *et al.,* 2014; Asimwe *et al.,* 2015a; Asimwe *et al.,* 2015b; Asizua *et al.,* 2017). The positive results obtained in these studies on weight gain, slaughter quality and meat quality call for studies, where nutrition for the whole lifetime production of the animals is improved as used in the present scenario calculations.

Methane production

Despite increased meat production, improved scenarios slightly decreased methane production per year from 588 thousand ton to 520 thousand ton, and methane per kg of meat was reduced substantially, from 3.61 to 1.96 kg CH_4/kg meat moving from present situation (M0, F0) to the most improved (M200, F100) scenario, equivalent to a 46% reduction (Table 8). Despite an increased total NE use, the in average increased energy concentration in

Table 2: M0 scenario (115 g daily weight gain, 4.5 MJ NE/kg DM)

Age interval, year	0-1	1-2	2-3	3-4	4-5	5-6	6-6.4*	Total
Animals start period, Nx1000	1700	1275	1148	861	559	336	190	6068
Death rate/year	25%	10%	10%	10%	10%	10%	10%**	
Slaughter, Nx1000	0	0	172	215	168	101	178	834
Carcass weight/group, ton	0	0	11610	19026	18361	13130	26756	88883
Total NE/group, 1000xMJ/d	15331	18502	22405	20867	16089	11116	7039	111350
DM/animal, kg/d	2.00	3.22	4.34	5.39	6.39	7.36	8.24	
GE animal, MJ/d	35.9	57.7	77.7	96.4	114.4	131.7	147.4	
Total CH_4, ton/year	14999	36204	43841	40832	31482	21751	5971	195079
CH_4/kg meat, kg								2.19

**6.4 = 6 years and 158 days. ** 43 % of the whole year (6-7) used*

Table 3: M100 scenario (215 g daily weight gain, 5.5 MJ NE/kg DM)

Age, year	0-1	1-2	2-3	3-3.44*	Total
Animals start period, Nx1000	1700	1275	1098	885	4958
Death rate/year	25%	10%	10%	10%**	
Slaughter, Nx1000	0	50	50	833	933
Carcass weight/group, ton	0	3767	5768	127406	136941
Total ME/group, 1000xMJ/d	2277	31948	39247	40129	134095
DM/animal, kg/d	2.44	4.56	6.50	8.24	
GE/animal, MJ/d	43.6	81.6	116.4	147.4	
Total CH4, ton/year	18227	51148	62833	28637	160845
CH4/kg meat, kg					1.17

**3.44 = 3 years and 161 days. ** 44 % of the whole year (3-4) used.*

Table 4: M200 scenario (315 g daily weight gain, 6.5 MJ NE/kg DM)

Age, year	0-1	1-2	2-2.35*	Total
Animals start period, Nx1000	1700	1275	1032	4007
Death rate/year	25%	10%	10%**	
Slaughter, Nx1000	0	50	966	1016
Carcass weight/group, ton	0	5264	150665	155929
Total NE/group, 1000xMJ/d	31899	49009	55701	136610
DM/animal, kg/d	2.89	5.91	8.31	
GE/animal, MJ/d	51.7	105.9	148.7	
Total CH_4, ton/year	21606	66390	31699	119695
CH_4/kg meat, kg				0.77

**2.35 = 2 years and 127 days. ** 40 % of the whole year (2-3) used.*

Table 7: Comparison of scenarios, meat production and methane emission

Scenario/factor	M0	M100	M200	F0	F100
Weight gain, g/d	115	215	315	115	215
Total animals, Nx1000	6068	4958	4007	10922	9690
Total animals (>1 year), Nx1000	4368	3258	2306	8874	7643
Total slaughtered animals, Nx1000	834	933	1016	648	771
Total carcass meat, ton	88883	136941	155929	74115	108571
Total NE, 1000xMJ/d	111350	134095	136610	200645	216930
Total CH_4, ton/year	195079	160845	119695	392606	399838
Meat/animal, kg	107	147	154	114	141
CH_4/kg meat, kg	2.19	1.17	0.77	5.30	3.68

Table 5: F0 scenario (115 g daily weight gain until mature weight 280 kg, 4.5 MJ NE/kg DM)

