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The Emission from Rabbits Breeding in Slovakia

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Abstract: Statistical surveys about rabbits in households brought interesting results about their breeding. The survey shows that approx. 8.3% of Slovak households breed rabbits, of which the majority are bred in the countryside (61%), followed by breeding in cities (35%), and 4% of households stated both options. As part of the investigation, information was also obtained on the method of breeding rabbits. The results showed that housing with the restriction of movement is the predominant breeding method. Housing without the restriction of movement is higher in cities compared to rural areas, while free breeding is absent in households for both options. The information on excrement recovery showed that approximately 59.5% of all farm waste is composted, 15.8% of respondents said that they apply farm excrement to the soil, and the remaining respondents did not answer. The post-processing survey results led to new estimates of methane and nitrous oxide emissions from domestic rabbit farming. The emissions were estimated using the methodology of the tier 2 approach outlined in the IPCC 2019 Refinement. The results indicated that rabbit breeding in households and farms in Slovakia generates an average of 0.51 Gg of methane and 0.13 Gg of nitrous oxide annually. Additionally, when free-range rabbit breeding is considered, emissions are 0.001 Gg of nitrous oxide. These greenhouse gas emissions from rabbit farming contribute to 7% of the total emissions from animal farming, ranking it as the third highest emitter after sheep. Consequently, it is imperative to prioritize the inclusion of this category in Slovakia's national emissions report.

Keywords: rabbits; breeding; emission; estimations; GHG

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1. Introduction

Climate change is the biggest challenge in modern history. The increase in human-induced greenhouse gas (GHG) emissions disrupts the earth's energy balance and causes a rapid rise in global temperature.

Approximately 14.5% of global anthropogenic GHG emissions are caused by livestock farming-related activities [1]. In Slovakia, animal breeding and crop production produce approximately 6% of total GHG emissions. Taking into consideration the CO_2 emissions since 1850, almost 17% of the cumulative CO_2 emissions occur between 2010 and 2019 [2]. Livestock farming is known for its contribution to GHG emissions and is responsible for 2.5 Gt of CO_2 eq. per year in Slovakia. The emission inventory of greenhouse gases in the agriculture sector contains information on the numbers, methods of breeding, and disposal of livestock waste. The Ministry of Agriculture and Rural Development of the Slovak Republic monitors the most economically important animals in cooperation with the Statistical Office of the Slovak Republic (ŠÚ SR); however, there are also fewer significant animals that are kept in domestic conditions and are not statistically monitored, for example, cats, dogs, and other fur animals, data on their numbers are missing, and an official collection of that kind of information is not systematically monitored. The aim of the study is to determine and review the information about the number of rabbits in Slovakia, which are bred in commercial farms and households, and only the anthropogenic emissions are estimated in this article. During the preparation of the study, important questions were formulated about how to manage manure production and whether farmers and households use abatements to cut emissions from breeding. This information is important for national entities that produce national emission inventory submissions in terms of completeness and the improvement of inputs into the national inventories of greenhouse gases and inventories of air pollutants, and for other kinds of regulation, for example, veterinary considerateness and welfare of animals. Several studies have been carried out in order to study rabbit management, nutrition, and genetics, but the impact on environmental pollution of this activity is not well known. In particular, few research papers can be found related to the emissions from rabbits. Quantifying and mitigating the environmental impact of the livestock sector is part of global interest as it plays an important role in global climate change [3,4]. Although accurate estimation of greenhouse gas (GHG) emissions from livestock production systems is complex, there are several available tools to assist with the emissions estimation [5]. A rabbit breed's production efficiency depends on the feed conversion and quantity of meat. Rabbits are mono-gastric herbivores. During their breeding, a diet is required, characterized by a high level of fiber that contributes significantly to poor feed conversion [3]. The primary assumption about the rabbit's breeding is a significant contribution to greenhouse gas emissions.

