Proceeding Book of ISESER 2023

O 30. COMPARISON OF METHODOLOGIES TO CALCULATION CARBON FOOTPRINT IN LIVESTOCK FARMS

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ABSTRACT: The concepts of carbon footprint have emerged in order to investigate the share of intensive livestock farming in global warming and to clearly determine production-consumption outputs. It is estimated that 15% of the world's greenhouse gas emissions come from animal breeding. It is known that a significant portion of these emissions originate from enteric fermentation and manure management systems. This study was carried out to evaluate and compare the methodologies used to calculate the carbon footprint resulting from animal breeding, which has become very important in recent years. In the study, the methodologies (TIER 1, TIER 2, TIER 3) used in calculating the carbon footprint by the International Panel on Climate Change (IPCC) were examined. It can be said that a significant part of the carbon footprint of animal products originates from feed production.

Keywords: Livestock Businesses, Carbon Footprint, Global Warming,

1. INTRODUCTION

Existing resources are becoming insufficient or even depleted due to reasons such as the increasing world population and human needs, changing lifestyles, and increasing expectations and demands. This has pushed humanity to increase food production and animal production, which has a large share in food production, and to develop technologies based on it (Thornton 2010).

The increasing world population has brought with it many environmental problems as a result of the needs it brings. Climate change, decrease in underground and aboveground biodiversity, and most importantly, the problem of global warming are among these.

Global warming; Greenhouse gas emissions, which mostly occur as a result of human activities, cause temperature increases on the world. The concept of carbon footprint has emerged in order to investigate the share of intensive farming enterprises in global warming and to clearly evaluate their production and consumption outputs.

Carbon footprint; The indicator converted into carbon equivalent(CO_2eq) for products and services throughout the entire life discussion from cradle to grave is called carbon footprint(Weidmann 2008). The carbon footprint includes the total amount of all greenhouse gases, especially carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), emitted by an activity(Aycaguer2001).

It is estimated that globally the livestock sector is responsible for 15% of greenhouse gas emissions. 80% of these emissions come from ruminant animal products, which involve enteric fermentation and manure management (Perrson 2015). In global measurements, it is expressed as a ton, and in measurements per animal it is expressed as a unit (kg CO_2eq per year).

In Brazil (Cerri et al. 2016), beef production on 22 farms with a cumulative pasture area of 60,000 hectares observed that the largest source of greenhouse consumption (89-98%) was from animals (67-79% by enteric fermentation, 20% by 33% manure).

This study was prepared to introduce and compare carbon footprint calculation methods from livestock farms.

2. METHODS USED TO CALCULATE CARBON FOOTPRINT

The most common method used to measure carbon footprint is the IPCC (The Intergovernmental Panel on Climate Change) approach. According to the IPCC approach, carbon footprint is calculated by methods called Tier 1 (Simple calculation method), Tier 2 (Mid-level calculation method), Tier 3 (Detailed calculation method).

2.1. Simple calculation method (Tier 1)

Tier 1 is approaching; Estimated emission rates calculated using the Tier 2 method with data from the literature are used. It is a simplified method that includes selected data according to animal species, subcategories and climate zones or temperatures (IPCC 2019).

It may be suitable for most animal species where enteric fermentation is not a major source or where advanced classification data are not available.

2.1.1 Tier 1a

An advanced Tier 1 method can be applied to countries that have different production systems, particularly where low and high productivity systems coexist, or whose agricultural production systems are transitioning from low to high productivity.

High efficiency systems; 100 percent market-oriented high-efficiency systems with high levels of capital input and high levels of overall herd performance. Feed is purchased from the local or international market or produced intensively on the farm. It is based on animal feeding systems that use feed (e.g. high-quality grass) and concentrates in closed production systems, or supplementary grazing, or animal feeding systems that provide high rates of daily weight gain on improved pastures (FAO et al. 2014).

Low productivity systems; Systems driven by the local market or self-consumption, with low capital inputs requirementsand low overall herd performance levels, typically using large areas or backyards for production. Locally produced forages (residues from intercrops) or low-quality pastures represent the main forage products. These are animal feeding systems where daily weight gain is low (Table 1) (FAO et al. 2014).

