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Estimation of the Carbon Footprint in Dairy Sheep Farm

Research Article

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ABSTRACT

By 2050, the earth's population is expected to be more than 9 billion. The need for secure food and water supply will force agriculture to increase production. The major greenhouse gases (GHGs) from the livestock sector are carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) throughout the production process. These gases are the key contributor to an increasing earth's surface temperature. Global warming occurs as a result of gases emitted by humans into the atmosphere, creating a greenhouse effect. The livestock sector contributes between 25 and 40% of anthropogenic methane emissions. Human-derived animal production contributes to global warming by producing 9% of CO_2 emissions, 35-40% of CH_4, and 65% of N_2O gas emissions. Carbon footprint is a measure of the damage that human activities cause to the environment in terms of the amount of GHGs produced as a unit of CO_2. The most common method used in carbon footprint calculations is the Tier 1-2-3 approach developed by the intergovernmental panel on climate change (IPCC). In this study, the carbon footprint of a dairy sheep farm in Niğde province was calculated using Tier 1 method to determine global warming potential. The carbon footprint of this farm from both sources like N_20 and CH_4 was 85535.2 CO_2eq year-^{1}. The estimation of GHGs is very obligatory to evaluate global warming stress and avoidance from some fatal diseases.

KEY WORDS carbon footprint, dairy sheep, greenhouse gas, sustainability.

INTRODUCTION

In this era, the ecosystem is transmuted by global warming with threatening the life of the present and future population and its economics. The climate change rate is more rapid than in some previous decades. The international panel of climate change (IPCC) forecasted that in the coming 10 decades, the global temperature will rise to 1.8-4.0 ˚C (Marino *et al.* 2016). Globally this climate change causes a devastating effect on human beings and animals by promoting the germs of dangerous diseases. By 2050, the population of earth planet is estimated at more than 9 billion with a massive claim of the food supply. The production of sufficient food to gratify the need of the population also associate with climate change and nature preservation (Ibidhi *et al.* 2017).

The livestock sector contributes to a major part of the agricultural food supply with a significant change in climate by anthropogenic greenhouse gases (GHGs) emission in nature. Globally 18% portion of GHGs emissions is directly or indirectly related to the livestock sector (Herrero *et al.* 2013). Enteric fermentation and manure production of a ruminant is greatly responsible for the emission of GHGs up to 80% (Havlík *et al.* 2014) depending on species, production purpose, soil type, landscape, climate, and altitude (Hadjigeorgiou *et al.* 2005). The livestock plays a vital role in ecosystem change as the emission of CO_2 is at the rate of 7.1 GT / year (Gerber *et al.* 2013a; Gerber *et al.* 2013b). The emission of GHGs methane (CH_4) and carbon dioxide (CO_2) is directly associated with both enteric fermentation and manure management while nitrous oxide depends only on manure management (Gerber *et al.* 2013a). Small ruminants donate 55% GHGs by enteric fermentation and 35% by feed production with a very minute amount by manure (Gerber *et al.* 2013b). The Carbon footprint (CF) is a measure of the damage that human activities cause to the environment in terms of the amount of GHGs CH_4, CO_2, and N_2O associated with off-farm and on-farm level. In this context, CF provides information on GHGs emissions as expressed CO_2 equation and evaluate the products with environmental loads and bio-physical policies of trades (Galli, 2015).

