**Supplementary material**

**The greenhouse gas abatement potential of productivity improving measures applied to cattle systems in a developing region**

G. R. Salmon1, 2, K. Marshall3, S. F. Tebug3, A. Missohou4, T. Robinson5,and M. MacLeod1

1*SRUC, West Mains Road, Edinburgh, EH9 3JG, UK*

2*The University of Edinburgh, King’s Buildings, West Mains Road, Edinburgh EH9 3JN, UK*

3*The International Livestock Research Institute, PO 30709, Nairobi 00100, Kenya*

4*Inter-State School of Veterinary Science and Medicine (EISMV), Dakar, Senegal*

5*FAO-AGAL, Viale delle Terme di Caracalla, 00153 Rome, Italy*

Corresponding author: Gareth Salmon. Email: gareth.salmon@sruc.ac.uk



Figure S1 *Summary of the calculation of emissions intensity for protein production (kgCO2eq/kg protein) within the version of GLEAM used in this study. Bold italicised text indicates model user inputs. Dashed boxes indicate the emission categories included in the assessment. NE - net energy, GE - gross energy, CH4 - methane, N2O - nitrous oxide, CO2 - carbon dioxide, N - nitrogen. For more information, see Food and Agriculture Organization of the United Nations (2017).*

Table S1 *Model input parameters, assumptions and source information defining baseline systems. ‘+’ refers to levels of management, see main text for details of this.*

