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RESEARCH ARTICLE

Introducing A New Tool to Calculate Greenhouse Gas Emissions from Feedlot Cattle [1]

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Summary

Agriculture in Australia contributed 15.5% of total national greenhouse gas (GHG) emissions produced in 2009, mainly as methane (CH_4) and nitrous oxide (N_2O). In this study, a new tool (Feedlot greenhouse gas accounting framework also known as F-GAF) incorporating all components of the GHG emissions produced from feedlot systems was demonstrated. The objective of developing the F-GAF was to create awareness of the various sources of GHG emissions from feedlots in order to stimulate thinking and action aimed at reducing these emissions while further improving farming efficiency. It was found that the main source of total GHG emissions was CH_4 from enteric fermentation, contributing around 60% of the total emissions. The N_2O emissions were mainly produced from manure and contributed 30% of the total emissions. The F-GAF can be used as a practical tool to calculate GHG emissions from feedlot systems. Further studies can be conducted to incorporate mitigation options into the tool.

Keywords: *Australia, Calculator, Feedlot cattle, Greenhouse gas*

Açık Besi Sığırlarının Sera Gazı Üretiminin Hesaplanmasında Yeni Bir Araç

Özet

Avustralya'da 2009 yılında tarım ve hayvancılık kaynaklı sera gazı üretimi, başta metan (CH_4) ve nitroz oksit (N_2O) gazları olmak üzere, toplam ulusal sera gazı üretiminin %15.5'ini oluşturmuştur. Bu çalışmada, açık besi sistemlerinden üretilen sera gazı emisyonlarının bütün bileşenlerini içeren yeni bir aracın (F-GAF olarak da bilinen açık besi sığırlarının sera gazı hesaplanması sistemi) kullanılması tanıtılmaktadır. Bu aracın (F-GAF) geliştirilmesinin amacı, bir yandan çiftlik etkinliğinin iyileştirmesini sağlarken, diğer yandan sera gazlarının azaltılmasını amaç edinen düşünce ve çalışmaları stimüle etmek için açık besi sığırlarından üretilen sera gazı emisyonlarının kaynakları hakkında farkındalık yaratmaktır. Bu çalışmada toplam sera gazı üretiminin büyük bir çoğunluğunun (yaklaşık %60) enterik fermentasyon kaynaklı CH_4 gazı üretimine dayandığı tespit edilmiştir. Diğer yandan, gübre yönetimi kaynaklı N_2O gazı üretimi toplam sera gazı üretiminin yaklaşık olarak %30'unu oluşturmuştur. Bu çalışmada tanıtılan F-GAF açık besi sistemlerinden üretilen toplam sera gazı emisyonunun hesaplanmasında pratik bir araç olarak kullanılabilir. Ayrıca, sera gazı üretiminin azaltılması seçeneklerini F-GAF'a uyarlayacak çalışmalara ihtiyaç bulunmaktadır.

Anahtar sözcükler: *Açık besi, Avustralya, Hesaplayıcı, Sera gazı*

INTRODUCTION

In 2009, Australia produced a total of 545.8 million tonnes (Mt) of CO_2-eq greenhouse gas (GHG) emissions excluding land use, land use change and forestry sector (LULUCF) emissions. The agriculture sector produced 84.7 Mt CO_2-eq emissions (15.5% of total national emissions) of which livestock production emitted 58.1 Mt CO_2-eq (10.6% of total national and 68.5% of total agricultural emissions) [1]. The three main GHGs emitted at a farm

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scale contributing to global warming are methane (CH_4), nitrous oxide (N_2O) and carbon dioxide (CO_2) [2]. The global warming potentials (GWP) of CH_4 and N_2O are 21 and 310 times higher than CO_2, respectively [3].