CF delivers viable labeling for consumer buying decisions and most importantly provides awareness against the influence of food production in GHGs emissions in nature (Röös *et al.* 2011). Media discussion and populace acknowledgment about livestock production and its impact on climate change promote the reduction and mitigation of GHGs through CF assessment (Luo *et al.* 2015). The CF is stated in kg of CO_2 equation per unit of product in livestock of indoor animal production systems (e.g. poultry farms), whereas in grazing farming systems, the impact of soil carbon (C) sequestration from soil C inputs is substantial to climate change (Gutiérrez-Peña *et al.* 2019). Soil carbon can be affected by different crop variety and management. For example, negative net balance carbon as CO_2 loss gives a positive effect on the emission of N_2O (Batalla *et al.* 2015). It means soil carbon sequestration in grassland pastures can be seen as a mitigating option for extensive ruminant systems (Soussana *et al.* 2010). The carbon of nature related to the animal directly concerns the two producing engines of CH_4 from enteric fermentation and manure management of livestock while N_2O of livestock production has a strong concern with manure management. The ruminal activity of digestion is a basic factor to secrete a high amount of CH_4 in livestock but manure is sharing the very little amount of CH_4 in nature. However, estimates of small ruminant GHGs emissions are often centered on diverse approaches and not easy to attain in practice due to a deficiency of data, especially for the dairy sector. The IPCC gives 3 types of method analysis called Tier 1, Tier 2, and Tier 3 although the selection of the Tier method depends on information and the aspect of the reflected system. Estimations related to big ranges are generally gathered by the application of Tier 1 and Tier 2, whereas Tier 3 is habitually functional in constrained areas (Marino *et al.* 2016).

In this study, the carbon footprint of Awassi sheep farm in Niğde region was calculated using Tier 1 method to determine global warming potential. This is typically a dairy sheep farm with a population of 2000 heads adult sheep and 2340 heads growing lambs of 6 months ages.

Process of GHGs formation in ruminant management system

The breakdown of carbohydrates during the digestion of feed in ruminants (sheep, goat, buffalo, camel, and cattle) produces CH_4 and CO_2 gases as a by-product resulted from the action of micro-organisms in the digestive tract (Patra, 2012). The quantity of GHGs emissions depends on the animal age, animal size, feed type, and kind of digestive tract. The ruminant livestock produces more CH_4 and CO_2 as compared to non-ruminant because they have four compartments digestive tract (except camels) with maximum fermentation of feed (Patra and Saxena, 2009). The feed is always required according to the need of animals so its quantity and quality both have significant prominence in GHGs emissions of sheep farming. The manure is a very immense source of N_2O emission at the dairy farms but it also produces an amount of CH_4 and CO_2 at a small scale (Tauseef *et al.* 2013). The manure is composed of both solid dung and liquid urine collectively. Basic GHGs production in the form of CH_4 is related to the decaying of manure, storage, and treatment of manure at the farm level (Aluwong *et al.* 2011). This study is grounded on a congested dairy farm of sheep with a dry solid manure management system. The quantity of manure production per animal, herd size, the system of manure management, emission factor and temperature are very significant features to estimate the accurate value of methane gas from manure (Intergovernmental Panel on Climate Change, 2006). In manure (dung and urine) management, N_2O emission happens in direct and indirect ways collectively as it prerequisites distinct consideration for the calculation of its amount before the use of manure as for feed, fuel and another beneficial purpose like storage and treatment. As for indirect N_2O emission of manure management, some factors are very essential like the presence of nitrates, low PH and aerobic situations for oxidized form of nitrogen while indirect emission occurs in the form of ammonia and NO (volatile nitrogen). In the process of N_2O emission, two progressions like nitrification (ammonia nitrogen to nitrate nitrogen) and denitrification (nitrate to N_2O formation) are very obligatory with aerobic and anaerobic environments respectively (Intergovernmental Panel on Climate Change, 2006).

Role of sheep in GHGs emissions

Globally the domestic ruminant population has 56% portion of small ruminants with 1178 million population of sheep, which is expected to increase by 60% in 2050 (Faostat, 2013).