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Model parameters | Unit information | IZ | | IZ x GZ | | | IZ x BT | | BT | Explanation/  source information |
| + | ++ | + | ++ | | ++ | +++ | ++++ |
| *Animal productivity* | |  |  |  |  | |  |  |  |  |
| Adult female weight | kg | 294.4 | 316.8 | 301.7 | 309.2 | | 333.3 | 413.6 | 432.6 | SDG |
| Calf weight at birth | kg | 20.6 | 22.2 | 21.1 | 21.6 | | 23.3 | 29.0 | 30.3 | SDG |
| Milk offtake | kg/year/lactating cow | 323.4 | 876.9 | 411.0 | 988.8 | | 937.1 | 2 032.1 | 2 196.8 | SDG |
| Milk suckled | kg/year/lactating cow | 516.2 | 516.1 | 463.6 | 463.6 | | 511.4 | 511.4 | 488.6 | SDG |
| Milk fat content | % by mass | 4.9 | 4.9 | 5.1 | 5.1 | | 5.1 | 5.1 | 5.8 | Ema *et al.* (2014) |
| Milk protein content | % by mass | 3.7 | 3.7 | 3.7 | 3.7 | | 3.5 | 3.5 | 3.7 | Ema et al. (2014) |
| Age at first calving | years | 4.3 | 3.8 | 3.7 | 3.7 | | 3.5 | 3.5 | 3.3 | SDG |
| Fertility rate adult females | proportion giving birth/year | 0.57 | 0.63 | 0.55 | 0.71 | | 0.55 | 0.71 | 0.63 | SDG |
| Death rate at birth | proportion dying at birth/1st week | 0.04 | 0.04 | 0.14 | 0.14 | | 0.04 | 0.04 | 0.08 | SDG |
| Death rate female calves (0-1) | proportion dying aged 0-1 | 0.02 | 0.02 | 0.02 | 0.02 | | 0.03 | 0.03 | 0.07 | SDG |
| Death rate male calves (0-1) | proportion dying aged 0-1 | 0.04 | 0.04 | 0.04 | 0.04 | | 0.04 | 0.04 | 0.04 | SDG |
| Death rate young animals (1-2) | proportion dying aged 1-2 | 0.03 | 0.03 | 0.03 | 0.03 | | 0.04 | 0.04 | 0.06 | SDG |
| Death rate young animals (2-3) | proportion dying aged 2-3 | 0.03 | 0.03 | 0.03 | 0.03 | | 0.04 | 0.04 | 0.06 | SDG |
| Death rate adult females | proportion dying/year | 0.02 | 0.02 | 0.02 | 0.02 | | 0.03 | 0.03 | 0.07 | SDG |
| Death rate adult males (AFC - death) | proportion dying/year | 0.04 | 0.04 | 0.04 | 0.04 | | 0.04 | 0.04 | 0.04 | SDG |
| Offtake young males age 0-1 | proportion sold /year | 0.09 | 0.09 | 0.09 | 0.09 | | 0.09 | 0.09 | 0.09 | SDG |
| Offtake young males age 1-2 | proportion sold /year | 0.20 | 0.20 | 0.20 | 0.20 | | 0.20 | 0.20 | 0.20 | SDG |
| Offtake young males age 2-3 | proportion sold /year | 0.26 | 0.26 | 0.26 | 0.26 | | 0.26 | 0.26 | 0.26 | SDG |
| Offtake young females age 0-1 | proportion sold /year | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 | SDG |
| Offtake young females age 1-2 | proportion sold /year | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 | SDG |
| Offtake young females age 2-3 | proportion sold /year | 0.16 | 0.36 | 0.17 | 0.30 | | 0.25 | 0.36 | 0.26 | SDG |
| Offtake adult females | proportion sold /year | 0.19 | 0.17 | 0.17 | 0.17 | | 0.15 | 0.15 | 0.11 | SDG |
| Offtake adult males | proportion sold /year | 0.29 | 0.29 | 0.29 | 0.29 | | 0.29 | 0.29 | 0.29 | SDG |
| *Herd information* | |  |  |  |  |  | |  |  |  |
| Adult female replacement rate | proportion of cows replaced/year | 0.21 | 0.19 | 0.19 | 0.19 | 0.18 | | 0.18 | 0.18 | SDG |
| Bull:cow ratio |  | 0.25 | 0.30 | 0.22 | 0.27 | 0.25 | | 0.30 | 0.28 | SDG |
| Labour | average hours of draft work/year | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | 0.00 | 0.00 | SDG |
| *Ration compositions and lifecycle information* | |  |  |  |  |  | |  |  |  |
| Maize grain | % of ration | 0.6 | 2.0 | 1.9 | 1.8 | 2.2 | | 3.3 | 11.4 | SDG |
| Millet stover | % of ration | 10.1 | 10.0 | 11.6 | 10.9 | 7.3 | | 3.1 | 15.4 | SDG |
| Bran | % of ration | 4.9 | 11.0 | 8.3 | 6.8 | 9.2 | | 13.4 | 24.9 | SDG |
| Purchased compound feed (PC) | % of ration composed of PC | 3.6 | 9.1 | 7.7 | 8.1 | 8.9 | | 16.5 | 32.0 | SDG |
| Groundnut cake | % of ration | 5.0 | 7.2 | 5.4 | 5.9 | 10.4 | | 13.1 | 17.3 | SDG |
| Groundnut shells | % of ration | 0.4 | 1.1 | 0.9 | 1.0 | 1.0 | | 1.8 | 3.5 | SDG |
| Senegal pasture | % of ration | 74.1 | 55.6 | 62.3 | 63.5 | 51.6 | | 34.2 | 7.8 | SDG |
| Pasture (cut and carry) | % of ration | 1.0 | 3.6 | 1.2 | 1.6 | 3.2 | | 5.9 | 2.7 | SDG |
| Senegal hay | % of ration | 3.9 | 9.5 | 8.5 | 8.5 | 14.9 | | 25.2 | 17.0 | SDG |
| *Synthetic fertiliser application* | |  |  |  |  |  | |  |  |  |
| Maize grain | kgN/ha/year | 53.9 | 53.9 | 53.9 | 53.9 | 53.9 | | 53.9 | 53.9 | Brazil import1; Richetti and Ceccon (2015) and FAO (2004) |
| Millet stover | kgN/ha/year | 7.9 | 7.9 | 7.9 | 7.9 | 7.9 | | 7.9 | 7.9 | Sonneveld *et al.* (2016) and IFDC (2014) |
| Bran | kgN/ha/year | 17.8 | 17.8 | 17.8 | 17.8 | 17.8 | | 17.8 | 17.8 | Sonneveld *et al.* (2016) and IFDC (2014) |
| Groundnut cake | kgN/ha/year | 5.5 | 5.5 | 5.5 | 5.5 | 5.5 | | 5.5 | 5.5 | Sonneveld *et al.* (2016) and IFDC (2014) |
| Groundnut shells | kgN/ha/year | 5.5 | 5.5 | 5.5 | 5.5 | 5.5 | | 5.5 | 5.5 | Sonneveld *et al.* (2016) and IFDC (2014) |
| Senegal pasture | kgN/ha/year | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | 0.0 | 0.0 | Assumed zero |
| Pasture (cut and carry) | kgN/ha/year | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | 0.0 | 0.0 | Assumed zero |