Methane emissions are produced mainly from enteric fermentation and effluent ponds [4]. Enteric CH_4 comprises the highest proportion (64.6%) of the total agricultural emissions, producing 54.7 Mt CO_2-eq emissions in Australia [1]. On the other hand, agricultural soils emits 14.2 Mt CO_2-eq emissions or 16.8% of the total agricultural emissions [1]. It is estimated that 2.8 gigatonnes (Gt) CO_2-eq of N_2O is produced from the global agriculture sector every year. This accounted for 60% of the global anthropogenic N_2O emissions in 2005 [5]. The N_2O emissions contributing 18% of total t CO_2-eq output (or 2 t CO_2-eq/t milk solids (MS)) are derived from four major sources: effluent ponds; fertiliser; indirect emissions; and excreta. Indirect emissions are produced from ammonia (NH_3) and nitrate (NO_3) losses. Lastly, direct CO_2 emissions from livestock farms are mainly sourced from diesel and electricity consumption [6].

When assessing the GHG emissions from livestock systems, quantification of GHG emissions is necessary to provide a common platform of information. Mathematical models, such as statistical or dynamic empirical models estimating the CH_4 emissions, are advantageous in terms of not requiring extensive and costly experiments. However, the statistical and empirical models may not be able to predict CH_4 emissions in the systems other than those they were initially built on. This can be overcome by developing mechanistic models that use commonly measured input variables such as dietary variables. The dry matter intake (DMI) (kg/d) and the metabolisable energy intake (MEI) (MJ/d) are good predictors of enteric CH_4 emissions [7]. Australian emissions are assessed by the National GHG inventory (NGGI) method [8] based on IPCC guidelines on the basis of animal species and classes, seasonal and geographical impacts (on livestock and pasture production/or emissions). This method has been prepared by the National Greenhouse Gas Inventory Committee (NGGIC) [8] and adopted by the Australian Government Department of Climate Change Energy Efficiency (DCCEE) [9] as the Australian methodology to estimate GHG emissions from livestock production systems. It reflects country-specific information, revised IPCC guidelines for national GHG inventories [10] and emission factors, and they are believed to represent international practice [9].

The objective of developing the current Feedlot - Greenhouse Accounting Framework was to create awareness of the various sources of GHG emissions on feedlot industry in order to stimulate thinking and action aimed at reducing these emissions while further improving farming efficiency. By entering in some simple data, which most farmers are likely to know, the model presents the user with a GHG emission profile for their farm. The model also then breaks down these GHG emissions into the various sources, and where they originate from on the farm. The user can then conduct some "What if" scenarios to explore the GHG impact of changes to farm management. The framework is on a spreadsheet which utilises calculations, models and assumptions based on the Australian National Greenhouse Gas Inventory method, as published by the Australian Government DCCEE in April 2012 [6].

MATERIAL and METHODS

Feedlot Greenhouse Gas Calculator

The F-GAF is a part of a suite of tools calculating GHG emissions from Australian dairy, beef, feedlot, sheep and grains industries, which are named as Dairy GHG accounting framework (D-GAF), beef GHG accounting framework (B-GAF), northern beef GHG accounting framework (B-GAFN), feedlot cattle GHG accounting framework (F-GAF), sheep GHG accounting framework (S-GAF) and grains GHG accounting framework (G-GAF). The tool is based on a Microsoft excel workbook where the calculation of GHG associated with a particular production system is based on the categories identified in the national inventory [6], where the inventory method has been adjusted where appropriate to apply to a farm boundary. The four categories for which the emissions are calculated in the F-GAF are (i) CH_4 emissions from enteric fermentation, (ii) CH_4 emissions from manure management, (iii) N_2O emissions from different manure management systems (MMSs), and (iv) N_2O emissions from agricultural soils. A summary page is provided where a pie chart features proportions of different GHGs (t CO_2-e) emitted in each production system through the outputs of CO_2 emissions from energy use, CH_4 emissions from enteric fermentation, CH_4 emissions from effluent ponds, N_2O emissions from effluent ponds, N_2O emissions from N fertiliser, Indirect N_2O emissions, N_2O emissions from manure, faeces and urine. After deducting the CO_2-eq emissions from tree planting finally, the summary page provides a sum value for total GHG emissions produced in the production system. The inputs of the F-GAF consist annual data entered for different animal classes.

Data

Data were obtained from various sources. The number of cattle on feed in Victoria was reported by the Australian Lot Feeders' Association and Meat and Livestock Australia Statistics in March 2013 as 40373 [11]. A same was assumed to apply for all three animal classes, namely domestic, export and Japan ox. Average maximum daily feed intake of the feedlot cattle was 2.5% of live weight [12], equalling to 9, 12.3 and 14.1 kg, for domestic (360 kg), export (490 kg), and Japan ox (565 kg), respectively. The lengths of stay in the feedlot for the three animal classes were 75, 140 and 250 days for domestic, export and Japan ox, respectively.