Different studies on mono-gastric species [3,6] reported that the main contributor to environmental impacts was feed production, in particular, purchased protein feeds, especially soybean meal, which is associated with deforestation-related emissions. Large amounts of manure produced are generated globally by livestock farming systems [7] and include an estimated global N content of 81.5–128.3 Tg yr.$^{-1}$ [8]. In Slovakia, livestock farming systems produce approximately 113.7–44.6 Gg yr.$^{-1}$ of nitrogen [9]. Intensive farming systems are a considerable challenge arising from improper manure and sewage management, with many potential adverse consequences, including climate change, eutrophication, acidification of ecosystems, and damage to biodiversity and human health [10]. Manure is a valuable by-product of animal agriculture. It fertilizes crop fields by delivering a full spectrum of plant nutrients and organic matter; however, treating and utilizing manure can be a particularly challenging task for modern animal feeding operations that are specialized in intensive production. These systems produce a considerable surplus of manure, which has a high risk of becoming a source of air, water, and soil pollution as well [11]. Manure denotes the mixture of animal excreta, beddings, feed, washing water, and other processes that generate waste from animal operations [12]. The contents of manure vary by the design of animal housing and manure collection system. Manure can be a liquid, slurry, or solid according to its dry matter level. Stored manure must be stored in an environmentally safe way without causing damage to soil, water resources, and agricultural production. Similarly, its transport has to be ensured so that it will not pose a threat to water pollution or the environment [13]. Manure management systems generally include manure handling, collection, processing/treatment, storage, and land application components. The physio-chemical composition and characteristics of excreted dairy and swine manure, i.e., total solids and the concentration of nitrogen, are highly dependent on the diet, breed, animal weight, and production stage [14]. In Slovakia, manure management systems and their abatements reduced nitrogen emissions, but it is tough to estimate the impact in the Slovak Republic due to a lack of official published statistical information. It has always been challenging to model gas emissions from manure management systems due to the variability in farming practices that affect the manure's physio-chemical characteristics [15]. In stored animal slurry, the NH_3, N_2O, and NO emissions are determined by a complex system, including physical and chemical processes and microbial function. Higher temperatures significantly increased the production of ammonia emissions and methane [16,17].

2. Materials and Methods

2.1. Data Collecting

For the purposes of this study and analysis of emissions from rabbit breeding in Slovakia, the following two data sources were used: data from commercial rabbit breeding farms (National Emission Inventory Database, Slovak Hydrometeorological Institute, Bratislava, Slovakia), and data from households (Slovak Survey data, Bratislava, Slovakia), which were collected for analysis purposes (Figure 1).

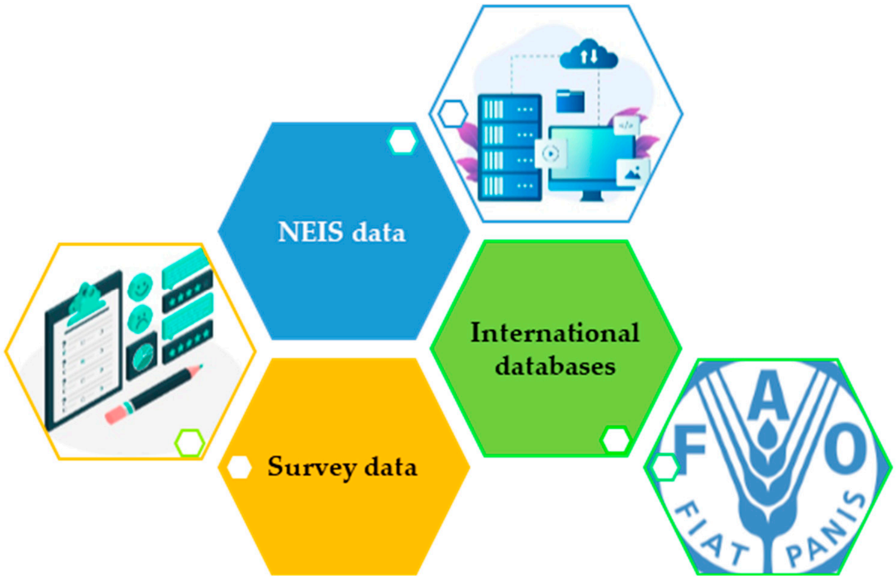
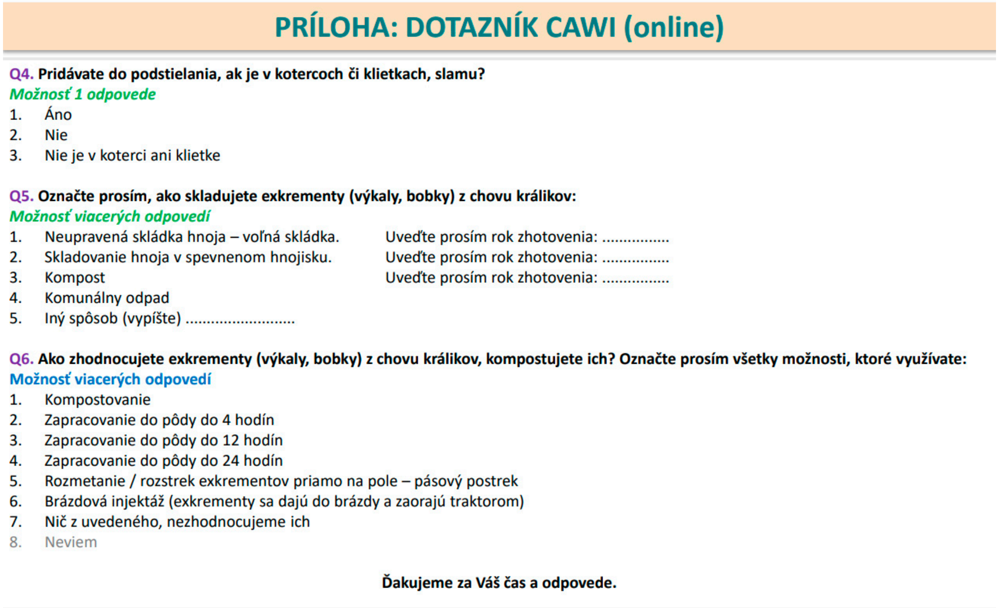