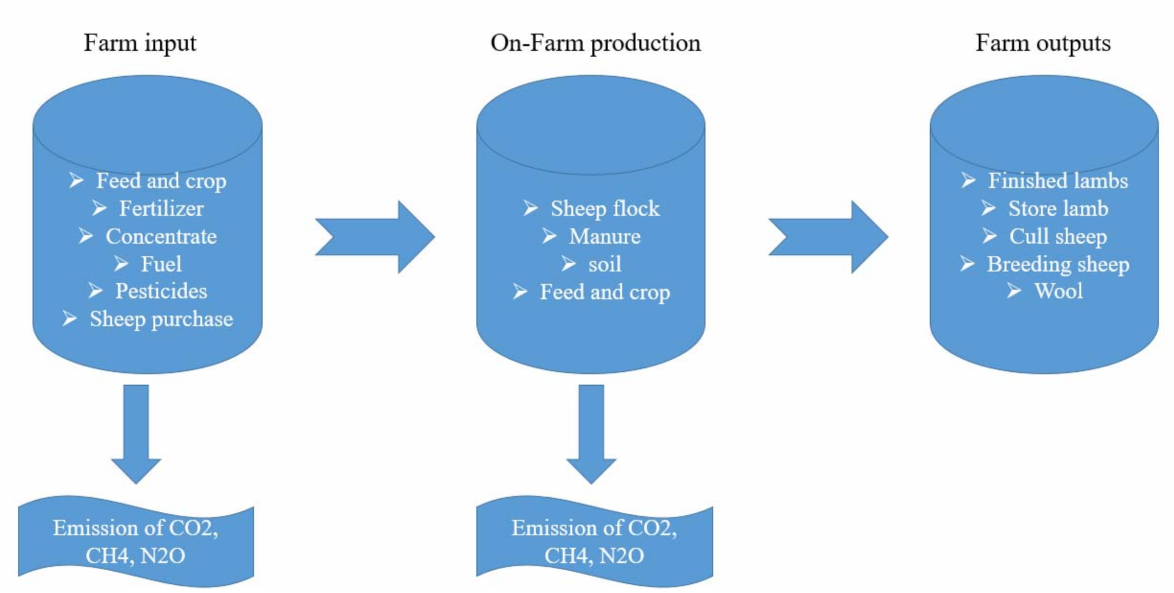

Figure 1 The complete life cycle of sheep production with the emission of GHGs (Marino *et al.* 2016)

In 2013, small ruminants especially sheep and goats produced 13 million tons of meat and 28 million tons of milk. Internationally, sheep production is sundry and multi-purpose animal generating meat, milk, skins and wool, although meat production is their primary function (Zygoyiannis, 2006). Sheep farms are primarily situated on hill or high country lands with the use of stumpy inputs and all-year grazing of perennial grasslands. In Turkey, the small ruminant especially sheep and goats are reared for meat, milk, mohair, and wool, sharing their quota of GHGs emissions in the atmosphere. Görgülü *et al.* (2009) quantified that Turkey is a very famous sheep-rearing country as it has a 30.2 billion sheep population, producing almost 203.800-ton enteric fermentation gases and 6.114-ton manure management gases. Based on Intergovernmental Panel on Climate Change (2006) guidelines and regulations, the livestock of Turkey produced 1.38 million tonnes of methane and 15.30 thousand tonnes N_2O within the year 2015 (Ersoy, 2017). In the region of Niğde, the environmental and grassy zone is pretty suitable for the rearing of sheep on a highly commercial level. Ersoy (2017) identified that the CF of N_2O in the livestock of the Niğde region is 53465 ton CO_2 eq year-^{1} as in this region livestock releases 148 ton N_2O year^{-1} in the form of direct N_2O while 24 ton N_2O year-^{1} in the form of indirect N_2O. According to the observation of Ersoy (2017) under the guidelines of Intergovernmental Panel on Climate Change (2006), the livestock sector of Niğde region shares an amount of 336.11×10^3 ton CO_2eq year-^{1} as methane CF, which consists of 15.72×10^3 ton CH_4 year-^{1} from enteric fermentation and 0.29×10^3 ton CH_4 year-^{1} from manure management.

The value of the CF for greenhouse gases depends on the management system as the grazing system has a different value and measurement parameters as compared to the on-farm feeding system.

MATERIALS AND METHODS

This study was carried out at the dairy sheep farm of Niğde province. Niğde is ecologically located at the very best section of Turkey with 37.97 latitudes, 34.68 longitudes, and at the altitude of 1243 meters above sea level. This is a God-gifted place of Turkey with a diversity of climate, hilly extents, agriculture, and plenty of forages.

