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Research Article

# Greenhouse gases and water and soil pollutants emitted from animal husbandry in Urzouyeih county of Kerman province

**Shoja Mousapour Mahmoud Hashamitabar*[*] Mahdi Safdari Ali Sardar-Shahraki**

Department of Agricultural Economics, University of Sistan and Baluchestan, Zahedan, I. R. Iran

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**ABSTRACT-** Greenhouse gas (GHG) emissions are a significant environmental crisis that has become a major concern in many countries. A primary contributor to GHG emissions is animal farming and meat production. The purpose of this study was to estimate GHG emissions, as well as water and soil pollutant emissions, resulting from these activities in Urzouyeih County using a linear optimization model. Based on the results, solid manure (feces) from each cattle animal emits 392.82 kg/year of soil and water pollutants, with chemical oxygen being the primary component of these emissions. In contrast, the pollutants emitted from the solid manure of sheep and goats are 11.06 kg and 9.93 kg, respectively, with total nitrogen being the main contributor. Furthermore, 99.55 kg, 8.38 kg, and 7.56 kg of pollutants enter water and soil from the liquid manure (urine) of cattle, sheep, and goats, respectively. Potassium (Kalium) was found to be the primary pollutant emitted from the liquid manure of all three animals. Additionally, methane emission from manure management and enteric fermentation for all three livestock in the area is $1.56 \times 10^6$ kg. Goats, due to their high population, emit 738,669 kg of methane. Nitrous oxide ($N_2O$) emissions resulting from animal farming in the area were estimated at 83,843 kg. Also, the carbon cost imposed on the region was investigated. This research can be precious for environmental decision-makers and policymakers.

## INTRODUCTION

Agriculture and animal farming are important sources of greenhouse gas (GHG) emissions and the pollution of water and soil resources (Panchasara et al., 2021). Animal products feed one billion people around the world (Sakadevan & Nguyan, 2017). Animals convert non-edible material (e.g., grass and waste) into high-quality foodstuff. Today, animal production systems influence global weather quality, soil quality, biodiversity, and water quality by changing the biogeochemical cycles of nitrogen, phosphorus, and carbon (GHG) (Hooda et al., 2000). However, intensive measures have polluted most rivers with various materials like N, P, and pathogens (like cryptosporidium). Animals generate manure that is used for crop production, and this manure contains nutrients such as nitrate, phosphate, and methane, as well as water and soil pollutants. Indeed, about 2 billion people in the world consume polluted water (WHO, 2019). The environmental impacts are manifested in the extensive eutrophication of rivers, the increased concentration of nutrients in water tables, and soil acidification (Cui et al., 2014).

On the other hand, animal farming activities are a significant source of GHG emissions, in addition to their role in emitting water and soil pollutants. The concentration of GHGs in the world has rapidly increased due to human activities since the pre-industrialization era, with adverse effects on the climate. Methane ($CH_4$) concentration has doubled, whereas atmospheric nitrogen oxide ($N_2O$) concentration is now 20% higher than its pre-industrialization levels (IPCC, 2013).

In the agricultural sector, animal production accounts for 14.5% of human-related emissions (Gerber et al., 2013) and about 37% and 65% of global $CH_4$ and $N_2O$ emissions, respectively (Steinfeld & Wassenaar, 2007; Rivera & Chará, 2021). Manure (feces and urine) that is managed and sedimented in pastures and grasslands is the second most significant source of GHG emissions after gastrointestinal methane and accounts for about 7% of $CH_4$ and $N_2O$ emissions by agriculture throughout the worldwide (Aguirre-Villegas & Larson, 2017). Livestock breeding and agriculture are the most important economic activities in Urzouyeih County. More than 246,000 light and heavy animals are raised in this area, which has a significant potential for pollutant and GHG emissions (AJDKP, 2022). The GHG emissions from livestock activities impose economic and social costs on society, leading to long-term climate changes, reduced human health, decreased well-being, and other adverse effects (IWGSCGG, 2021).

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[*] Corresponding author, Assistant Professor, Department of Agricultural Economics, University of Sistan and Baluchestan, Zahedan, I. R. Iran.
E-mail address: mhashemitabar@gmail.com

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Therefore, it is necessary to estimate the social cost of carbon in the area.

The present research used the constrained optimization model to estimate the rate of pollution emissions. The optimization model has been proven to be an effective and efficient method for managing water resources, agricultural lands, and environmental pollution (Li et al., 2020). The model is solved in this study by the interval single-objective mathematical programming technique, in which only the lower and upper boundaries are approximated (Yu et al., 2018). Finally, the outputs of the optimization model are used to estimate the social cost of carbon imposed on the area.

In an assessment of several river pollutants emitted by animal production worldwide, Li et al. (2022) concluded that cattle, pig, and chicken production accounted for 74-88% of the emissions to the rivers.