Figure 1. Sources of information.

The statistical survey on the breeding of rabbits in households in Slovakia with a focus on the number and method of breeding proceeded. The survey (Figure 2) was performed with a combined hybrid method for data collection using the online survey method with a computer-assisted telephone interview. The combined hybrid data collection using the computer-assisted web interviews (CAWI method) was proposed, in which there were approximately 10,000 respondents. The data collection was held from 23 June to 13 July 2022. The first question was about whether they have (keep) rabbits in the household. Those who, as part of the screening, answered that they keep rabbit(s) were subsequently asked questions from the prepared questionnaire. In this way, 250 answers were obtained, i.e., suitable respondents for the second round of research. The second round was carried out by computer-assisted telephone interview (CATI method), in which a representative sample of the adult population in Slovakia (N = 1000 adult inhabitants of the Slovak Republic) was addressed with the same question—whether they keep rabbits. The CATI method is processed as structured telephone survey interviews conducted by an interviewer who records the answers to mostly closed-ended questions [18]. This method was used to determine the percentage of rabbit breeders in the Slovak population. It was assumed that from the sample of 1000 respondents, 10–50 suitable respondents (rabbit breeders) would be obtained through screening. In the end, it was possible to receive answers from 83 respondents.

Using this method, in the first step, the percentage of rabbit breeders with equal representation of the urban and rural populations was determined. The survey shows that approx. 8.3% of Slovak households breed rabbits (3% as a pet, 0.4% for exhibitions, 4.9% for meat and fur), of which the majority are bred in the countryside (61%), followed by breeding in cities (35%) and 4% of households stated both options (Figure 3). One important aspect of data collection process, conducted through the CAWI method, was to gather information on the rabbit's manure handling in households. This information is crucial for GHG emissions inventory, specifically related to animal husbandry. Households were asked about their ways of excrement storage (recover or dispose). The designed questionnaire (Figure 2) aimed to maximize data yield and ensure that the respondents understood the questions clearly. The questions were carefully crafted to encourage comprehensive responses and to maximize the utilization of the research results in emissions modeling and reporting.



PRÍLOHA: DOTAZNÍK CAWI (online)

Q4. Pridávate do podstielania, ak je v kotercoch či klietkach, slamu?
Možnosť 1 odpovede
1. Áno
2. Nie
3. Nie je v koterci ani klietke

Q5. Označte prosím, ako skladujete exkrementy (výkaly, bobky) z chovu králikov:
Možnosť viacerých odpovedí
1. Neupravená skládka hnoja – voľná skládka. Uveďte prosím rok zhotovenia: ....
2. Skladovanie hnoja v spevnenom hnojisku. Uveďte prosím rok zhotovenia: ....
3. Kompost Uveďte prosím rok zhotovenia: ....
4. Komunálny odpad
5. Iný spôsob (vypíšte) ....

Q6. Ako zhodnocujete exkrementy (výkaly, bobky) z chovu králikov, kompostujete ich? Označte prosím všetky možnosti, ktoré využívate:
Možnosť viacerých odpovedí
1. Kompostovanie
2. Zapracovanie do pôdy do 4 hodín
3. Zapracovanie do pôdy do 12 hodín
4. Zapracovanie do pôdy do 24 hodín
5. Rozmetanie / rozstrek exkrementov priamo na pole – pásový postrek
6. Brázdová injektáž (exkrementy sa dajú do brázdy a zaorajú traktorom)
7. Nič z uvedeného, nezhodnocujeme ich
8. Neviem

Ďakujeme za Váš čas a odpovede.

Figure 2. Survey questionnaire (in Slovak language).