| Senegal hay | kgN/ha/year | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | 0.0 | 0.0 | Assumed zero |
| *Manure fertiliser application* | |  |  |  |  |  | |  |  |  |
| Maize grain | kgN/ha/year | 1.3 | 1.3 | 1.3 | 1.3 | 0.4 | | 0.4 | 0.1 | Assumed, based on time spent confined |
| Millet stover | kgN/ha/year | 1.3 | 1.3 | 1.3 | 1.3 | 0.4 | | 0.4 | 0.1 | Assumed, based on time spent confined |
| Bran | kgN/ha/year | 1.3 | 1.3 | 1.3 | 1.3 | 0.4 | | 0.4 | 0.1 | Assumed, based on time spent confined |
| Groundnut cake | kgN/ha/year | 1.3 | 1.3 | 1.3 | 1.3 | 0.4 | | 0.4 | 0.1 | Assumed, based on time spent confined |
| Groundnut shells | kgN/ha/year | 1.3 | 1.3 | 1.3 | 1.3 | 0.4 | | 0.4 | 0.1 | Assumed, based on time spent confined |
| Senegal pasture | kgN/ha/year | 1.3 | 1.3 | 1.3 | 1.3 | 0.4 | | 0.4 | 0.1 | Assumed, based on time spent confined |
| Pasture (cut and carry) | kgN/ha/year | 1.3 | 1.3 | 1.3 | 1.3 | 0.4 | | 0.4 | 0.1 | Assumed, based on time spent confined |
| Senegal hay | kgN/ha/year | 1.3 | 1.3 | 1.3 | 1.3 | 0.4 | | 0.4 | 0.1 | Assumed, based on time spent confined |
| *Transport by land* | |  |  |  |  |  | |  |  |  |
| Maize grain | km | 1 364 | 1 364 | 1 364 | 1 364 | 1 364 | | 1 364 | 1 364 | Brazil import1 |
| Millet stover | km | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | 0.0 | 0.0 | Local1 |
| Bran | km | 722 | 722 | 722 | 722 | 722 | | 722 | 722 | Guinea & St. Louis import1 |
| Groundnut cake | km | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | 0.0 | 0.0 | Local1 |
| Groundnut shells | km | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | 0.0 | 0.0 | Local1 |
| Pasture (cut and carry) | km | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | 0.0 | 0.0 | Local1 |
| Senegal hay | km | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | 0.0 | 0.0 | Local1 |
| *Transport by water* | |  |  |  |  |  | |  |  |  |
| Maize grain | km | 6 708 | 6 708 | 6 708 | 6 708 | 6 708 | | 6 708 | 6 708 | Brazil import1 |
| Millet stover | km | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | 0.0 | 0.0 | Local1 |
| Bran | km | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | 0.0 | 0.0 | Local1 |
| Groundnut cake | km | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | 0.0 | 0.0 | Local1 |
| Groundnut shells | km | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | 0.0 | 0.0 | Local1 |
| Senegal pasture | km | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | 0.0 | 0.0 | Local1 |
| Pasture (cut and carry) | km | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | 0.0 | 0.0 | Local1 |
| Senegal hay | km | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | 0.0 | 0.0 | Local1 |
| *Ration materials gross yields harvested* | |  |  |  |  |  | |  |  |  |
| Maize grain | kgDM/ha/year | 1 119 | 1 119 | 1 119 | 1 119 | 1 119 | | 1 119 | 1 119 | Brazil FAO STAT |
| Millet stover | kgDM/ha/year | 624 | 624 | 624 | 624 | 624 | | 624 | 624 | Senegal FAO STAT |
| Bran | kgDM/ha/year | 1 151 | 1 151 | 1 151 | 1 151 | 1 151 | | 1 151 | 1 151 | Senegal FAO STAT |
| Groundnut | kgDM/ha/year | 766 | 766 | 766 | 766 | 766 | | 766 | 766 | Senegal FAO STAT |
| Senegal pasture | kgDM/ha/year | 498 | 498 | 498 | 498 | 498 | | 498 | 498 | Sawadogo *et al.* (1999) |
| *Ration materials digestible energy* | |  |  |  |  |  | |  |  |  |
| Maize grain | DE% | 90.0 | 90.0 | 90.0 | 90.0 | 90.0 | | 90.0 | 90.0 | Feedipedia2 |
| Millet stover | DE% | 33.2 | 33.2 | 33.2 | 33.2 | 33.2 | | 33.2 | 33.2 | Jarrige *et al.* (1989) |
| Bran | DE% | 73.0 | 73.0 | 73.0 | 73.0 | 73.0 | | 73.0 | 73.0 | Feedipedia2 |
| Groundnut cake | DE% | 85.3 | 85.3 | 85.3 | 85.3 | 85.3 | | 85.3 | 85.3 | Feedipedia2 |
| Groundnut shells | DE% | 15.8 | 15.8 | 15.8 | 15.8 | 15.8 | | 15.8 | 15.8 | Jarrige *et al.* (1989) & Feedipedia2 |
| Senegal pasture | DE% | 55.2 | 55.2 | 55.2 | 55.2 | 55.2 | | 55.2 | 55.2 | Jarrige *et al.* (1989) |
| Pasture (cut and carry) | DE% | 55.2 | 55.2 | 55.2 | 55.2 | 55.2 | | 55.2 | 55.2 | Jarrige *et al.* (1989) |
| Senegal hay | DE% | 43.6 | 43.6 | 43.6 | 43.6 | 43.6 | | 43.6 | 43.6 | Jarrige *et al.* (1989) |
| *Ration materials nitrogen content* | |  |  |  |  |  | |  |  |  |
| Maize grain | gN/kgDM | 15.1 | 15.1 | 15.1 | 15.1 | 15.1 | | 15.1 | 15.1 | Feedipedia2 |
| Millet stover | gN/kgDM | 9.6 | 9.6 | 9.6 | 9.6 | 9.6 | | 9.6 | 9.6 | Jarrige *et al.* (1989) |
| Bran | gN/kgDM | 18.0 | 18.0 | 18.0 | 18.0 | 18.0 | | 18.0 | 18.0 | Feedipedia2 |
| Groundnut cake | gN/kgDM | 78.4 | 78.4 | 78.4 | 78.4 | 78.4 | | 78.4 | 78.4 | Feedipedia2 |
| Groundnut shells | gN/kgDM | 10.3 | 10.3 | 10.3 | 10.3 | 10.3 | | 10.3 | 10.3 | Jarrige *et al.* (1989)& Feedipedia2 |
| Senegal pasture | gN/kgDM | 14.8 | 14.8 | 14.8 | 14.8 | 14.8 | | 14.8 | 14.8 | Jarrige *et al.* (1989) |
| Pasture (cut and carry) | gN/kgDM | 14.8 | 14.8 | 14.8 | 14.8 | 14.8 | | 14.8 | 14.8 | Jarrige *et al.* (1989) |
| Senegal hay | gN/kgDM | 15.4 | 15.4 | 15.4 | 15.4 | 15.4 | | 15.4 | 15.4 | Jarrige *et al.* (1989) |