Zhang et al. (2022) studied the impact of agriculture and animal farming on heavy metal pollution in an aquatic environment and human health. Their findings revealed that agriculture significantly influenced the risk of arsenic hazard and the cancer risk of nickel and lead, while animal farming had a significant effect on the cancer risk associated with cadmium.

Li et al. (2020) reported that crop production and animal farming were the primary causes of GHG emissions and water pollution in the agricultural sector. The crop sector was found to emit more $CO_2$ and $N_2O$ than the animal sector, whereas the latter emitted more water pollutants and methane. To mitigate GHG emissions and water pollution from animal and crop residue, they proposed to generate biomass energy as a means of alleviating environmental pollution and reducing the consumption of fossil fuels.

In a non-point pollution estimation in Baiyangdian Basin, China, Tao et al. (2020) found that among the pollutants emitted from animal waste, chemical oxygen was the most abundant.

Sue et al. (2017), who studied low-carbon agriculture in Henan province, China, observed that labor, crop protection, and animal farming were the main contributors to carbon emissions in the agricultural sector.

In a study on nutrient recovery and emissions of ammonia, nitrous oxide, and methane from animal manure in Europe, Hou et al. (2017) concluded that the promotion of optimal manure treatment technologies could significantly contribute to achieving the $NH_3$ and GHG emission reduction goals set by the EU environmental policies.

Xiong et al. (2016) addressed the degree of impact on agricultural carbon emissions. They found that carbon emissions depended on a combination of the carbon intensity of cultivation, animal farming, and farm labor productivity. The economy was a factor involved in increasing agricultural carbon emissions, whereas efficiency was the primary factor inhibiting emission reduction.

Yun et al. (2014) investigated the spatial-temporal characteristics and the driving factor of agricultural carbon emissions in China. Their research revealed that farm inputs, paddy fields, soil, enteric fermentation, and manure management represented 33.59%, 22.03%, 7.46%, 17.53%, and 19.39% of the total agricultural carbon emissions, respectively.

Petersen et al. (2013) stated that methane and nitrous oxide constituted the greatest portion of GHG emissions in the animal farming sector. They also proposed centralized manure management as a way to reduce GHG emissions.

In a study on the reduction of GHG emissions, Johnson et al. (2017) reported that the manipulation of animal food regimes and manure management could reduce $CH_4$ and $N_2O$ emissions from animal farming.

The EPA's interim estimate for the social cost of carbon (SCC) is about $51 per ton of $CO_2$ using a 3% discount rate, which is applied in regulatory analyses to account for the economic impacts of $CO_2$ emissions. The IPCC compiles various estimates ranging from $50 to $150 per ton, depending on the assumptions about discount rates and economic models used. These figures highlight the range and importance of incorporating SCC in evaluating the economic impact of carbon emissions (Khabarov et al., 2022).

However, Rennert et al. (2022) rejected the EPA's $51 per ton and estimated the economic loss at $185 per ton using a new technique.

Archer et al. (2020) proposed a much higher ultimate cost of carbon at $100,000 per ton, taking into account long-term impacts, such as sea level rise over millennia. This approach highlights the immense burden on future generations, contrasting with the typical estimate of $100 per ton, which is influenced by economic discount rates. Their model emphasizes the extended duration and severity of climate change effects, aiming to offer a more comprehensive perspective on the long-term costs.

Previous research has primarily focused on the emissions of atmospheric pollutants, such as methane, nitrous oxide, and water and soil pollutants, including total P, total N, and ammoniacal nitrogen, mostly from solid manures. In contrast, the present work estimated the emission of various pollutants, such as total P (TP), total N (TN), total kalium (TK), ammoniacal nitrogen (NH-N), chemical oxygen (CO), and biochemical oxygen (BO) separately for liquid manure (urine) and solid manure (feces) by an interval uncertain optimization model in the Urzouyeih area. Additionally, the social cost of GHG emissions was estimated using the model's outputs.

## MATERIALS AND METHODS

Urzouyeih County, which has a hot climate, is located on latitude 28°27'21" N and longitude 56°21'54" E in the southwest of Kerman province. Fig. 1 shows the geographical location of the county. Livestock farming and agriculture are the most important activities in this area. Livestock farming is traditionally practiced through grazing in fields and pastures.