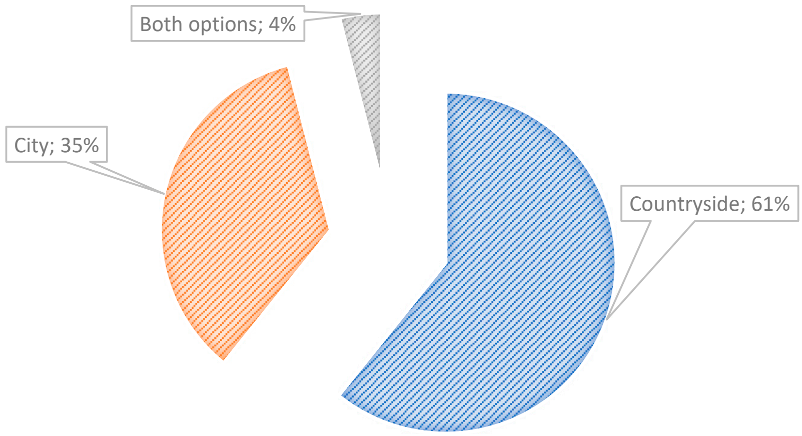


Figure 3. Information on the distribution of rabbit population from households.

The Slovak Hydrometeorological Institute (SHMÚ) administers the National Emission Information Systems. The NEIS has information about the emissions of pollution and abatements used by farmers. The SHMÚ conducts the NEIS under the Act of the Ministry of the Environment of the Slovak Republic No. 137/2010 Coll. on air [19] and Decree of the Ministry of the Environment of the Slovak Republic No. 410/2012 Coll [20]. The farmers, the operators of the source of air pollution, provide emission declarations to the District Environmental Office. This emission announcement contains detailed information about air pollution sources, emitted emissions, and air pollution charges into the relevant district in prescribed forms. The ŠÚ SR does not dispose of official information about the number of rabbits, manure storage systems, and abatement information. In the NEIS, only information from farms is available and was used for this study. The farms from the NEIS were examined analogically, and numbers of livestock and abatements were investigated, for example spreading after 12 and 24 h, storage for liquid and solid manure, and breeding situations of rabbits in farms. In the NEIS, no abatement systems, were registered and housing in cages has prevailed in rabbit farms.

2.2. Emissions Calculation Methodology

The post-processing survey results led to new estimates of methane and nitrous oxide emissions from domestic rabbit farming. To determine methane emissions from the storage of manure and slurry, tier 2 approach was used according to the 2019 IPCC Refinement methodology manual (Table 1).

Table 1. Parameters used for the calculation of methane from manure management and enteric fermentation.

Parameters			Sources of Parameters
Emission factor–enteric fermentation	kg CH_4 animal^{-1} year^{-1}	0.143	[21]
Emission factor–manure management	kg CH_4 animal^{-1} year^{-1}	0.001	Calculated value base of [22]
B_0	(m^3 kg VS)^4	0.32	[22]
VS	(kg vs. day^{-1})^4	0.10	[22]
$N_{cdg(s)}$	kg N year $^{-1}$	0	Base of survey
	MCF		
Municipal waste	%	0	[22]
Composting–Passive windrow	%	1	[22]
Solid storage–unconfined piles or stacks	%	2	[22]
Solid storage–covered/compacted	%	2	[22]
Solid storage–Bulking agent addition	%	0.5	[22]

The calculation of the methane emission factor from the storage of manure and slurry is based on the number of volatile solids (VS). VS can alternatively be obtained from laboratory measurements, which are absent in Slovakia and neighboring countries. The maximum methane production potential (B_0) is not a common parameter for all animal species; it depends on the feeding regime and is the theoretical yield of methane based on the amount of vs. in the manure. VS found in organic materials consists of biodegradable and non-degradable fractions vs. is determined on the basis of information on feed intake by animals. The content of vs. in manure is equal to the fraction of consumed feed that is not digested and thus excreted in the form of faces and urine (manure).

Methane conversion factor (MCF) is directly dependent on ambient temperatures. Each manure handling system has its MCF. National MCF values are not available, so they were taken from the 2019 IPCC Refinement [22] methodological manual, Table 10.17. MCF is designed for a specific manure management system. B_0 (the maximum methane-producing capacity of manure) varies according to the animal type and the feeding method. The amount of methane generated by a specific manure management system is affected by the number of volatile solids, the extent of anaerobic conditions present, the temperature of the system, and the retention time of the organic material in the system.

Liquid systems are sensitive to temperature changes. Average annual MCF values for a particular system are largely determined by the amount of vs. in the storage system during periods of maximum temperatures [23].