Dry matter digestibility (DMD) of the forage was 80% for all animal classes. Live weight gain varied among the animal classes with being 1.7, 1.5 and 1.2 kg/day for domestic, export and Japan ox, respectively [6].

Assumptions

The tool was run for Victoria and was assumed to derive electricity from brown-coal. A high rainfall area was chosen in the tool where type of the trees planted was hardwood as an offset against the emissions. The proportions of the feed components were assumed to remain as they were reported in the DCCEE [6]. That is, total grains (included molasses) constituted 0.779 of feed whilst the proportions of other concentrates, grasses and legumes were 0.048, 0.138, and 0.035 of feed, respectively. Feed components comprised of cellulose, hemicellulose, soluble residue, and nitrogen at different proportions for different feed components [6].

Ash content required to calculate the CH_4 emissions from manure management was a fraction of 0.08 as reported in the DCCEE [6]. Density of CH_4 was a fixed value of 0.662 [6]. The conversion factor to convert the elemental mass of N_2O to molecular mass was 1.57. Standard reference weight for steers older than 1 year old for Victoria was used as 660 kg. The fraction of N volatilised in each manure management system (MMS) was 0.3 and the emission factor was assumed to be 0.1 [6].

The calculation of enteric CH_4 fermentation follows the national inventory equations on annual basis in the F-GAF. The methane conversion factor (MCF) is a dynamic calculation that is based on a summation of all systems allocations (%) by their specific MCF to come up with the final composite. In the F-GAF, IPCC drylot MCF value for 'warm' regions is used for Queensland and Northern Territory (0.05) and MCF value for 'temperate' regions is used for all other states (0.0015) [6]. Total N_2O emissions are calculated for each of the MMS practised in each production system. The manure management systems incorporated in the GHG accounting framework suite are solid storage and drylot. N_2O emissions from synthetic fertiliser application are calculated in all systems. N_2O emissions from organic fertiliser (manure) application were not calculated. The only N_2O emissions calculated from agricultural soils was indirect NH_3 emissions because feedlot managers do not deal with pasture and fertiliser (synthetic and organic = manure), and also the cattle in this system do not deposit their faeces and urine on pasture directly. The waste is scraped and stored straightaway.

In order to allow users to explore the carbon offset value of planting trees, an option is included in the model to choose the type of trees and the rainfall zone, with the total carbon removed by trees being subtracted off the farm greenhouse gas emission total. It is important to note that this is a guide only [13], as actual tree growth is affected by the local growing conditions. In addition, the age of the plantation has a great impact on the carbon sequestration, whereas a linear growth function has been assumed here where type of trees planted was assumed to be *Eucalyptus nitens* in Victoria region receiving 500-700 mm rainfall per annum. The CO_2 emissions from diesel consumption and electricity use have also been added as a guide only. Farm electricity source was assumed to originate from brown coal. Users are encouraged to check updates and seek advice for the interpretation of their results.

RESULTS

The total net farm emissions were 18718 t CO_2e/farm for domestic, 45459 t CO_2e/farm for export, and 91474 t CO_2e/farm for Japan ox per year. The amount of CH_4 from enteric fermentation and manure management, and the amount of N_2O emissions manure management systems and agricultural soils are provided in *Table 1*.

The proportions of the total CH_4, N_2O and CO_2 emissions were 62-64%, 35-38% and 0.004-1%, respectively for all animal classes *(Fig. 1)*.

In terms of the two major gasses the highest emissions were produced from enteric fermentation for CH_4 (63%: 60%: 59%) and manure for N_2O (30%: 33%: 33%) for domestic, export and Japan ox, respectively. The lowest amounts of emissions resulted from manure for CH_4 (2-3%) and indirect ammonia for N_2O (5%) for all animal classes *(Fig. 2)*.