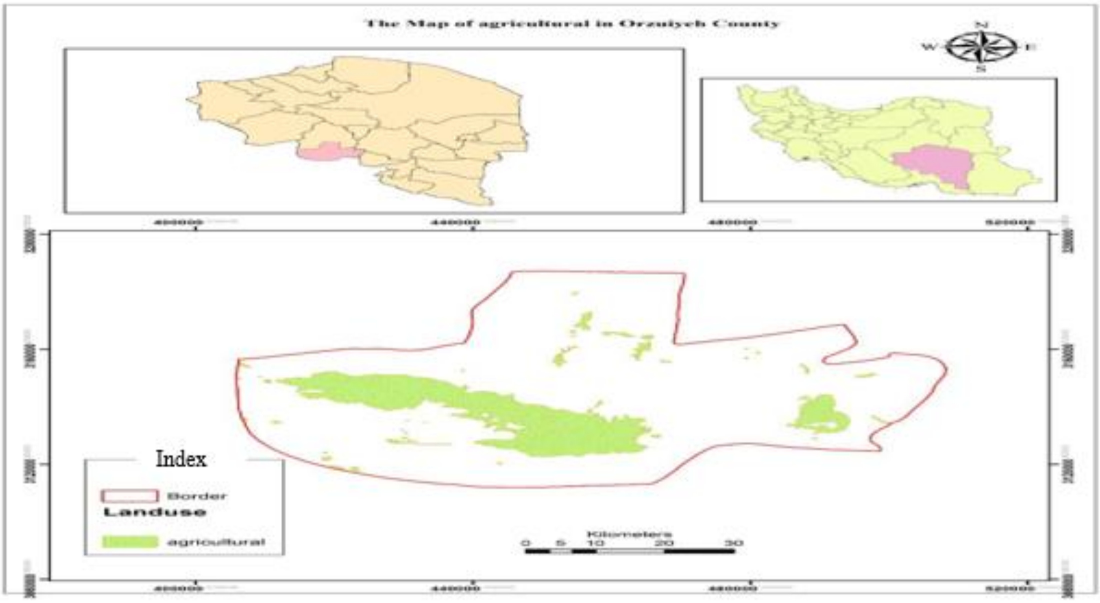

**Fig. 1.** The geographical location of Urzouyeih County.

The objective function for the optimization of environmental pollution can be defined by Eq. (1) (Eq. (2), Eq. (3), and Eq. (4) are expansions of the objective function) and constraints Eq. (5), Eq. (6), and Eq. (7) (Li et al., 2020):

$$Min\ EI^{\pm} = WP^{\pm}_{livestok} + \left(21E^{\pm}_{CH_4} + 310E^{\pm}_{N_2O}\right) \ (1)$$

in which EI represents environmental impacts (kg), $WP_{livestock}$ represents water pollution by livestock (kg), and $21E_{CH4}$ and $310E_{N2O}$ represent $CO_2$ equivalence of $CH_4$ and $N_2O$ emissions, respectively. EI is the dependent variable in the model, while WP, $E_{CH4}$, and $E_{N2O}$ represent the independent variables.

$$WP^{\pm}_{livestock} = \sum_{l=1}^{L} N_l \begin{pmatrix} ME^{\pm}_l \cdot \sum_{pl=1}^{PL} (\phi_{manu})_{pl,l} \cdot \tau^{\pm} \\ + UE^{\pm}_l \cdot \sum_{pl=1}^{pl} (\phi_{uri})_{pl,l} \cdot \tau^{\pm} \end{pmatrix} \ (2)$$

in which $N_l$ represents livestock count, $ME_l$ represents the coefficient of manure emission from each animal (kg/head), $(\Phi_{manu})p_{l,l}$ represents the coefficient of pollution emission from the manure of each animal, $\tau$ represents the coefficient of livestock pollutants entering water, $UE_l$ represents the coefficient of urine discharge per animal (kg/head), and $(\Phi_{uri})p_{l,l}$ represents the coefficient of pollutant emission for the urine of each animal. Table 1 presents the coefficient of pollutant emission from liquid and solid manures.

$$E^{\pm}_{CH_4} = \sum_{l=1}^{L} N_l \cdot \left(MEF^{\pm}_l + MM^{\pm}_l\right) \ (3)$$

in which $MEF_l$ is the coefficient of methane emission from enteric fermentation per animal (kg/head), and $MM_l$ is the coefficient of methane emission from manure handling of each animal (kg/head).

$$E^{\pm}_{N_2O} = \sum_{l=1}^{L} N_l \cdot NM^{\pm}_l \qquad (4)$$

in which $NM_l$ is the coefficient of $N_2O$ emission from manure handling (kg/ha). In Eq. (1), the global warming potential for the conversion of different forms of GHG emissions to $CO_2$ equivalent for $NH_4$ and $N_2O$ is 21 and 310, respectively (Li et al., 2020).

### Model constraints

Three constraints were defined for the model (Li et al., 2020). A livestock use policy constraint (a higher and upper limit) must be considered for the number of animals in each area to include the food requirement, common production methods, and regional planning. This constraint can be represented by Eq. (5).

$$N_{min,l} \leq N_l \leq N_{max,l} \quad and \quad N_l = integer\ (5)$$

in which $N_{max}$ and $N_{min}$ represent the minimum and maximum number of each livestock (head), respectively.