IZ = indigenous zebu; IZ x GZ = indigenous x Guzerat zebu cross; IZ x BT = indigenous zebu x taurine cross; BT = taurine; SDG = Information collected by, or derived from information collected by, the Senegal Dairy Genetics project (ILRI); AFC = Age at first calving; DE% - Digestible energy as a proportion of gross energy

1Personal communication with Dr Cheikh Alioune Konate, Nutritionist for NMA Sanders feed merchants, Dakar. 6 May 2016; (Konate CA, 2016, personal communication)

2Feedipedia (2016)

Table S2 *Sensitivity analysis results, showing the percentage change in emissions intensity (kg CO2eq per kg protein) when individual input parameters are altered by -10% and +10%. Values shown are average across all seven defined herd types.*

|  |  |  |
| --- | --- | --- |
| Input parameter | -10% | +10% |
| Ration digestible energy | 25.07 | -16.95 |
| Milk yield | 6.02 | -5.28 |
| Adult female fertility rate | 6.02 | -4.78 |
| Adult female body weight | -2.99 | 2.80 |
| Age at first calving | -2.97 | 3.40 |
| Bull:cow ratio | -1.40 | 1.42 |
| Ration nitrogen content | -0.58 | 0.58 |
| Calf birth weight | 0.11 | 0.09 |
| Adult female replacement rate | -0.08 | 0.08 |
| Death rate (averaged across cohorts) | -0.01 | 0.01 |