The area of trees required to offset 10% of the feedlot emissions (1872, 4562 and 9133 t CO_2e/farm) was 89, 217 and 435 ha of fast growing *Eucalyptus nitens* grown in a medium rainfall zone for domestic, export and Japan ox, respectively. This reflected the 21 t CO_2e/farm reduction in total farm emissions for every 1 ha of land being planted tree after 1990.

Table 1. *Greenhouse gas emissions produced from feedlot production (t CO_2e/farm)*
Tablo 1. *Açık besi üretiminden kaynaklanan sera gazı üretimi (t CO_2e/işletme)*

Animal Class	Enteric Fermentation	Manure Management CH_4	Manure Management N_2O	Agricultural Soils	Total
Domestic	11.780	294	5.711	857	18.721
Export	27.368	1.026	14.914	2.237	45.624
Japan ox	54.109	2.408	30.207	4.531	91.335

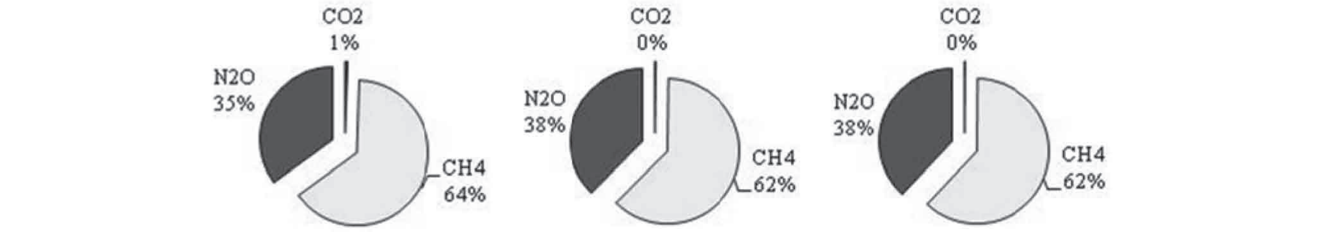

Fig 1. Proportion of CH_4, N_2O and CO_2 for the Domestic (left), Export (centre) and Japan ox (right) systems
Şekil 1. CH_4, N_2O and CO_2 gazlarının Domestic (sol), Export (orta) and Japan ox (sağ) sistemlerinde dağılımları

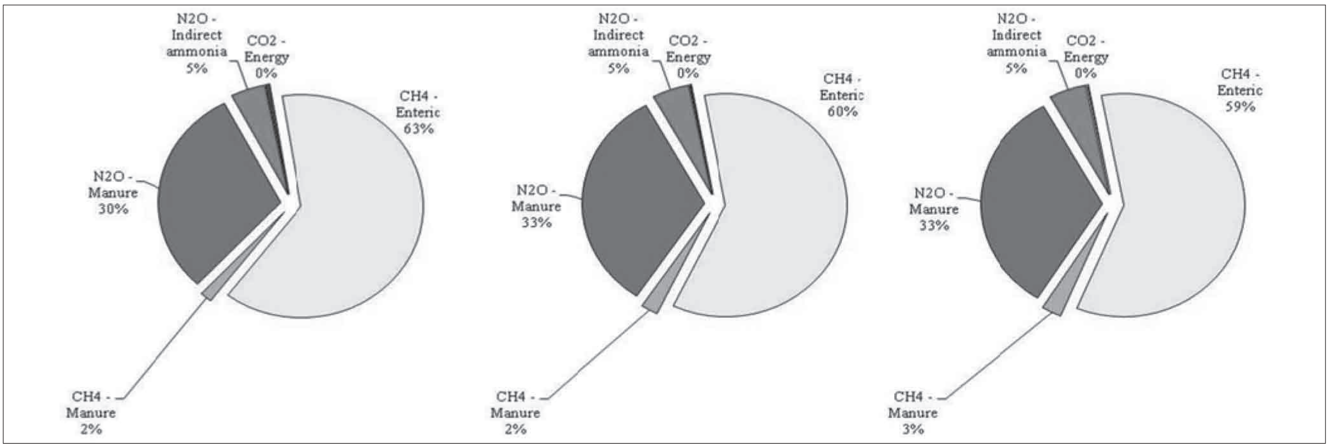

Fig 2. Greenhouse gas profile summary for all animal classes
Şekil 2. Bütün hayvan sınıfları için sera gazı profili