The water supply allocated for animal husbandry in the area should not be less than the water consumption of the livestock. This constraint can be expressed by Eq. (6).

$$\sum_{l=1}^{L} N_l \cdot DWQL^{\pm}_l \leq WS_{livestock} \ (6)$$

in which $DWQ_l$ represents the drinking water quota for each animal ($m^3$/head), while $WS_{livestock}$ denotes the total water supply for livestock in the area ($m^3$).

The other constraint is that no decision variable can be negative, which is expressed in Eq. (7).

$$N_l > 0 \quad (7)$$

In all equations, *l*, *pl*, *manu*, and *uri* are the subscripts for animal type, pollution emitted from each animal, the solid manure of the animal, and the liquid manure of the animal, respectively.

**Table 1.** The coefficient of pollutant emission from animal manure (per liter)

| Parameter | Symbol | Livestock type | BO | CO | NH-N | TN | TP | TK |
|---|---|---|---|---|---|---|---|---|
| Coefficient of pollutant emission from solid manure (feces) | $(\Phi_{manu})p_{l,l}$ | Cattle | 0.0245 | 0.031 | 0.0017 | 0.0045 | 0.0012 | 0.01 |
| | | Sheep | 0.0041 | 0.0046 | 0.0008 | 0.0075 | 0.0026 | 0.002 |
| | | Goat | 0.0041 | 0.0046 | 0.0008 | 0.0075 | 0.0026 | 0.002 |
| Coefficient of pollutant emission from liquid manure (urine) | $(\Phi_{uri})p_{l,l}$ | Cattle | 0.004 | 0.006 | 0.0035 | 0.008 | 0.0004 | 0.015 |
| | | Sheep | 0.005 | 0.006 | 0.0035 | 0.008 | 0.0004 | 0.01 |
| | | Goat | 0.005 | 0.006 | 0.0035 | 0.008 | 0.0004 | 0.01 |

The data for the model were collected for the period of 2016-2021 from the Agriculture Organization of Kerman province (AJDKP, 2022; Mousapour et al., 2023). The coefficients and parameters were all derived from Li et al. (2020), Su et al. (2017), and Xoing et al. (2016). To solve the model, the maximum and minimum values of the objective function were first estimated. Then, the optimal values for GHG emissions were determined by extending the fuzzy best-worst method (Debnath et al., 2023; Yazdani et al., 2022; Li et al., 2020) and genetic algorithm (Tu et al., 2022).

## RESULTS AND DISCUSSION

In Urzouyeih, light livestock is remarkably more populated than heavy livestock. Goats, with a population of 143,153, are the most populated livestock in the area, followed by sheep and cattle in the next ranks with populations of 98,997 and 3,933, respectively. The quantity of manure produced by an animal depends on various factors, including body weight, size, age, amount of feed, and type of animal (Avcioğlu and Türker, 2016). Area data indicate that, on average, each cow produces 14.45-14.78 kg of manure daily. Additionally, sheep and goats produce 1.34-1.39 kg and 1.20-1.26 kg of manure daily, respectively.

Also, field research shows that the urine of each animal is almost 50% feces, which was consistent with previous studies (Li et al., 2020).

Cattle, as heavy livestock, annually produce 5,396 kg of solid manure and 2,698 kg of liquid manure. Also, sheep and goats annually produce 510 and 460 kg of solid and 255 and 230 kg of liquid manure, respectively. Table 2 presents the livestock population and the maximum manure production by each animal.

### Emission of water and soil pollutants

The wise and sustainable application of manure can help feed crops with nutrients and apply less mineral fertilizers. However, sustainable and environmentally friendly management of manure (production, storage, and application) has been very slow in many countries since manure is considered a residue (waste), not a source. Understanding the dynamism of the nutrients applied by fertilizers under changing environmental conditions helps develop management methods that reduce the risk of fertilizers' environmental pollution in livestock production systems. Along with producing dairy and protein, animals are a source of air and water pollutants. In the animal farming sector, cattle are the biggest emitter of water and soil pollutants. In this sector, dairy cattle are more polluting since they consume more forage to produce more milk. The main pollutants emitted from solid manure (feces) include TP, TN, TK, NH-N, CO, and BO. The highest annual pollutant emission from the cattle's solid manure is CO, reaching 167.27 kg, and the lowest is TP at a rate of 6.47 kg/year. The annual emission rate of each pollutant from solid cow manure was estimated using the first part of Eq. (2), which can be seen in Fig. 2.