Age interval, year	0-1	1-2	2-3	3-4	4-5	5-6**	6-7	7-8	8-9	9-10	10-11	11-12	>12*	Total
Animals start period, Nx1000	2048	1536	1305	1083	943	825	722	631	553	483	423	370	324	10922***
Death rate/year	25%	10%	10%	10%	10%	10%	10%	10%	10%	10%				
Slaughter, Nx1000	0	77	91	33	24	21	18	16	14	12	11	9	324	648
Carcass weight/group, ton	0	3492	6074	2843	2555	2669	2526	2210	1934	1692	1481	1296	45344	74115
Total NE/group, 1000xMJ/d	15765	19518	22609	23499	24403	24710	15906	13918	12178	10656	9324	8158		200645
DM/animal, kg/d	1.71	2.82	3.85	4.82	5.75	6.66	4.90	4.90	4.90	4.90	4.90	4.90		
GE/animal, MJ/d	30.6	50.6	68.9	86.3	103.0	119.2	87.7	87.7	87.7	87.7	87.7	87.7		
Total CH_4, ton/year	30849	38192	44239	45981	47749	48350	31124	27234	23829	20851	18244	15964		392606
CH_4/kg meat, kg														5.30

When cows reach group >12 they are assumed slaughtered. ** Mature weight (280 kg) reached in period * Hereof 2048 calves, 3925 heifers, 4950 cows (Nx1000)*

Table 6: F100 scenario (215 g daily weight gain until mature weight 280 kg, 5.5 MJ NE/kg DM)

Age interval, year	0-1	1-2	2-3	3-4**	4-5	5-6	6-7	7-8	> 8*	Total
Animals start period, Nx1000	2048	1536	1367	1216	1064	931	815	713	624	9690***
Death rate/year	25%	10%	10%	10%	10%	10%	10%	10%		
Slaughter, Nx1000	0	15	14	30	27	23	20	18	624	771
Carcass weight/group, ton	0	1119	1563	4214	3800	3325	2909	2546	89096	108571
Total NE/group, 1000xMJ/d	25179	36501	47082	30503	23460	20527	17961	15716		216930
DM/animal, kg/d	2.73	5.28	7.65	5.57	4.90	4.90	4.90	4.90		
GE/animal, MJ/d	48.9	94.6	137.0	99.8	87.7	87.7	87.7	87.7		
CH4/animal, kg/year	24.1	46.5	67.4	49.1	43.1	43.1	43.1	43.1		
Total CH_4, ton/year	24635	71423	92127	59686	45904	40166	35145	30752		399838
CH_4/kg meat, kg										3.68

** When cows reach group >8 they are slaughtered. ** Mature weight (280 kg) reached in period *** Hereof 2048 calves, 2902 heifers, 4740 cows (Nx1000)*

Table 8: Combinations of male and female scenarios

Combination	Herd	Total NE	CH4	Meat	NE/meat	CH4/meat
	1000xN	1000xMJ/d	ton/year	ton/year	MJ/kg	kg/kg
M0+F0	16990	311994	587685	162998	699	3.61
M100+F100	14648	351025	560684	245512	522	2.28
M200+F100	13697	353539	519534	264446	488	1.96

feed DM resulted in a reduced total methane emission. Combined with a 62% increase in meat production, the methane production per kg of meat decreased 46%.

Implications

It is clear from the scenario calculations, that the feed resources in Tanzania can be used much more efficient, and result in both reduced methane yield and higher meat production, and probably also higher quality of the carcass and meat. However, it is crucial that the increased productivity is followed by a decreased national herd size to sustain more and better feed for cattle feeding, however reducing herd size is challenging when most pasture is on communal land. Further, if improved scenarios should be obtained mainly on pasture, it requires conservation of forage, with harvest of high quality pasture in the wet season to be used as supplementation to poor pasture in the dry season.

Conclusion

For scenario M0-F0, M100-F100 and M200-F100, total number of cattle were 17.0, 14.6 and 13.7 million, total feed requirement in NE was 312, 351 and 354 million MJ/day, total kg of carcass meat harvested was 163, 246 and 264 million kg/year, and total methane emission was 588, 561 and 520 million kg/year, respectively. NE requirement was 699, 522 and 488 MJ/kg carcass, and methane emission was 3.61, 2.28 and 1.96 kg/kg carcass. In conclusion, the potential for improving productivity and reducing total methane emission and methane yield and intensity at the same time in Tanzanian cattle production is immense.

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