Table S3 *Summary of mitigation measure shortlisting process*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Measure type | Mitigation measure shortlist (following literature review) | Comments from expert consultation | Mitigation measure shortlist (following expert consultation) | Comments from field visits | Mitigation measure (following field visits) |
|  |  |  |  |  |  |
| Diet & nutrition | Groundnut cake | Highly dependent on availability, but effective | Groundnut cake | Cost is a barrier for many farmers | Groundnut cake |
| Diet & nutrition | Effective concentrate feed supplementation | Quality is important. Effective supplementation can improve utilisation of poor quality forages | Effective concentrate feed supplementation | Cost is a barrier for many farmers | Effective concentrate feed supplementation |
| Diet & nutrition | Incorporation of legume crops into diet | Effective supplementation can improve utilisation of forages. There is contention between crop choices for human feed, cereals have more emphasis. | Incorporation of legume crops into diet | Competition for space and communal land access is a barrier for growing crops, which is currently unlikely to be resolved. | REMOVED |
| Diet & nutrition | Pasture & grazing management to improve quality (e.g. pasture age) | Communal use of pasture makes this problematic and unlikely to work. | Pasture & grazing management to improve quality (e.g. pasture age) | Competition for space and communal land access is a barrier, which is currently unlikely to be resolved | REMOVED |
| Diet & nutrition | Choice of straw type avoid low quality | Due to severe feed shortages, it is unlikely a choice between straw types can be made | REMOVED |  |  |
| Diet & nutrition | Chemical treatment of stovers (urea) | Highly effective, but rarely employed by farmers in SSA (due to labour, resources etc.) | Chemical treatment of stovers (urea) | The majority of study farmers positive. However barriers include: finance, resource, knowledge | Chemical treatment of stovers (urea) |
| Diet & nutrition | Make silage from fodder in wet season | Commonly storage problems; climate suites hay making. | Make silage from fodder in wet season | Most farmers say they are time, labour and resource limited |  |
| Diet & nutrition |  |  | Make hay at correct maturity for times of feed shortage | Most farmers say they are time and labour limited | Make hay at correct maturity for times of feed shortage |
| Animal health | Remove the burden of key diseases (to be identified) | Diseases primarily identified by farmer recall information (SDG data) | Lumpy skin disease | Understanding the prevalence and burden of specific diseases is challenging, farmers say vets are rare and expensive. Conversations with practicing vets confirmed shortlist | Lumpy skin disease |
| Foot and mouth disease | Foot and mouth disease |
| Trypanosomiasis | Trypanosomiasis |

Table S4 *Revenue and cost assumptions. ‘+’ refers to levels of management, see main text for details of this. All values are in Central African Franc (CFA), with approximate exchange rate 1CFA = 0.0016 USD*

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | IZ | | IZ x GZ | | IZ x BT | | BT |  |
|  |  | + | ++ | + | ++ | ++ | +++ | ++++ | Source |
| *Revenue sources* |  |  |  |  |  |  |  |  |  |
| Milk sale price | per litre | 500 | 500 | 500 | 500 | 500 | 500 | 500 | SDG |
| Male calf sale price | per animal | 160 500 | 160 500 | 160 500 | 160 500 | 212 000 | 212 000 | 627 000 | SDG |
| Young male sale price | per animal | 176 000 | 176 000 | 205 500 | 205 500 | 536 000 | 536 000 | 933 000 | SDG |
| Mature male sale price | per animal | 261 500 | 261 500 | 385 500 | 385 500 | 434 000 | 434 000 | 800 000 | SDG |
| Young female sale price | per animal | 251 000 | 251 000 | 262 500 | 262 500 | 551 500 | 551 500 | 1 100 000 | SDG |
| Adult female sale price | per animal | 216 500 | 216 500 | 251 000 | 251 000 | 625 000 | 625 000 | 625 000 | SDG |
| *Baseline health costs* |  |  |  |  |  |  |  |  |  |
| Female calf health-care cost | per calf per annum | 120 | 244 | 198 | 287 | 444 | 459 | 573 | SDG |
| Male calf health-care cost | per calf per annum | 56 | 114 | 92 | 134 | 207 | 214 | 267 | SDG |
| Young male health-care cost | per young per annum | 52 | 105 | 86 | 124 | 192 | 199 | 248 | SDG |
| Young female health-care cost | per young per annum | 106 | 215 | 175 | 253 | 392 | 405 | 506 | SDG |
| Mature male health-care cost | per mature male per annum | 28 | 56 | 46 | 66 | 103 | 106 | 133 | SDG |
| Cow health-care cost | per cow per annum | 210 | 425 | 345 | 500 | 775 | 800 | 1 000 | SDG |
| *Baseline feed costs* |  |  |  |  |  |  |  |  |  |
| Male calf | per calf per annum | 12 500 | 33 000 | 19 500 | 35 500 | 36 000 | 65 500 | 123 500 | SDG |
| Young male | per animal per annum | 34 500 | 90 000 | 53 500 | 98 500 | 99 000 | 175 000 | 330 500 | SDG |
| Mature male | per animal per annum | 55 500 | 138 000 | 81 000 | 149 000 | 145 500 | 258 500 | 473 500 | SDG |
| Female calf | per animal per annum | 9 000 | 24 500 | 14 500 | 26 500 | 27 000 | 49 000 | 92 000 | SDG |
| Female young | per animal per annum | 25 000 | 65 500 | 39 000 | 71 500 | 71 500 | 127 000 | 239 500 | SDG |
| Cows | per animal per annum | 25 000 | 65 500 | 39 000 | 71 500 | 71 500 | 127 500 | 240 500 | SDG |
| Labour cost | per herd per annum | 350 000 | 350 000 | 350 000 | 350 000 | 350 000 | 350 000 | 350 000 | SDG |
| Watering costs | per herd per annum | 22 000 | 22 000 | 22 000 | 22 000 | 22 000 | 22 000 | 22 000 | SDG |
| *Additional feed costs* |  |  |  |  |  |  |  |  |  |
| groundnut cake | CFA/kg as purchased | 190 | 190 | 190 | 190 | 190 | 190 | 190 | SDG200400 studylling toconsidered. It is not enough to base local plans on /field visits |
| brans | CFA/kg as purchased | 77 | 77 | 77 | 77 | 77 | 77 | 77 | SDG/ field visits |
| purchased compound feed | CFA/kg as purchased | 240 | 240 | 240 | 240 | 240 | 240 | 240 | SDG/ field visits |
| hay | CFA/kg as purchased | 11 | 11 | 11 | 11 | 11 | 11 | 11 | SDG/ field visits |
| *Additional health costs* |  |  |  |  |  |  |  |  |  |
| FMD Vaccine | CFA/dose | 50 | 50 | 50 | 50 | 50 | 50 | 50 | field visits |
| LSD vaccination | CFA/dose | 67 | 67 | 67 | 67 | 67 | 67 | 67 | field visits |
| Trypanocides | CFA/  treatment | 500 | 500 | 500 | 500 | 500 | 500 | 500 | field visits |
| Antibiotic | CFA/  treatment | 500 | 500 | 500 | 500 | 500 | 500 | 500 | field visits |