**Table 2.** The maximum manure production rate per annum

| Livestock | Population | Solid manure per animal per year | Liquid manure per animal per year |
|---|---|---|---|
| Cattle | 3933 | 5396 | 2698 |
| Sheep | 98997 | 510 | 255 |
| Goat | 143153 | 460 | 230 |

The solid manure of light livestock, including sheep and goats, can emit all pollutants emitted from the cattle's solid manure, but at significantly different rates. As is evident in Fig. 3, the highest emission rate for the light livestock is related to TN, which is 3.82 kg for sheep and 3.45 kg for goats, and the lowest is related to ammoniacal nitrogen, which is 0.40 kg for sheep and 0.36 kg for goats. In total, 392.82 kg of pollutants are emitted from the feces of cattle in a year, while this figure is 11.06 kg for sheep and 9.93 kg for goats. It is observed in Fig. 2 and Fig. 3 that the highest pollutant emitted from cattle is CO, but it is TN for sheep and goats. The emission rate of various pollutants from sheep and goats solid manure was estimated using the first part of Eq. (2). In the study of Li et al. (2020), CO was the pollutant in cattle feces with the highest rate of emission, whereas TN had the highest rate of emission in the feces of light livestock, including goats and sheep. Tao et al. (2020) investigated pollutant emissions of manures. However, they did not consider the pollutants of feces and urine separately. They found that CO had the highest rate of emission from the animals. Our results, therefore, corroborate those reported by Li et al. (2020) and Tao et al. (2020).

Fig. 2 and Fig. 3 display the rate of pollutant emissions from solid manure. However, liquid manure (urine) also emits solid manure pollutants into water and soil. The pollutants with the highest rate of emission from the cattle manure are TK, TN, CO, BO, NH-N, and TP, respectively. In total, 40 kg of TK and 1 kg of TP enter water tables, surface waters, agricultural lands, and pasture soils from the urine of each cattle every year. The pollutants emitted from the cattle's liquid manure are presented in Fig. 4.