So, in this region, sheep farming is a very propagative occupation to secure the lack of food and upsurge local and national economies. The methane gas production from sheep enteric fermentation and manure is as well as to be reckoned but N_2O emission is only related to manure management. The CO_2 is not to be considered as a giant concern because it is equalized by CO_2 of plant photosynthesis in the atmosphere (Intergovernmental Panel on Climate Change, 2006). This study is carried out with an on-farm boundary which includes all production aspects of sheep farming.

All the data were obtained from a dairy farm of sheep located in Niğde province and 2000 heads Awassi sheep and their 2340 heads lambs were used. The Awassi sheep of this farm has an average of 65 kg live weight and lambs have 40 kg live weight at 6 months of age.

The Awassi sheep originates from Syria, Lebanon and some other Arabic countries nonetheless now it is also reared in turkey under the name of Arab and Ivesi sheep.

It is typically a dairy breed with an average live weight ranging from 50-70 kg. This sheep has a wide-body size with white body wool, brownish neck, and legs wool (Yalcin, 1986).

This farm has an intensive feeding system for animals with an automatic milking parlor as it is more reliable on concentrate and forage feeding (corn silage, alfalfa, wheat straw, etc.) in the form of a mixture. At the farm, the rudimentary excretion of manure is in both solid and liquid forms (dung and urine) nevertheless its complete storage is managed in dry solid form.

The carbon footprint values were calculated by using the Tier 1 method developed by the Intergovernmental Panel on Climate Change (2006). As it is known, the net emissions of greenhouse gases in a production unit are called carbon footprint (CF).

Equations

Methane emission from enteric fermentation:

$$Emissions = EF_T \times \left[\frac{N_{(T)}}{10^6}\right] \quad (2.3.1)$$

Methane emission from manure management:

$$CH_{4\ manure} = \sum_{(T)} \frac{(EF_T \times N_T)}{10^6} \quad (2.3.2)$$

Where:
Emissions: methane productions per year.
EF_T: emission factor (kg CH_4 head-^{1} yr-^{1}).
$N_{(T)}$: number of animals.
T: species of animal.

Direct nitrogen emission from manure management:

$$N_2O_{D(mm)} = \left[\sum_S\left[\sum_T\left(N_{(T)} \times N_{ex(T)} \times M_{S(T,S)}\right)\right] \times EF_{3(S)}\right] \times \frac{44}{28} \quad (2.3.3)$$

Where:
N_2O_D (mm): emissions of direct nitrogen oxide in kg N_2O per year from manure.
$N_{(T)}$: number of animals.
$N_{ex(T)}$: yearly average N emission per animal in kg N per animal per year.
$MS_{(T,S)}$: fraction of total yearly nitrogen secretion for the specific type of animal.
$EF_{3(S)}$: nitrogen oxide emission factor for manure managing system.
S: type of system.
T: types of animal.
44/28: change of (N_2O-N) (mm) secretions to N_2O (mm) secretions.

Indirect N_2O estimation is caused by the volatilization process.

$$N_2O_{G(mm)} = (N_{volatilization\text{-}MMS} \times EF_4) \times 44 / 28 \quad (2.3.4)$$

$N_2O_{G(mm)}$: emissions of indirect nitrogen oxide in kg N_2O per year from dung volatilization of N.
EF_4: emission factor with default value is 0.01.

Calculations

In this study, it was calculated greenhouse gas emissions for 2000 sheep and 2340 sheep lambs of an Awassi dairy sheep farm located in Nigde. All the calculation takes place with Tier 1 method and according to the Guidelines for National Greenhouse Gas Inventories (Intergovernmental Panel on Climate Change, 2006).