It is a good practice to ensure the uniformity of the definition of climatic zones. For the calculation, a cold climate zone was selected. All these parameters are included in the calculation of the emission factor (Equation (1)):

$$EF = (VS \times 365) \times \left[B_o \times \frac{0.67\text{kg}}{\text{m}^3} \times \sum \frac{MCF}{100} \times AWMS \right] \quad (1)$$

where: VS = amount of volatile solids in excrement in kg of animal dry matter $^{-1}$ day $^{-1}$ 365 = coefficient for the annual production of vs. in days, B_o = maximum production potential of methane arising from manure, for an individual category of farm animal in

m^3 CH_4 kg^{-1}), 0.67 = conversion factor in m^3 CH_4 per kilogram of CH_4, *MCF* = methane conversion factor by category and for the selected climate region (%), AWMS = share of manure system in %.

N_2O emissions were balanced based on tier 2 approach (Equation (2)), which was taken from the 2019 IPCC Refinement [22] methodological manual. The principle is to estimate rabbits' average annual rate of nitrogen excretion. Slovakia does not have a national value; therefore, it was taken from the named methodological guidebook (Table 2). By multiplying the annual rate per rabbit with the amounts for all households in Slovakia, the total rate of produced nitrogen per year for all rabbits was obtained. In the next step, the annual rate for all rabbits is redistributed proportionately between the types of excrement management systems. Shares were obtained on the basis of a survey. The degree of denitrification in manure is different depending on the fertilization systems used, this feature also affects the resulting emission factor, and each fertilization system generates a different amount of emissions; thus, the emission factor used is different when storing manure in an open, unconsolidated landfill and different in a consolidated manure field. Emission factors specific to Slovakia do not exist, so the default emission factors from the 2019 IPCC Refinement [22] manual were used in the balancing. The used parameters are available in Table 2.

$$N_2O_{D(\mathrm{mm})} = \left[\sum_{S}\left[\sum_{T,P}\left((N \times N_{Ex}) \times AWMS\right) + N_{cdg(s)}\right] \times EF_3\right] \times \frac{44}{28} \quad (2)$$

where: $N_2O_{D(\mathrm{mm})}$ = emissions of N_2O from the storage of fertilizers and manure, N = conditions of rabbits, N_{Ex} = average annual rate of nitrogen excretion by rabbits, $N_{cdg(s)}$ = annual supply of nitrogen through co-digested in the country, kg N $year^{-1}$ (in our case, neglected in the calculation), $AWMS$ = proportion of total nitrogen excretion rate for all rabbits managed in a manure management system, EF_3 = emission factor in kg N_2O N (kg nitrogen excreted)$^{-1}$/kg N in manure systems, 44/28 = stoichiometric conversion of nitrogen to nitrous oxide.

Table 2. Used parameters for the calculation of N_2O from the storage of manure and manure.

Parameters			**Sources of Parameters**
$\mathbf{N_{EX}}$	**kg N rabbit^{-1} year^{-1}**	8.1	[22]
Emission factor—Grazing	kg N_2O N (kg excluded nitrogen)$^{-1}$	0.003	[22]
Emission factor—solid storage unconfined piles or stacks	kg N_2O N (kg excluded nitrogen)$^{-1}$	0.010	[22]
Emission factor—composting–passive windrow	kg N_2O N (kg excluded nitrogen)$^{-1}$	0.005	[22]
Emission factor—Solid storage–Bulking agent addition	kg N_2O N (kg excluded nitrogen)$^{-1}$	0.005	[22]

3. The Results and Discussion

3.1. Activity Data

The estimated total number of rabbits in households in 2021 is 4,412,916, of which 4,017,988 are kept as livestock, 115,686 are kept for exhibitions, and 279,242 rabbits are kept as pets. The NEIS database registered that only 14,602 heads were bred in cages (100%), and the produced manure was applied into the soil (Table 3). In 2021, only a few big farms were underway and categorized as medium farms. As part of the investigation, information was also obtained about how the rabbits are kept (pasture in the farmyard, housing systems). Pasture in farmyards is not carried out.

Table 3. Statistical information from the NEIS database.

Number of Rabbits		14,602
Breeding Conditions	**Manure Management Systems**	**Application of Manure into Soils**
Cages breeding	Without storage systems	spreading manure on the field (without abatements)

The results from households showed that housing with restriction of movement is the predominant method of farming in the countryside. Housing without the pasture in the farmyard of movement is higher in cities compared to rural areas, and whiffed breeding is absent in households that mentioned both options. Summary information is available in Figure 4.