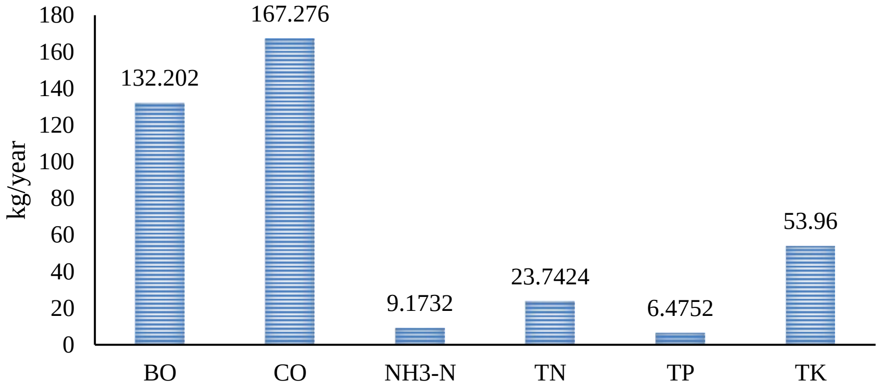

**Fig. 2.** The rate of pollutant emissions from the solid manure for each cattle (yearly).

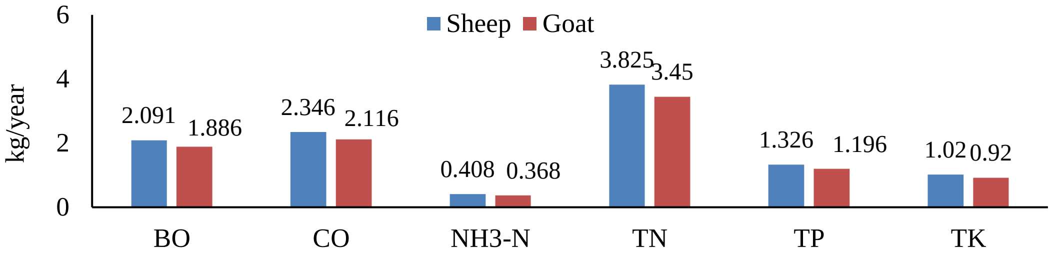

**Fig. 3.** The rate of pollutant emission from the solid manure for each sheep and goat (yearly).

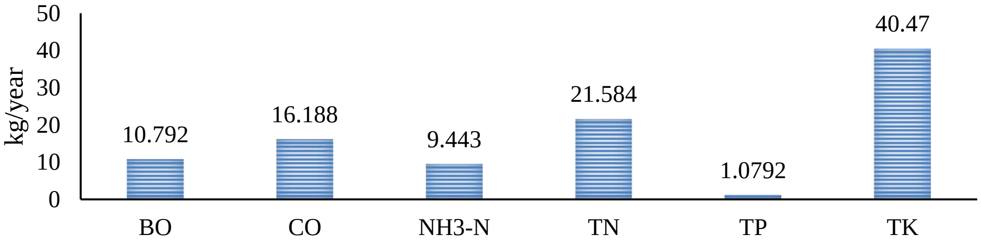

**Fig. 4.** The rate of pollutant emissions from the liquid manure for each cattle (yearly).

Pollutants also emit from the liquid manure of the light livestock as they do from that of the cattle. The highest emission rate is for TK from sheep (2.55 kg) and goats (2.3 kg), and the lowest is for TP (0.10 kg for sheep and 0.9 kg for goats). Cattle, sheep, and goats are among the biggest emitters of water and soil pollutants in Urzouyeih by their solid and liquid manures. Fig. 5 displays the rate of pollutant emissions from the liquid manure of light livestock. The total pollutant emitted to the environment from the urine of cattle is 99.5 kg/year, whereas it is 8.38 and 7.56 kg/year for sheep and goats, respectively. The emission rate of different pollutants from cattle, sheep, and goat liquid manure was estimated from the second part of Eq. (2), which can be seen in Fig. 4 and Fig. 5. Accordingly, the highest rate of emission from the urine of all three animals belongs to TK. In general, cattle are more polluting than the other two animals. The emissions from their feces and urines are 38.5 and 12 times as great as those from the feces and urine of the other two animals, respectively. Unlike the emissions from feces, the rates of pollutants emitted from the urine of cattle, sheep, and goats are similar, and the highest is for TK. This finding agrees with the results of Li et al. (2020).

Methane emission from animal farming enteric

fermentation depends on the daily intake of the animals. At all reporting levels, cattle are divided into two primary groups: dairy cattle and others. Other animals are categorized based on sex, age, and nutritional status. The default methane emission by dairy cattle varies from 40 kg/year in Africa and the Middle East to 121 kg/year in North America. For the other groups, it varies from 27 kg in India to 60 kg in Oceania (IPCC, 2006). To calculate the rate of methane emission from enteric fermentation, the emission rate can be multiplied by the number of animals in the area (Eq. (3)). Based on Li et al. (2020), we assumed the maximum and minimum emissions to be 47.8-65, 4.98-5, and 4.98-5 for cattle, sheep, and goats, respectively. These values show the enteric fermentation for each animal in one year. Cattle have an absolute advantage in this emission to all light animals. Its methane emission is 10 times as great as that of light livestock. However, the light livestock population (goats and sheep) had the highest rate of methane emission by enteric fermentation in the study site since they were the dominant animals. Fig. 6 displays the minimum and maximum enteric fermentation of each animal.

### Methane emission from manure management

The rate of GHG emissions from manure storage and treatment depends on the amount of manure, its carbon and nitrate content, which is decomposed anaerobically, and the storage temperature, duration, and type. Methane emission from manure management is the result of the animal population in each category multiplied by the emission coefficient of that group (Eq. (3)). In this research, the emission coefficient was derived from Li et al. (2020). The values of 8.89-16, 0.11-0.16, and 0.11-0.16 were used for the methane emission from manure management per animal per year for cattle, sheep, and goats, respectively. Based on the results, cattle have the highest rate of methane emission from manure management in the study site since its manure management emission coefficient is almost 1000 times as great as that of the light livestock. Fig. 6 depicts the rate of methane emission from manure management in the area for different animals. According to the results, cattle have the highest methane emissions per animal. But, the conditions vary for the population of different animals in the area. The highest enteric fermentation emission for the area is related to goats, amounting to 715765 kg/year. On the other hand, cattle account for the highest rate of methane emission from manure management in the area.

Goats, whose population is approximately 36 times as great as cattle, have lower methane emissions from manure management because the coefficient of methane emission from manure management is 100 times as great for cattle as for light livestock. So, cattle have a higher capacity for methane emission from both enteric fermentation and manure management. In total, the total annual methane emission from the enteric fermentation of cattle is higher than that from its manure management. This is consistent with the reports of Su et al. (2017), Yun et al. (2014), and Xiong et al. (2016) in which methane emission has been reported to be higher from enteric fermentation than from manure management. However, manure management emits not only methane but also $N_2O$ (Li et al. 2020).