Table 1. Tier 1 and Tier 1a Enteric Fermentation Emission Factors for Cattle and Buffalo

ASIA	Category	E.F.	Comment
Cattle: The commercialized dairy sector is experiencing fundamental changes due to the increase of large farms with intensive production systems based on seasons and feeds. They are more complex than other structures of each type.	**Dairy cattle**	78	average milk production 3,200 kg head $^{-1}$ year $^{-1}$
	High efficiency systems	96	average milk production 5,000 kg head $^{-1}$ year $^{-1}$
	Low Productivity Systems	71	average milk production 2,600 kg head $^{-1}$ year $^{-1}$
	Other Cattle	54	It includes mature males, mature females, growing and reserve animals, and calves.
	High efficiency systems	43	
	Low Productivity Systems	56	
Buffalo: Buffaloes are generally swamp type. Buffaloes are raised by farmers as a draft power source when they are young.	**Buffalo**	76	It includes breeding and working challenges, growing animals and calves.

2.2. Mid-level calculation method (Tier 2)

According to Tier 1, the annual population estimate is taken into account.Animal population and feed intake estimates for each animal are taken into account for each subcategory.It aims to accurately estimate the amount of feed taken for the accuracy of methane production by enteric fermentation.For accurate feed estimation, we need to know the animals, their productivity, diet quality and management conditions.

The following information is required for one of the representative animal categories defined:

1. Annual average population
2. Average daily feed (energy) intake (megajoules (MJ) per day or kg per day)
3. Methane conversion factor (Ym) percentage of feeder panel energy converted to methane

1. Annual average population

N_T = Animal life x (NAPA/365)

N_T : Number of livestock species in the country / category *T* (equivalent to the annual average population)

NAPA = number of animals produced annually

2. Daily feed intake (megajoules (MJ) per day or kg per day)

In general, data on average daily feed intake, especially for grazing livestock, are not available. Consequently, the following general data should be collected to estimate the feed intake of a representative category of animals;

A. Weight (kg): Body weight data should be obtained from representative sample studies or statistical databases, if readily available.Annual average weight is required for each category of animals (e.g. mature beef cows). For young animals, their weight at birth, at weaning, at one year of age, or at the time of slaughter if slaughtered within the year is required.

B. Weight gain per day (kg) $^{-1}$:It is usually collected for livestock and growing animals. It is generally assumed that the net weight of mature animals does not change over the course of a year.

C. Nutritional status-activity: Table 2

D. Daily milk production (kg/day): Lactating sheep, dairy cows and buffalos must be registered. Lactation days per year or estimated seasonal production along with daily production should be reported divided by days per season.

Table 2. Activity Coefficients Appropriate to the Nutritional Status of the Animal

Situation	**Definition**	**Ca (Activity Coefficient)**
Cattle and Buffalo (Ca unit is dimensionless)		
Barn	Animals are confined to a small area (tethered, corral, barn). They obtain feed by consuming little or no energy.	0
Pasture	Animals obtain feed by consuming a small amount of energy. It is kept in areas where there is sufficient roughage.	0.17
Grazing in large areas	Animals graze in open fields or rough terrain and expend significant amounts of energy for feed intake.	0.36

e. Average amount of work done per day (hour day^{-1}): For load-carrying animals, the average daily working hours should be recorded.

f. Percentage of females giving birth in a year: It is collected for cattle, buffalos, sheep and goats.

g. Wool growth: To estimate the amount of energy stored for wool production (after drying but before washing) the amount of wool produced in kilograms is needed. For goats, this only applies if the country has the relevant number of fibre-producing goats.

h. Number of offspring: This is limited to female livestock (e.g. sheep) that give birth more than once a year.

i. Digestibility of feed (DE, percent): Table 3

The portion of the gross energy (GE) in the feed that is not excreted in the feces is known as digestible energy (expressed as a percentage). Feed digestibility is often expressed as percentage GE or TDN (total digestible nutrients). Changes in feed digestibility are the main reason for the change in methane emissions and the amount of manure excreted. A 10% change in DE results in an increase of 12 to 20% when estimating methane emissions, and even more (20 to 45%) for the amounts of manure discarded. Feed characteristics should be recorded when developing digestibility data.