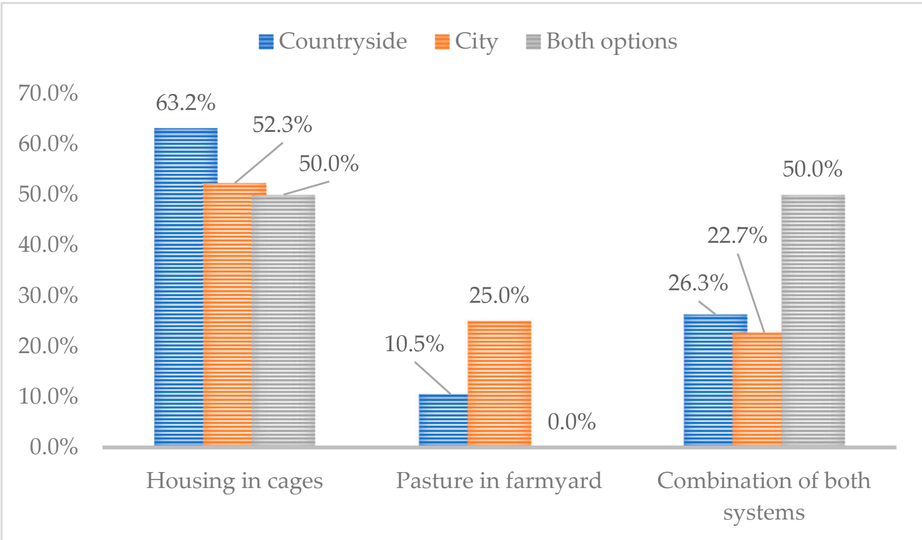


Figure 4. Information on rabbit housing systems from households.

The welfare implications associated with conventional cages primarily stem from their small size, which restricts the movement, resting, and social behavior of the animals. To address these concerns, it is recommended to increase the cage size or incorporate structures, such as platforms, which enable more efficient space utilization. This transition from conventional cages to enriched ones can significantly enhance animal welfare [24,25]. Additionally, reducing stocking density can help mitigate problems encountered by growing rabbits. In terms of thermal stress, while not directly caused by the cages themselves, it is important to minimize the stress through appropriate building and ventilation design. Daily checks should be conducted to ensure the proper functioning of drinkers and automatic feeders (Figure 5). To mitigate the issue of restriction of movement, enhancing the sheltered portion of the housing during periods of limited outdoor access can help alleviate this welfare concern. This could involve providing larger enclosed spaces where rabbits can move more freely [26,27].

To address thermal stress, such as heat or cold stress, additions such as proper shelter insulation and the incorporation of shade structures within the outdoor area can contribute to creating a more thermally comfortable environment for rabbits [27].

Resting problems can be mitigated through the utilization of enrichments that provide shade and resting areas, particularly during the warmer months. Furthermore, improving the insulation and hygiene of the shelter can contribute to creating a conducive resting environment for rabbits [28,29].

Figure 5. An example of cage housing for rabbits in households.

Implementing rigorous housing hygiene practices, employing appropriate feeding strategies, and conducting regular health checks are essential to effective management. To minimize the fear and stress in growing rabbits, utilize protective measures against potential predators, such as installing robust electrified fences and net top protections to prevent access from predators [29]. In our survey, households were informed of these recommendations.

3.2. Timelines

For the purposes of greenhouse gas reporting, it was necessary to model the time series of rabbit conditions up to 1990. Linear extrapolation was performed. The adult population was the main parameter for modeling the number of rabbits up to 1990. The final trend correlated with the adult Slovak population is visible in Figure 6.