IZ = indigenous zebu; IZ x GZ = indigenous x Guzerat zebu cross; IZ x BT = indigenous zebu x taurine cross; BT = taurine; SDG = Information collected by, or derived from information collected by, the Senegal Dairy Genetics project (ILRI); field visits = carried out by corresponding author May 2016

**Supplementary material references**

Ema PJN, Marshall K, Tebug S, Lassila L, Poole EJ, Baltenweck I, Tapio M, Juga J and Missohou A 2014. Milk composition of dairy cattle breeds in Senegal. In Food and Nutrition Security in Africa: Book of Abstracts (ed. S Rokka), pp. 16. MTT Agrifood Reseach Finland, Jokioinen, Finland.

FAOSTAT 2016. FAOSTAT. Retrieved 20 December 2016 from <http://www.fao.org/faostat/en/#data>

Feedipedia 2016. Feedipedia: animal feed resources information system (INRA, CIRAD, AFZ and FAO). Retrieved on 20 December 2016, from <http://www.feedipedia.org/>

Food and Agriculture Organization of the United Nations 2004. Fertilizer use by crop in Brazil. Food and Agriculture Organization of the United Nations, Rome, Italy.

Food and Agriculture Organization of the United Nations 2017. Global Livestock Environmental Assessment Model Version 2.0: Model description, revision 3. Food and Agriculture Organization of the United Nations, Rome, Italy.

International Fertilizer Development Center (IFDC) 2014. Senegal fertilizer assessment. IFDC, Alabama, USA.

Jarrige R 1989. Ruminant nutrition: recommended allowances and feed tables. INRA, Paris, France.

Richetti A and Ceccon G 2015. Viabilidade econômica da cultura do milho safrinha, 2015, em Mato Grosso do Sul. Embrapa, Dourados, Brazil.

Sawadogo GJ, Belemsaga DMA, Yameogo N, Manirarora JN and Toukour M 1999. Improvement of zebu cattle productivity in the Sahel region: feed supplementation on smallholder farms in peri-urban Dakar. Inter-State School of Veterinary Science and Medicine (EISMV), Dakar, Senegal.

Sonneveld BGJS, Keyzer MA and Ndiaye D 2016. Quantifying the impact of land degradation on crop production: the case of Senegal. Solid Earth 7, 93-103