J. Dietary crude protein (CP, percent): The total amount of protein present in the animal diet. It was determined by analyzing the nitrogen content in animal feed and multiplying by 6.25. Data on the percentage of CP are required for the indication of nitrogen excretion using the Tier 2 method.

Table 4. Equations used to estimate gross daily energy intake

Metabolic functions and other estimates	For cattle and buffalo	Equations for sheep and goats
Maintenance (NE_m)	Cf_i x $(Weight)^{0.75}$	Cf_i x $(Weight)^{0.75}$
Activity (NE_a)	C_a x NE_m	C_a x Weight
Growth (NE_g)	22.02 x $(BW/CxMW)^{0.75}$ x$WG^{1.097}$	[WG_{lamb}x (a+0.5b(BW_i+BW_f))]/365
Lactation (Ne_l)	Milk x (1.47+0.40 x fat)	Milk x EV_{milk}
Attraction Power (NE_{work})	0.10 x NE_mx hour	NA
Wool Production (NE_{wool})	NA	(EV_{wool}x Pr_{wool})/365
Pregnancy (NE_p)	$C_{fertility}$x NE_m	
Ratio of net energy available in the diet to digestible energy consumed (REM) for maintenance	$[1.123-(4.092x10^{-3} xDE)+(1.126x10^{-5} x(DE)^2)-(25.4/DE)]$	
The ratio of net energy available for growth in a diet to digestible energy consumed (REG)	$[1.164-(5.16x10^{-3} xDE)+(1.308x10^{-5} x(DE)^2)-(37.4/DE)]$	
Gross Energy (GE)	Equation 10.16	
Source: Cattle and buffalo equations based on NRC (1996) and sheep and goats based on AFRC (1993; 1995). NA: not valid		

GROSS ENERGY equations for Cattle/Buffalo, Sheep and Goats:

$$\left[\frac{\left(\frac{NE_m + NE_a + NE_l + NE_{work} + NE_p}{REM}\right) + \left(\frac{NE_g + NE_{wool}}{REG}\right)}{DE}\right]$$

After calculating GE values, feed intake in daily dry matter units (DMI) (kg day^{-1}) should also be calculated. To convert GE to dry matter intake (DMI), GE is divided by the energy density of the feed (NEmf). By default, there is a dry matter value of 18.45 MJ $kg^{-1.}$ Daily dry matter intake should be between 2% and 3% of the body weight of mature or growing animals. In high-producing dairy cows, intakes can provide up to 4% of body weight.

3. Methane Conversion Factor (Y_M)

Y_M: Reduction as a percentage of gross energy intake converted to methane. Traditional methods, respiratory calorimeters, head enclosures are used to measure Y_M (Johnson and Johnson 1995). When specific Y_M values for cattle and buffalo are not available, the values given in Table 5 are available.

Table 5. Cattle/Buffalo Methane Conversion Factors (Y_m)

LIVESTOCK CATEGORY	DEFINITION	(DE%) AND NEUTRAL DETERGENT FIBER (NDF, %DMI)	Y_M
*Dairy cattle and buffalo	Highly productive cows (> 8500 kg/head/year^{-1})	DE ≥ 70 NDF ≤ 35	5.7
	Highly productive cows (> 8500 kg/head/year^{-1})	DE ≥ 70 NDF ≥ 35	6.0
	Medium productive cows (5000 -8500 kg per year^{-1})	DE 63-70 NDF > 37	6.3
	Low productive cows (<5000 kg head year^{-1})	DE ≤ 62 NDF > 38	6.5
Non-dairy multi-purpose cattle and buffalo	> 75% feed	DE ≤ 62	7.0
	Rations with >75% high quality forage and/or mixed rations, 15 to 75% forage of the total ration and/or silage mixed at intervals.	DE 62-71	6.3
	Feedlot (all other reports, 0- 15% feed)	DE ≥ 72	4.0
	Feedlot (steam milky corn, ionophore property-0-10% feed)	DE > 75	3.0
*Y_m is for dairy cattle. In their dry phase, for dairy cattle in high and medium production systems, a value of (6.3) should be selected as standard for non-dairy high-quality feed, and for low-production systems with >75% low-quality feed, a value of (7.0) should be selected.			

