# Feeding straw to suckler cows spared land but did not decrease the climate impact of beef – Supplementary materials

## Nutritional values of feeds

The nutritional values of feeds used were extracted from Spörndly (2003) and Norfor (n.d) (Table S1)

Table S1: Nutritional values of feeds.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Digestibility, % | Crude protein, g/kg dry matter | Ash, g/kg dry matter | Fatty acids, g/kg dry matter | Gross energy, MJ/kg dry matter | Neutral detergent fibre, g/kg dry matter |
| Semi-natural pastures | 72 | 140 | 74 | 10.1 | 18.3 | 560 |
| Grass silage, suckler cows | 69 | 128 | 54.5 | 20.8 | 18.2 | 576 |
| Grass-clover silage, suckler cows | 63 | 144 | 80 | 12 | 18.2 | 506 |
| Barley straw | 42 | 51 | 60 | 3.25 | 17.9 | 771 |
| Grass-clover silage, bulls | 68 | 149 | 79 | 12.9 | 18.4 |  |
| Grass-clover silage, heifers | 65 | 133 | 69 | 11.7 | 18.4 |  |
| Ley, aftermath | 68 | 146 | 83 | 12.1 | 18.3 |  |
| Whole crop silage, barley | 60 | 126 | 66 | 11.7 | 18.4 |  |
| Barley | 84 | 117 | 23 | 14.7 | 19.1 |  |
|  |  |  |  |  |  |  |
| Milk | 93.1 | 254 | 61 | 297.5 | 25.1 |  |

## Methane from enteric fermentation

For suckler cows, methane emissions were calculated with Equation S1 from Nielsen et al. (2013) (Bertilsson, 2016):

CH4 = 1.39\*DMI – 0.091\*FA (MJ/cow/day) (S1)

where DMI is the feed intake and FA the amount of fatty acids in the feed.

For other animals, methane emissions were calculated with Equation S2 from Nielsen (2012) (Bertilsson, 2016):

CH4= ((-0.046\*ConcP+7.1379)/100) \* GE (S2)

where ConcP is the proportion of concentrate feed in the ration and GE is the gross energy intake.

## Methane from manure management

Methane emissions from manure management were calculated using Equation S3 (IPCC, 2019a):

Methane emissions (kg) = VS \* B0 \* 0.67 \* MCF (S3)

where VS is the organic material (VS=Volatile Solids) in the excreted feces, B0 is the methane production potential (0.18 m3 per kg VS) and MCF (Methane Conversion Factor) indicates what percentage of the methane production potential is achieved. VS was calculated based on feed-specific values for gross energy, digestibility, and ash (NorFor, n.d.) and 4 percent urine energy (IPCC, 2019a). MCF was set at 3.5 percent for liquid manure (Rodhe et al., 2009) and 17 percent for deep bedded manure (IPCC, 2019a).

## Nitrous oxide from manure management

Direct and indirect emissions of nitrous oxide from manure management were calculated based on emission factors from IPCC (2019a) (Table S2). The amount of nitrogen in manure was calculated by subtracting the yearly average amount of nitrogen in feed taken up by the cattle from the nitrogen intake during different periods (grazing and stable period). The cattle’s nitrogen uptake was calculated using Equation S4 (IPCC, 2019a):

Nitrogen uptake = (WG\*(268-(7.03\*NEg/WG))/1000)/6.25 (S4)

where WG is the animal's average weight gain per day (between 0 and 1.4 kg per day depending on the animal) and NEg is the net energy required for the animal's growth, which was calculated according to IPCC (2019a). The amount of N ending up in manure management was proportional to the time the cattle spent indoors (all N excreted during winter period).

Table S2: Emission factors for nitrogen related emissions from manure management

|  |  |  |
| --- | --- | --- |
|  | Emission factors | Per kg |
| Direct N2O, kg N2O-N |  |  |
| Deep-bedded manure | 0.01 | Nitrogen in deep-bedded manure |
| Liquid manure | 0.005 | Nitrogen in liquid manure |
| Indirect N2O, kg N2O-N |  |  |
| Volatilization | 0.014 | Volatilized ammoniac nitrogen and nitric oxide nitrogen |
| Leaching | 0.011 | Leached nitrogen |
| Volatilization (NH3 and NOx), kg NH3-N + NOx-N |  |  |
| Deep-bedded manure | 0.25 | Nitrogen in manure |
| Liquid manure | 0.3 | Nitrogen in manure |
| Leaching, kg N |  |  |
| Deep-bedded manure | 0.035 | Nitrogen in manure  |
| Liquid manure | 0 | Nitrogen in manure |

## Nitrous oxide emissions from pastures

Emissions from pastures included emissions from manure ending up on the pastures from grazing animals. Direct and indirect emissions of nitrous oxide from pastures were calculated based on emission factors from (Table S3; IPCC, 2019a).

*Table S3: Emission factors for direct and indirect emissions of nitrous oxide from pastures*

|  |  |  |
| --- | --- | --- |
|   | Emission factors | Per kg  |
| Direct N2O, kg N2O-N |   |   |
| Manure excreted on pasture  | 0.006  | Nitrogen in manure on pastures |
| Indirect N2O, kg N2O-N |   |   |
| Volatilization  | 0.014  | Volatilized ammoniac nitrogen and nitric oxide nitrogen |
| Leaching | 0.011  | Leached nitrogen |
| Volatilization (NH3 and NOX), kg NH3-N + NOx-N  |   |   |
| Manure excreted on pasture | 0.21  | Nitrogen in manure on pastures |
| Leaching, kg N |   |   |
| Manure excreted on pasture | 0.24  | Nitrogen in manure on pastures |

## Nitrous oxide from feed production

Nitrous oxide emissions from land use in feed production were calculated using the method and factors from (Table S4; IPCC, 2019b) including both direct and indirect emissions.