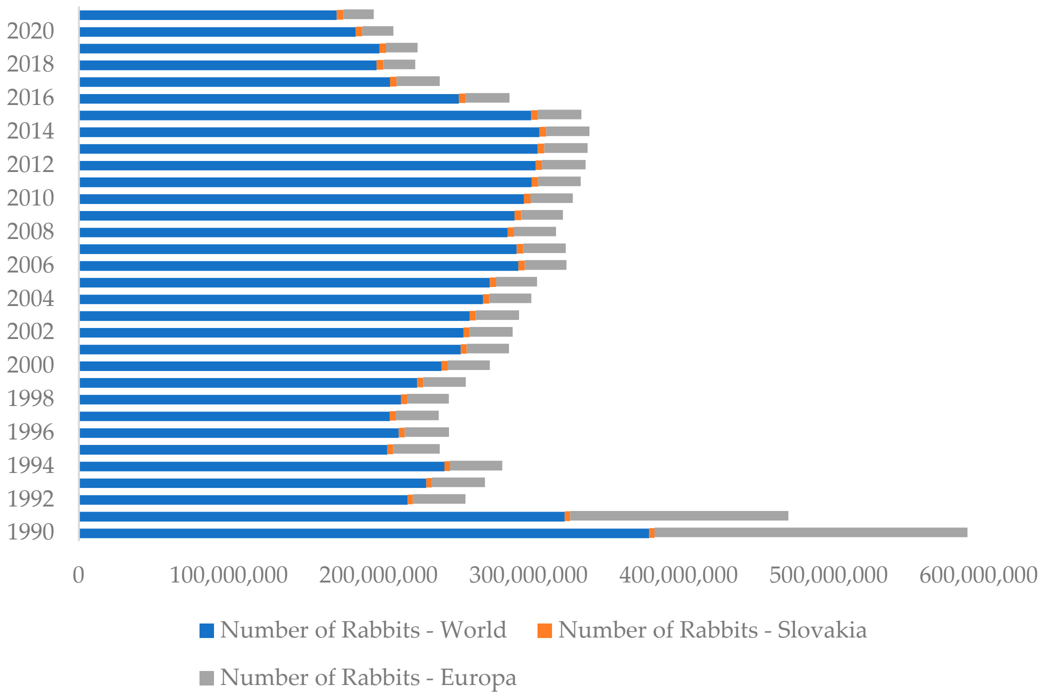


Figure 6. The number of rabbits across several statistical datasets.

The basis of the definition by Glantz and Mun [30], extrapolation involves making statistical forecasts by using historical trends that are projected for a specified period of time into the future, or in our case, the past. It is only used for time series forecasts. For cross-sectional or mixed panel data (time series with cross-sectional data), multivariate regression is more appropriate.

The estimated dataset was compared with other available databases Faostat. Based on Faostat data [31] the world's domesticated rabbit population is estimated at approximately 59,234,878 thousand heads. The European population of rabbits moves on a level of approximately 71,187 thousand heads. About 0.007% of the world's population and about 6% of European production are bred in Slovakia.

Information was also collected on the recovery of excrement from farms in households. This information is important for the emissions estimation of nitrous oxide and methane. Approximately 61% of all waste is stored for further recovery. For the estimation of nitrous oxide emissions, it is important how the storage of these wastes is ensured. In total, 53% of the wastes are stored in covered solid storage, which does not leach nutrients from the manure and partially prevents contamination of the surrounding environment. In total, 25% of the surveyed households claimed composting of the excrement. In total, 13% of excrement ends up in municipal waste. The ratio can be seen in Figure 7.

When we look at the same results from the point of view of excrement storage and animal husbandry, we find that excrement from rabbits bred for pleasure is mostly placed in municipal waste. In households that breed rabbits for their own consumption, covered solid manure storage. The situation is slightly different with rabbits bred for exhibitions, where manure is stored in covered solid storage. A similar situation is seen in rabbits kept for their own consumption; this system is dominated by composting excrement and storage of excrement in a covered manure pit (Figure 8).

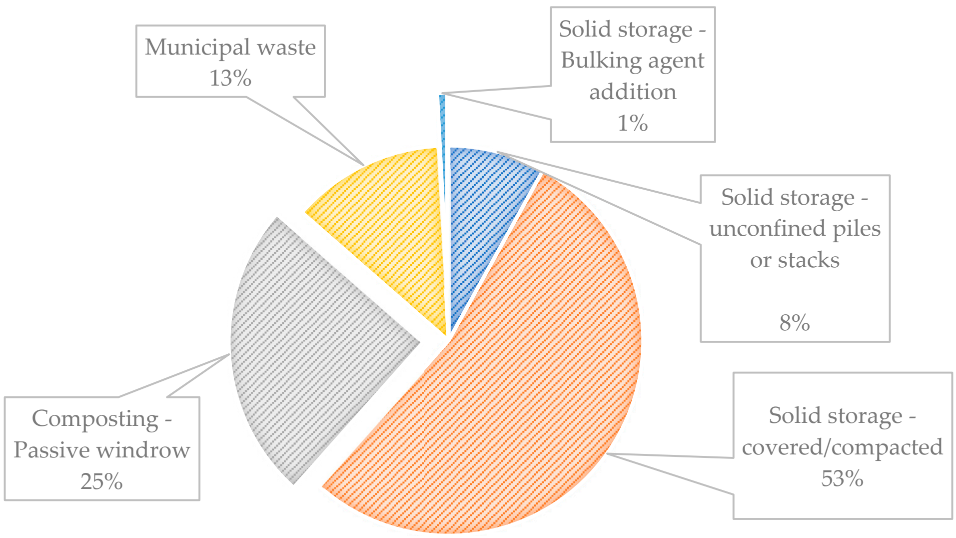


Figure 7. Manure management systems in rabbit breeding.

Manure storage is followed by disposal. In the last question of the questionnaire, we were interested in how households dispose of rabbit breeding waste and whether they are recovered in a recommended and environmentally appropriate way. The resulting values were aggregated based on the type of farming reported by the households. The overview shows that excrement is mostly composted for exhibition rabbits (59%); for rabbits kept as pets, it is at the level of 37%, and for unspecified breeding, it was up to 100%. Another way is to incorporate excrement into the soil. Approximately 28% of households recycle excrement in this way. In total, 3% of households could not answer whether excrement is recovered in their households, and approximately 25% of households do not recover this waste in any way. Detailed information is shown in Figure 9.