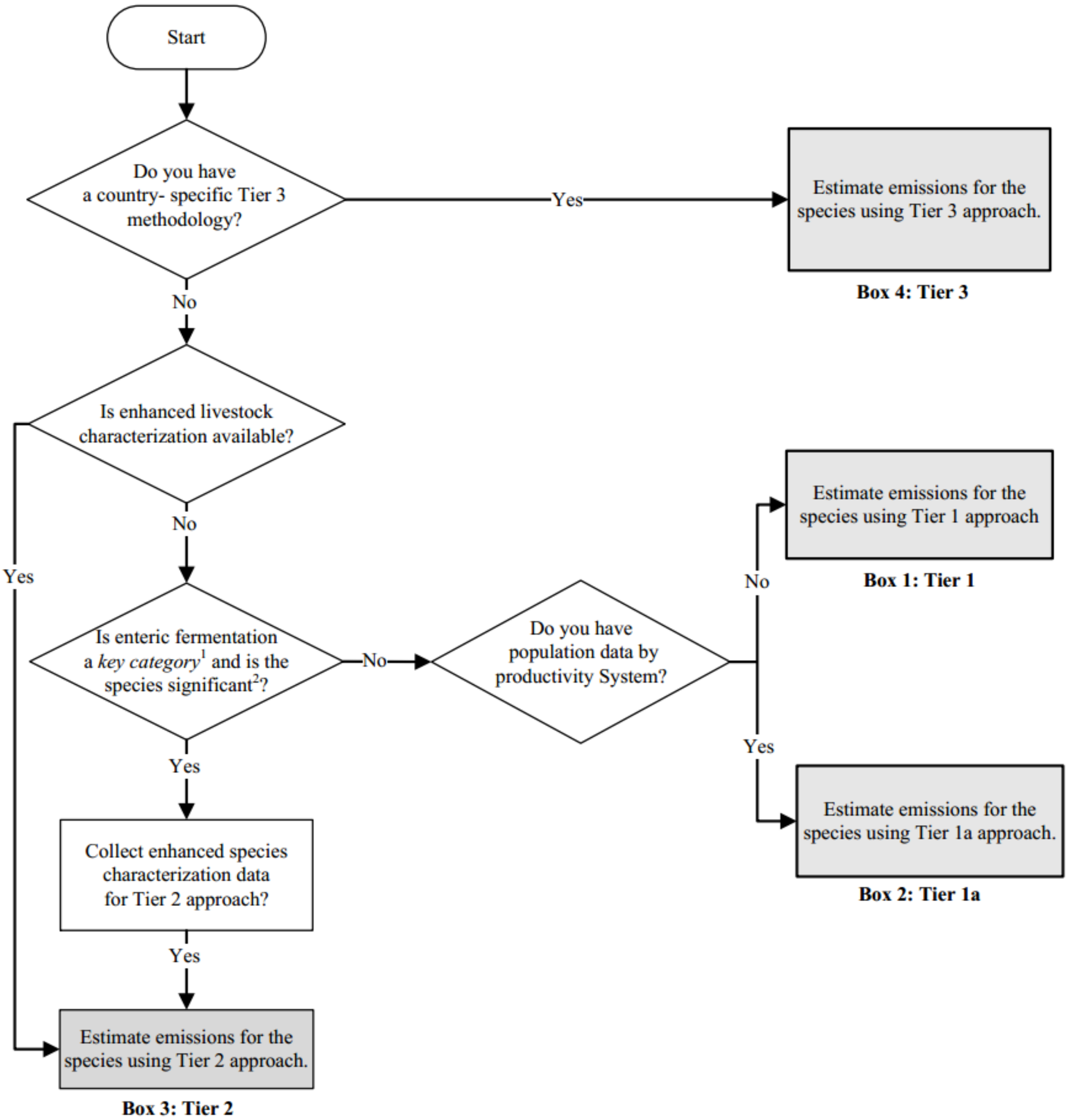

Figure 1. Enteric Fermentation Methane Emissions Decision Tree(IPCC Figure 10.2)