Table S4: Emission factors for nitrogen related emissions from feed production

|  |  |  |
| --- | --- | --- |
|  | Emission factors, | Per kg |
| Direct N2O, kg N2O-N |  |  |
| Spreading of synthetic fertilizers | 0.016 | N in mineral fertilizers |
| Crop residues and spreading of manure  | 0.006 | N in crop residues or manure |
| Indirect N2O, kg N2O-N |  |  |
| Volatilization  | 0.014 | Volatilized ammoniac nitrogen and nitric oxide nitrogen |
| Leaching | 0.011 | Leached nitrogen |
| Volatilization (NH3 and NOx), kg NH3-N + NOx-N  |  |  |
| Spreading of Manure | 0.21 | Nitrogen in manure |
| Spreading of synthetic fertilizers (AN) | 0.05 | Nitrogen in synthetic fertilizers |
| Leaching, kg N |  |  |
| Deep-bedded manure | 0.035 | Nitrogen in manure |
| Liquid manure | 0 | Nitrogen in manure |
| Crop residues, spreading of manure and spreading of synthetic fertilizers | 0.24 | Nitrogen in manure, synthetic fertilizers or crop residues |

Emissions from inputs

Emissions from inputs (electricity, heating oil, diesel, synthetic fertilizers, and purchased feed), were calculated using factors from various references (Table S5).

Table S5: Emission factors for inputs

|  |  |  |  |
| --- | --- | --- | --- |
|   | Emission factor | Per unit | Process: |
| Electricity, g CO2e | 90.4  | kwh | Nordic electricity mix 2016-2018 (Sandgren & Nilsson 2021).  |
| Oil, kg CO2e | 79.61  | MJ | Production and distribution and combustion in car (Gode et al. 2011)   |
| Diesel, kg CO2e | 80.27  | MJ | Production and use in heating plant, 0 % RME (Gode et.al. 2011)  |
| Synthetic fertilizer, kg CO2e | 3.523  | kg N | EU average for calcium ammonium nitrate (Hoxha & Christensen 2019)  |
| Mineral feed, gCO2e | 763  | kg | Monocalcium phosphate (Flysjö et.al. 2008)  |
| Calf (Breeding bull), Mg CO2e | 3.621  | One calf | One year of emissions from a suckler cow from the reference system in this study |

## Soil carbon stock changes

Changes in soil carbon stocks as a result of the changes in crop production were modelled using the Introductory Carbon Balance Model (ICBM) (Andrén et al., 2004), which divides carbon into one old and one young carbon pool. The young pool receives all the fresh carbon input, from which most of the carbon is eventually broken down to CO2, while the rest enters the old pool. The young pool can be subdivided into several sub-pools, receiving input from different sources: aboveground crop residues (such as straw), below ground residues (such as roots) and other carbon amendments (such as manure). These sources differ in their contribution to the old pool, and hence affect carbon stock levels. Carbon from the young pool transfers to the old pool based on the 'humification' factor h. Here h=0.155 was used for crop residues above ground, h=0.395 for crop residues below ground and h=0.266 for manure (Bolinder et al., 2018).

The annual amount of carbon added to the soil in crop residues above- and below-ground and manure was used as input to the model. The amount of carbon from added crop residues was calculated according to Bolinder et al., (2007) with factors from Bertilsson and Nilsson, (2020) (Table S6). For the new pasture, values for ley were used. The amount of carbon in manure was calculated from the amount of nitrogen added and carbon/nitrogen ratios for different types of manure (Andersson et al., 2022).

Table S6: Added amount of carbon from crop residues above and below ground for the different crops and scenarios (Reference / Straw – food / Straw - pasture)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Above-ground crop residues (tonnes C/ha): | Below-ground crop residues (tonnes C/ha): | Manure (tonnes C/ha) |
| Ley: Grass-clover mixture | 0.63/0.68/0.68 | 1.6/1.6/1.6 | 0.75/0.67/0.84 |
| Ley: Grass | 0.48 | 1.6 | 0.96/0.84/1.1 |
| Whole crop barley | 0.28 | 0.31 | 0.10/0.10/0.12 |
| Spring barley | 0.71 | 0.50 | 0.26/0.24/0.30 |
| Fava beans | 1.7 | 0.31 |  |
| Peas | 1.2 | 0.06 |  |
| Winter wheat | 2.6/1.6/0  | 1.0/1.0/1.0 | 0.71/0.63/0.80 |
| New pasture | 0/0/0.96 | 0/0/0.57 | 0/0/0.53 |

The storage and degradation of carbon in soil is affected by a number of parameters such as soil type, crop and climate which is taken into account in the ICBM model through the parameter re. The re-values used in this study apply to the climate in Götaland's forested areas, which where 0.87 for leys, 1.08 for wheat, 1.16 for barley and 1 for fava beans and peas (Eriksson, 2023). Since the soil type was unknown, average values for different soil types were used and re for fava beans and peas was assumed to be 1, as this was also unknown. For the new pasture, the value for lay was used. The pools decomposition rates are set with the decomposition constant, Ky for the young pools and Ko for the old, where Ky=0.756 and Ko=0.005 were used in this study (Bolinder et al., 2018).

Soil carbon stock change was expressed as the difference between the Straw scenarios and the Reference, in which the soil was assumed to be in steady state (neither losing nor sequestering carbon). The total change for 30 years was then calculated to -6.6 and -10 tonnes C for Straw-Food and Straw-Pasture, respectively.

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