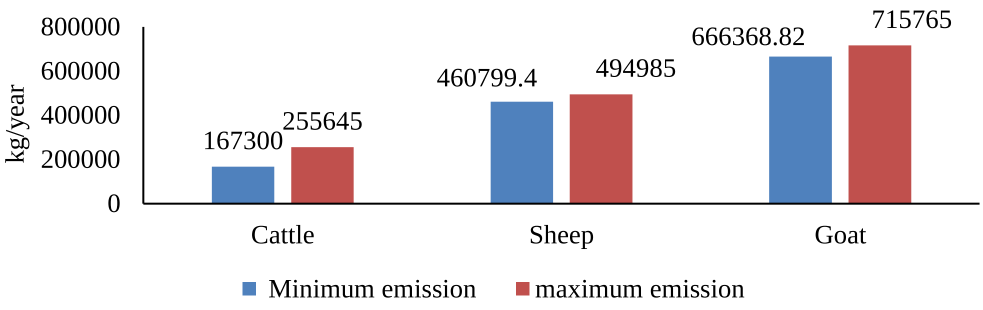

**Fig. 5.** The rate of pollutant emissions from the liquid manure for each sheep and goat (yearly).

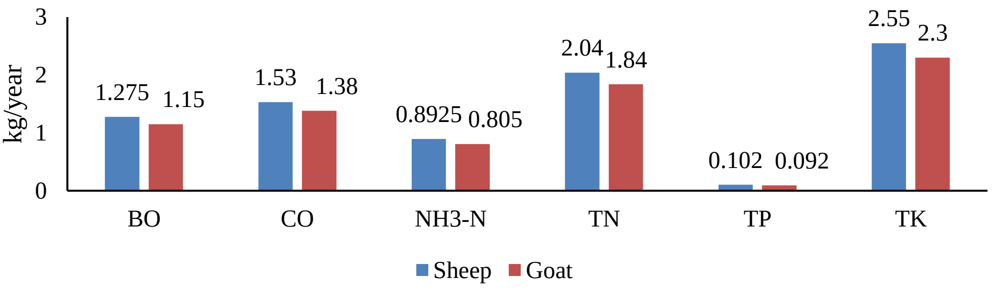

**Fig. 6.** The minimum and maximum annual emissions from enteric fermentation of each animal (kg).

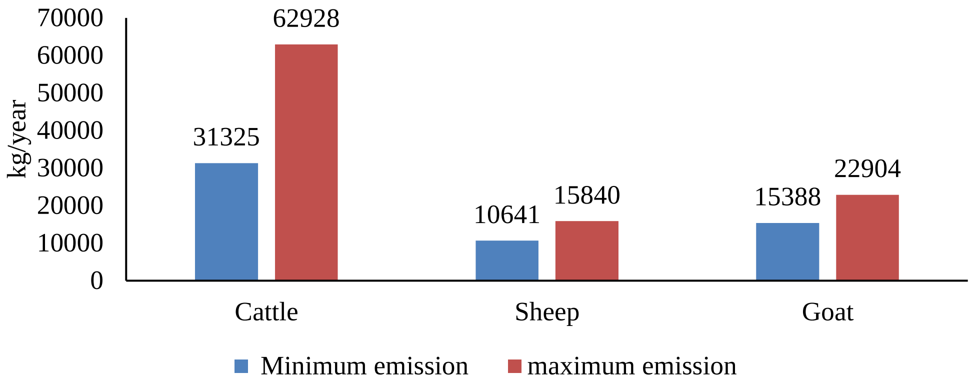

**Fig. 7.** The minimum and maximum yearly methane emissions from manure management of each animal (kg).

### $N_2O$ emission

$N_2O$ emissions are the result of ammonium nitrification to nitrate or partial denitrification of nitrate. It can be emitted directly from stored fertilizers, organic fertilizers, or mineral fertilizers applied to the soil or from the direct deposition of nitrogen by grazing animals (Crosson et al., 2011). In addition, indirect agriculture-related $N_2O$ emission is caused by manure evaporation. Nitrogen penetrates soil texture and water tables by runoff and leaching from farmlands and pastures. Manure emits not only methane but also $N_2O$, which mostly pollutes surface water, groundwater, and soil texture. In this study, the $N_2O$ emissions from the dominant livestock in the area were estimated using Eq. (4). The maximum and minimum $N_2O$ emission for each animal was derived from Yun et al. (2014), Su et al. (2017), Zhang et al. (2016), and Li et al. (2020) to be 0.35-1, 0.22-0.33, and 0.22-0.33 for cattle, sheep, and goats, respectively. Among the animals, cattle have the highest rate of $N_2O$ emission to the water and soil in the area. However, since goats are the most crowded, they account for the highest amount of $N_2O$ emission, amounting to 47240 kg/year.

It is evident in Fig. 6, Fig. 7, and Fig. 8 that the rate of methane emission is much greater than that of $CO_2$, which is consistent with Su et al. (2017) and Philippe and Nicks (2015). The rate of $N_2O$ emission is almost three times as great from cattle manure as from the manure of light livestock. This means that methane emitted from the animal sector has the greatest share in GHGs emitted, which agrees with Rivera and Chará (2021) and Ji and Park (2012).

The estimation of the optimization model reveals that in the Urzouyeih area, the total emissions of pollutants and GHGs are, at least, $4.93 \times 10^7$ and, at most, $6.02 \times 10^7$ kg $CO_2$ equivalent, out of which methane accounts for, at most, $1.56 \times 10^6$ kg. According to Eq. (1), the thermal energy of methane is 21 times as great as that of $CO_2$. This means that $1.56 \times 10^6$ kg of methane emission by the animal farming sector is equivalent to $3.29 \times 10^7$ kg $CO_2$.

### Social cost of carbon

The social cost of carbon (SCC) represents the estimated economic damage associated with emitting one additional ton of carbon dioxide into the atmosphere. It encompasses a wide range of impacts, including health costs, environmental degradation, and reduced agricultural productivity, which collectively strain economies and societies. By quantifying these costs, the SCC provides a crucial metric for policymakers to assess the benefits of reducing GHG emissions and to implement more effective climate change mitigation strategies (EPA, 2023).