Emission equation from enteric fermentation (Tier 1)

$E_T = \sum EF_{(T)} \times (N_{(T)}/10^6)$

E_T = T animal's EF methane emissions, Gg CH_4 years $^{-1}$

$EF_{(T)}$ = emission factor for defined livestock distribution T in kg CH_4 head $^{-1}$ year $^{-1}$

$N_{(T)}$ = number of animal species/category heads

T = livestock species/category

To estimate total emissions, selected emissions factors are multiplied by the relevant animal population.

Total emission equation due to enteric fermentation (Tier 1)

$$Total\ CH_{4\ Enteric} = \sum_{i,P} E_{i,P}$$

Total$CH_{4\ Enteric}$ = Total methane emissions from Enteric Fermentation, Gg CH_4 years $^{-1}$

E_{iP} = emissions of animal categories and subcategories based on *i.th production systems*

Tier 2 enteric fermentation emission factor equation:

$$EF = \frac{GE \bullet \left(\frac{Y_m}{100}\right) \bullet 365}{55.65}$$

EF = emission factor, kg CH_4 head^{-1} year^{-1}
GE = gross energy intake, MJ per^{-1} day^{-1}
E_m = methane conversion factor is the energy content of methane at 55.65 percent (mj/kg CH_4)of the gross energy in the feed converted to methane.

Methane Emissions from Fertilizer

Tier 1 method is applied using IPCC default VS excretion factors, default typical animal mass, default CH_4 emission factors and default animal waste management systems (AWMS)

Tier 2 is based on country-specific rich solids estimates and surface impact of total CH_4 emissions during manure management systems (including manure treatments such as biogas production), disposal and storage. When manure is stored as a liquid or treatment permits (in lagoons, ponds, tanks or pits), it decomposes anaerobically and may contain significant amounts of CH_4.

Animal Waste Management System (Manure Management Systems) data are collected by FAO for regions and countries and are presented in tables of average individual sections treated by different management systems (IPCC 2019).