Calculation of methane emission from enteric fermentation by equation 2.3.1

$$Emissions = EF_T \times \left[\frac{N_{(T)}}{10^6}\right]$$

EF_T= 8 kg CH_4 per head year^{-1} for the Tier 1 method (sheep)

Emission= $8 \times \left[\frac{2000}{10^6}\right]$= 0.016 Gg CH_4 yr^{-1} (2000 sheep)

EF_T= 5 kg CH_4 per head year^{-1} for the Tier 1 method (lamb)

Emission= $5 \times \left[\frac{2340}{10^6}\right]$= 0.0117 Gg CH_4 yr^{-1} (2340 lamb)

Total emission= 0.0277 Gg CH_4 yr^{-1}

Calculation of methane emission from manure management by equation 2.3.2

$$CH_{4\ manure} = \sum_{(T)} \frac{(EF_T \times N_T)}{10^6}$$

EF_T= 0.10 KG CH_4 head-^{1} year-^{1} (sheep)

$CH_{4\ Manure} = \sum_{(T)} \frac{(0.10 \times 2000)}{10^6}$= = 0.0002 Gg CH_4 yr^{-1}

EF_T= 0.19 KG CH_4 head-^{1} year-^{1} (lamb)

$CH_{4\ Manure} = \sum_{(T)} \frac{(0.19 \times 2340)}{10^6}$= 0.0004446 Gg CH_4 yr^{-1}

Total emission= 0.0006446 Gg CH_4 yr^{-1}

Calculation of direct N_2O emission from manure management by equation 2.3.3

$$N_2O_{D(mm)} = \left[\sum_S\left[\sum_T\left(N_{(T)} \times N_{ex(T)} \times M_{S(T,S)}\right)\right] \times EF_{3(S)}\right] \times \frac{44}{28}$$

Annual N excretion rate;

$$N_{ex(T)} = N_{rate(T)} \times \frac{TAM}{1000} \times 365$$

$TAM_{(T)}$: typical animal mass in kg per animal.
TAM: 65 kg for sheep and default factor is 0.90 kg N (1000 kg annual mass^{-1}) year^{-1}.
TAM: 40 kg for lams and default factor is 1.17 kg N (1000 kg annual mass^{-1}) year^{-1}.
$N_{ex(T)}$= 0.90 × 0.065 × 365= 21. 35 (sheep)
$N_{ex(T)}$= 1.17 × 0.04 × 365= 17. 08 (lambs)
By using the value of $N_{ex(T)}$.

$$N_2O_{D(mm)} = \left[\sum_S\left[\sum_T\left(N_{(T)} \times N_{ex(T)} \times M_{S(T,S)}\right)\right] \times EF_{3(s)}\right] \times \frac{44}{28}$$

$$N_2O_{D(mm)} = [\Sigma_S[\Sigma_T(2000 \times 21.35 \times 100)] \times 0.02] \times \frac{44}{28}$$

Result= 134200 kg N_2O yr^{-1} (sheep)

$$N_2O_{D(mm)} = \left[\sum_S\left[\sum_T(2340 \times 17.08 \times 100)\right] \times 0.02\right] \times \frac{44}{28}$$

Result= 125611.2 kg N2O yr^{-1} (lambs)
Total result= 259811.2 kg N_2O yr^{-1}

Calculation of Indirect N_2O of manure management by equation 2.3.4

$N_2O_{G(mm)}$= ($N_{volatilization\text{-}MMS}$×$EF_4$) × 44 / 28

The N $_{volatilization\text{-}MMS}$ value:

$$N_{volatilization-MMS} = \sum_S\left[\sum_T\left[\left(N_T \times N_{ex(T)} \times MS_{(T,S)}\right) \times \left(\frac{fraction_G}{100}\right)_{(T,S)}\right]\right]$$

$$N_{volatilization-MMS} = \sum_S\left[\sum_T\left[(2000 \times 21.35 \times 100) \times \left(\frac{12}{100}\right)_{(T,S)}\right]\right]$$

$N_{volatilization\text{-}MMS}$= 512400 (sheep)

$$N_{volatilization-MMS} = \sum_S\left[\sum_T\left[\left(N_T \times N_{ex(T)} \times MS_{(T,S)}\right) \times \left(\frac{fraction_G}{100}\right)_{(T,S)}\right]\right]$$

$$N_{volatilization-MMS} = \sum_S\left[\sum_T\left[(2340 \times 17.08 \times 100) \times \left(\frac{12}{100}\right)_{(T,S)}\right]\right]$$

$N_{volatilization\text{-}MMS}$= 479606.4 (lambs)
By using the N_{VOL_MMS} and default factor (EF_4) value 0.010