DISCUSSION

Greenhouse gas accounting frameworks for dairy, beef, sheep and cropping systems have been used widely to account for the GHG emissions produced in Australia. For instance, Bell et al.[14] used the S-GAF to assess the impact of future climate scenarios on productivity and GHG emissions from sheep grazing systems. Similar approach was used by Cullen and Eckard [15] using the D-GAF to evaluate the impact of future climate scenarios on productictivity and GHG emissions from pasture-based dairy production systems. A comparative study was conducted by Browne et al.[16] to estimate the GHG emissions from different agricultural production systems, utilising D-GAF, B-GAF, S-GAF and G-GAF. The F-GAF was developed in June 2012 and reported in this paper for the first time. There are also other tools available to calculate the GHG emissions from different agricultural systems such as FarmGAS allowing farmers, researchers and advisors to assess the impact of different farm management practices on farm GHG emissions [17] and enabling users to alter emission factors, feed factors for livestock, stubble management or manure management systems. Given that feedlot systems also require estimation of their GHG emission profiles, F-GAF presents an opportunity for feedlot farms to account for their GHG emissions.

The F-GAF is well suited to feedlot systems as it accounts for all CH_4 emissions produced from enteric fermentation, manure management, and N_2O emissions produced from manure management systems and agricultural soils. However, the calculation of total GHG emissions in F-GAF is only possible for a maximum of four groups of animals managed in a year. Systems managing more than four groups are advised to run the model for each group separately. It is important to note that if feedlot waste is applied to crop or pasture land, other calculators will be needed to account for manure applied to land. That is, in the F-GAF, no waste is assumed to apply to land directly.

In this study, enteric CH_4 was shown to be the major source of the GHG emissions produced from all feedlot systems by contributing to around 60% of the total GHG emissions. This is consistent with those reported by Christie et al.[18] analysing dairy farms and Bell et al.[14] estimating GHG emissions from sheep farms. Beauchemin et al.[19,20] also reported that around 63% of the total GHG emissions produced on beef production systems can be attributed to enteric CH_4 emissions. It is important to note that the manure management systems used in the current model were solid storage and drylot. Where there are different manure management systems, an assessment should be made more carefully to account for the emissions from different manure management systems. For instance, Öztürk and Ünal [21] reported three systems in dairy cattle farms in Turkey, namely collection, storage, and treatment. The differences among the three production systems for total GHG emissions produced in this study can be due either to the length of stay or the live weights of the animals, which varied greatly between these classes. There were no differences among the animal classes in terms of the feed profile of the ration they were fed.

When assessing emissions produced in a livestock production system, it is important to choose the most relevant metric. For example, emissions produced per ha is a metric that can vary with climate, soil type and production system. It is a useful metric to describe the amount of emissions on a certain amount of farm area; however, it can provide no information about resource efficiency. To better measure the resource efficiency, emissions intensity can be used as a metric. Emissions intensity usually defined as emissions produced per unit of product is a technical metric which cannot reveal the economic value of the production. On the other hand, comparing the emissions produced per MEI may be a potentially better metric to use as it can also demonstrate the impact of different management practices, such as quality of the supplement fed to the animals on the farm [16]. However, the metric used will depend on the purpose of the study as well as the data availability.

In this study, an excel based spreadsheet was developed to calculate GHG emissions of typical Australian feedlot systems. The calculation of GHG emissions associated with feedlot farms was based on the categories identified in the Australian national GHG inventory published by the DCCEE in 2012 [6]. By utilising total feedlot cattle numbers published by the Australian Lot Feeders' Association and Meat and Livestock Australia Statistics in March 2013, it was found that the majority of the emissions resulted from enteric fermentation (around 60%). The main source of the N_2O emissions was manure contributing to around 30% of the total emissions. By using the calculator, a baseline strategy can be compared with a hypothetical farm management practice [18] such as changing the quality of the supplement and/or the quality and quantity of the pasture fed. The F-GAF spreadsheet model can be a practical tool for farmers and researchers to assess GHG emissions produced on feedlot systems. It can be further developed to include mitigation strategies to reduce the emissions of these systems.

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