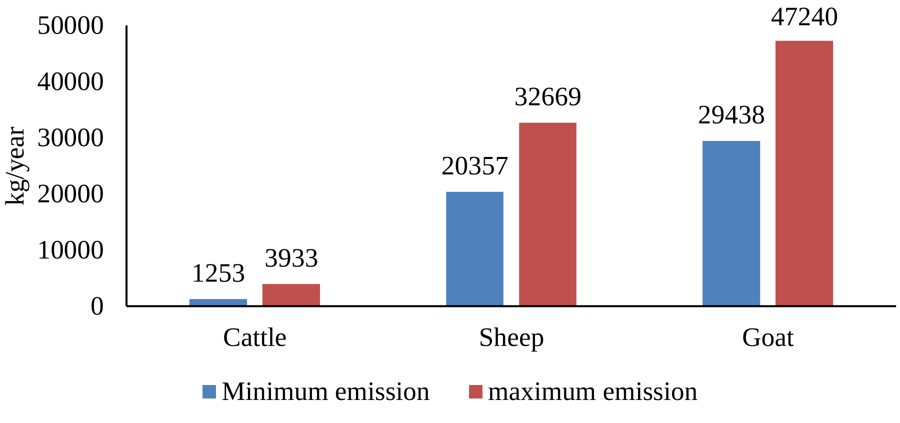

**Fig. 8.** The minimum and maximum $N_2O$ emission for each anima (yearly).

**Table 3.** Maximum cost of carbon imposed on the area

| Source | Social cost per ton of $CO_2$ ($) | Total $CO_2$ emissions from livestock farming in the area (ton) | Total social cost of $CO_2$ emissions in the area ($) |
|---|---|---|---|
| EPA | 51 | $6.02 \times 10^4$ | 3,070,200 |
| IPCC (Average) | 100 | $6.02 \times 10^4$ | 6,020,000 |
| Rennert et al. (2022) | 185 | $6.02 \times 10^4$ | 11,137,500 |
| Archer et al. (2020) | 100000 | $6.02 \times 10^4$ | 6,020,000,000 |

According to the model's output, $6.02 \times 10^4$ tons of carbon dioxide are released annually from livestock farming activities in the area. The SCC, however, varies across different studies. Table 3 presents these varying social cost estimates. Rennert et al. (2022) provide a more comprehensive estimate of the SCC using newer methodologies compared to the EPA and IPCC studies, and this estimate was utilized in this research. Based on Table 3, the SCC from animal husbandry activities in the area amounts to $11,137,000.

In Mousapour et al. (2023), the economic profit from cattle, sheep, and goat farming in the Urzouyeih area for 2021 was estimated at $7,006,392, which is 59% less than the social cost imposed on the area. It is noteworthy that the benefit of livestock farming in the area exceeds the social cost estimates provided by the EPA and IPCC. However, the forecast by Archer et al. (2020), which considers a period of one million years, is beyond the scope of this research.

As a result, if the output is compared to the study by Rennert et al. (2022), animal husbandry activity in the area is not cost-effective from an environmental point of view. However, when compared with the EPA and IPCC studies, it appears to be cost-effective environmentally.

## CONCLUSION

In conclusion, sustainable manure management offers significant potential to provide crop nutrients and reduce dependency on mineral fertilizers. However, its implementation has been slow, primarily because manure is often viewed as waste rather than a resource. Effective management requires understanding nutrient dynamics under varying conditions to minimize pollution in livestock systems.

Cattle, especially dairy cattle, are significant contributors to air and water pollution, emitting high levels of pollutants, such as CO and TN. Although sheep and goats also emit these pollutants, their rates are lower compared to cattle. Both solid and liquid manure from livestock significantly impact the environment, necessitating robust management strategies.

Methane and nitrous oxide emissions from manure management and enteric fermentation are substantial, particularly from cattle. This highlights the need for targeted mitigation strategies. Comprehensive manure management, informed by scientific research and supported by appropriate policies, is essential for reducing the environmental footprint of livestock farming and promoting agricultural sustainability, while aligning with climate change mitigation efforts.

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## CRediT AUTHORSHIP CONTRIBUTION STATEMENT

All authors contributed to the conception and design of the study. Data preparation, collection and analysis were done by [Shoja Mousapour], [Mahmoud Hashemi Tabar] and [Mehdi Safdari]. The first draft of the manuscript was written by [Shaja Mousapour] and [Ali Sardar-Shahreki], and all authors commented on earlier versions of the manuscript. All authors read and approved the final manuscript.

## DECLARATION OF COMPETING INTEREST

The authors have no relevant financial or non-financial interests to disclose.

## ETHICAL STATEMENT

In this study, no human or animal experiments were performed.

## DATA AVAILABILITY

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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