$N_2O_{G(mm)}$= ($N_{volatilization\text{-}MMS}$×$EF_4$) × 44 / 28
$N_2O_{G(mm)}$= (512400×0.010) × 44 / 28
$N_2O_{G(mm)}$= 8052 kg N_2O yr^{-1} (sheep)
$N_2O_{G(mm)}$= (479606.4×0.010) × 44/28
$N_2O_{G(mm)}$= 7536.6 kg N_2O yr^{-1} (lambs)
Total= 15588.6 kg N_2O yr^{-1}

RESULTS AND DISCUSSION

This study was held at a dairy sheep farm in Nigde region in Turkey and all these calculations for estimation of GHGs are taken under the guidelines and rules of Intergovernmental Panel on Climate Change (2006) (Table 1). In the view of this study results, the GHGs emission from a dairy sheep farm of Nigde province has a noticeable value of 85535.2 CO_2eq year-^{1} as a CF and these gases are a direct source to denature the ozone layer and alternate the atmosphere temperature. The CF value of this farm is not much higher as compared to the CF value of the Nigde region's livestock which is 53465 ton CO_2 equation year-^{1} and 336.11 × 10^3 ton CO_2 equation year-^{1} for N_2O and CH_4 respectively.

Görgülü *et al.* (2009) and Ersoy (2017) had been estimated GHGs emissions of this region and their findings were very high as compared to this study. According to scientific studies and some author's point of view, the main font of GHGs emission is cattle farming as compared to goat and sheep farming (Robertson *et al.* 2015). So the emission of GHGs from dairy sheep in this specific area of study is very miner and less destructive. There are very limited studies available for the estimation of greenhouse gases emission from sheep dairy farms.

The results of different studies can be different due to data, production differences, and variations in methodologies of every study. This study was very indispensable to estimate the greenhouse emission from the sheep farm of Nigde region as it is the most prominent profession of this region. Bernués Jal *et al.* (2017) identified that evaluation between different studies is very challenging as every study has its standards and boundaries of the system with special data.

Table 1 The carbon footprint of Awassi sheep dairy farm

Type of GHGs	Quantity of GHGs	Value of carbon footprint
Methane production from enteric fermentation*	27.7 ton CH^4 year-^{1}	595.2366 CO_2 equation year-^{1}
Methane production from manure management*	0.6446 ton CH^4 year-^{1}	
Direct N_2O production from manure management**	259 ton N_2O yr^{-1}	84940 CO_2 equation year-^{1}
Indirect N_2O production from manure management**	15 ton N_2O yr^{-1}	
Total carbon footprint		85535.2 CO_2 equation year-^{1}

* It was used the coefficient of 21 in the conversion of methane from enteric and manure for total CO_2 equation calculation.
** It was used the coefficient of 310 in the conversion of direct and indirect N_2O_2 for total CO_2 equation calculation.

This study was proposed on on-farm boundaries and mix ration feeding with a dry solid dung management system while Ersoy (2017) and Görgülü *et al.* (2009) had done their studies under all management systems. So new incipient authors can take an idea about the system of boundaries, rules, methods, and new technologies of estimating GHGs. The value of the result can be different for different authors depending on the base of the Tier method and correlated data.

CONCLUSION

GHGs emission of this dairy sheep farm was 85535.2 CO_2 equation year-[1] that was not a big source of GHGs but the mitigation of GHGs is very obligatory even at this low gas-emitting farm to secure the nature and atmospheric temperature. It is known that the growing population demands much agricultural food nevertheless it should also be used as a proper management system for minimum emission of GHGs for living a healthy life. The normal temperature and microbial load are to be growing higher with these GHGs emissions as it is dangerous for human health. The basic tenacity of this study was to alert about the emission of GHGs from sheep farming and denote the share of a single sheep farm in total GHGs emissions to make governments ready to adapt each step to diminish their emission by developing a sound management system. So the basic purpose of this study was to estimate the GHGs of a specific dairy sheep farm and provide an alert of researchers to find novel ways to control its emissions and prevent the disturbance in the natural ecosystem.

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