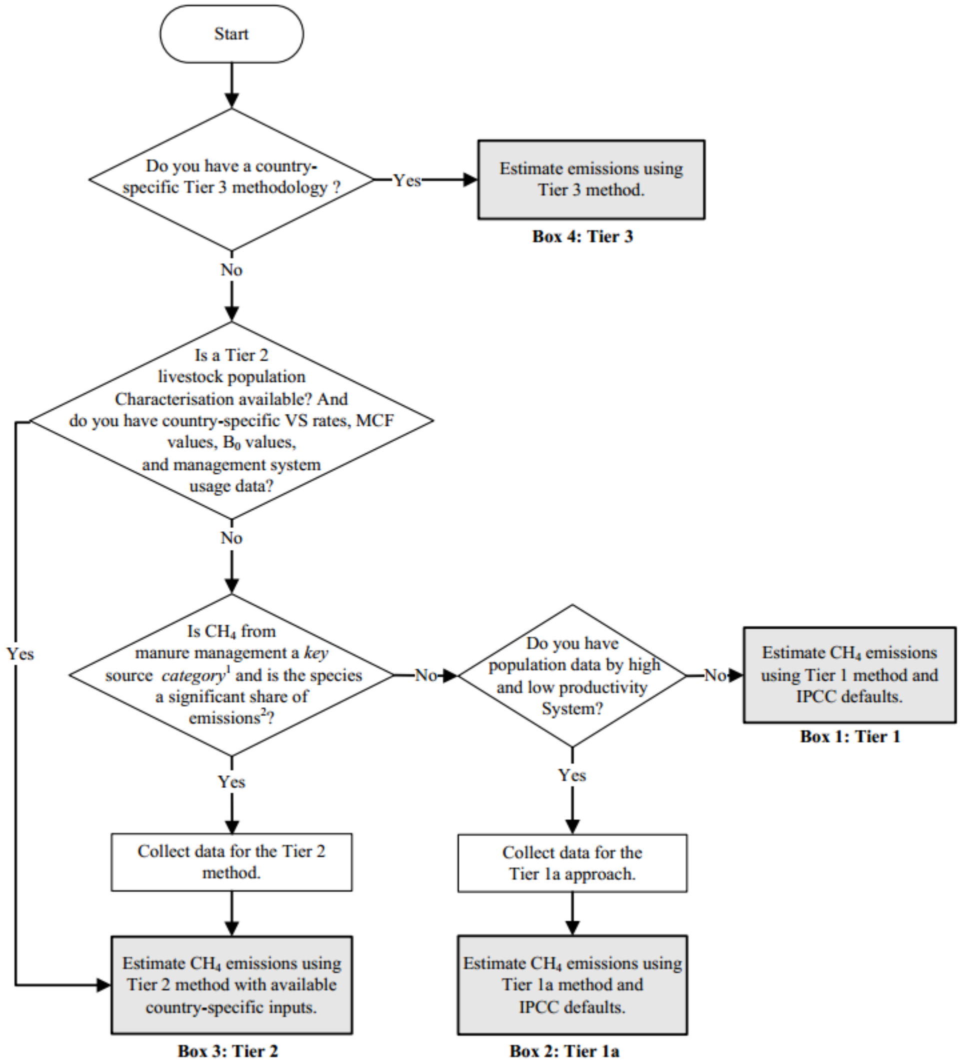

Figure 2. Methane Emissions from Fertilizer Decision Tree (IPCC Figure 10.3)

Equation for CH4 emissions of fertilizers (Tier 1-Tier 1a):

$$CH_{4(mm)} = \left[\sum_{T,S,P} \left(N_{(T,P)} \bullet VS_{(T,P)} \bullet AWMS_{(T,S,P)} \bullet EF_{T,S,P} \right) / 1000 \right]$$

$CH_4\,(mm)$ = CH_4 emissions contained in the fertilizer in the country, kg CH_4 year^{-1}
$N\,(T, P)$ = Number of head of livestock species/category in the country
VS (T, P) = Average annual VS excretion per Species/Category T as kg VS animal^{-1} year^{-1}when applicable for the P productivity system (calculated from Table 10.13a, Equation 10.22a)
$AWMS$ (T, S, P) =Total annual Vs fraction of manure for each livestock type/category T
EF (T, S, P) = Emission factor for direct CH_4 emissions ofanimal manure management policies Species/Category T, Manure Management System S , Productivity System P, where applicable
S = Manure management system
T = Livestock species/category
P = High Efficiency System or Low Efficiency System for Use in Advanced Level 1A - Taken from a simple Level 1 approach.

2.3. Detailed calculation method (Tier 3)

Although countries are encouraged to increase the amount of the Tier 2 method when data are available, complex analyzes are only discussed. The Tier 3 method is subject to extensive international evaluation, such as peer-reviewed publications, to ensure that predictions improve their accuracy and/or precision.

Table 6. Recommended Emission Inventory Methods for Enteric Fermentation

farming	recommended emission regime methods
Dairy Cattle	Tier 2 [a] / Tier 3
Other Cattle	Tier 2 [a] / Tier 3
Mandate	Tier 1/Tier 2
Sheep	Tier 1/Tier 2
Goat	Tier 1/Tier 2
Camels	Tier 1
Horses	Tier 1
Mules and Donkeys	Tier 1
Pig	Tier 1
Poultry	not developed
Other (e.g., Llamas, Alpacas, Deer, Ostrich)	Tier 1
[a]Tier 2 method is recommended for countries with large animal distribution. It may be desirable to improve the Tier 2 method for additional livestock subgroups when category emissions account for a large proportion of the total methane emissions for the country.	

3. CONCLUSION

Developments in the world in recent years have shown how important it is to calculate carbon emissions. In order to reach more accurate results in calculating the carbon footprint, it would be more useful to support existing methods with on-site measurements in different countries. Therefore, new applied studies are needed on this subject.

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