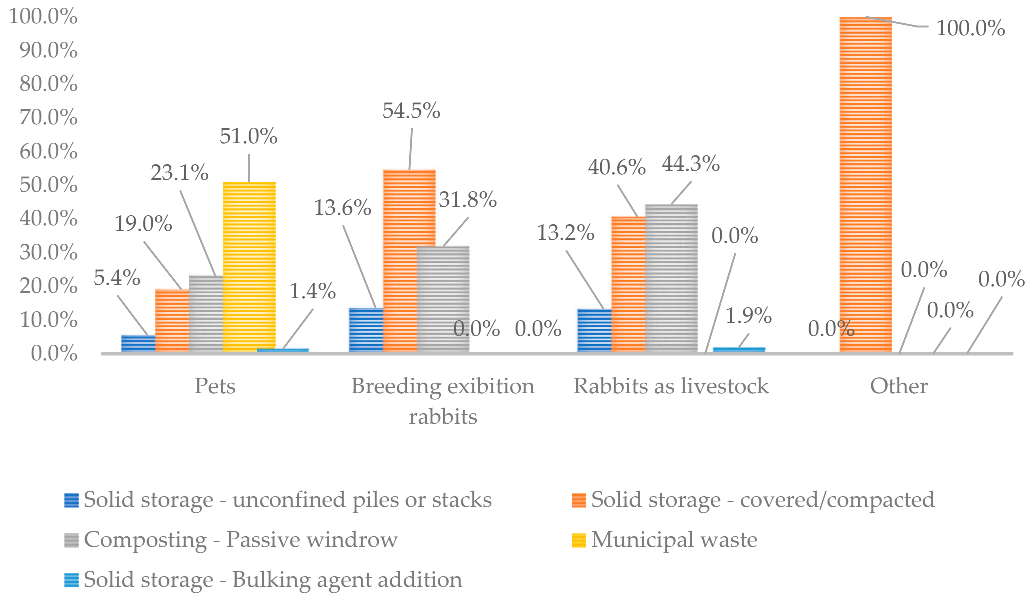


Figure 8. Method of excrement storage in different types of breeding.

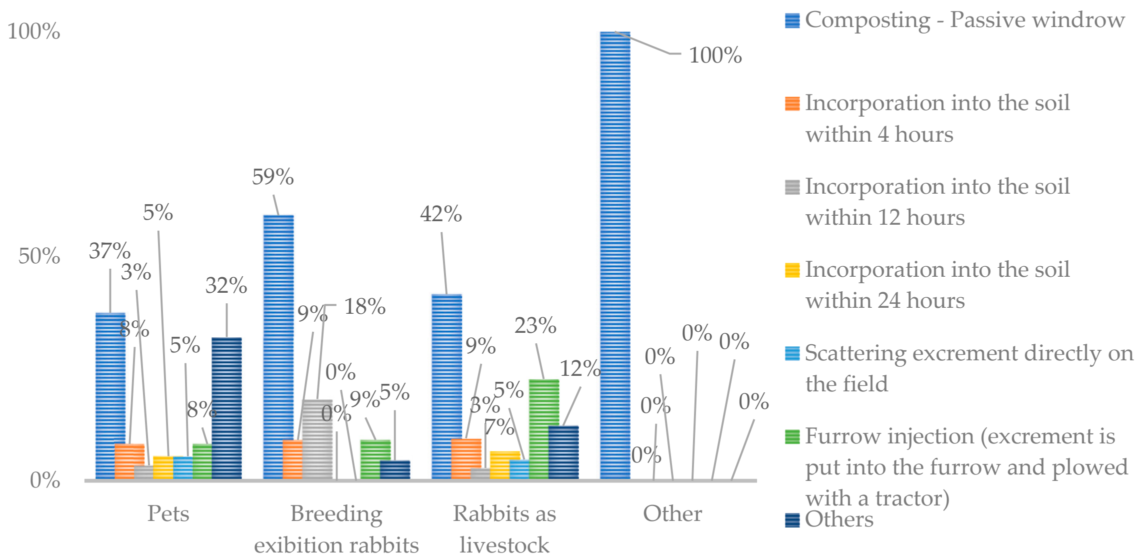


Figure 9. Method of disposal of excrement in different types of breeding.

3.3. Emission Results

The presented emissions include sources from domestic rabbit breeding in Slovakia from the years 1990 to 2021; the emissions from commercial fur farms are included in the results. Information on the number of rabbits from farms and information on the storage of excrement and its recovery was available from the NEIS. On the other hand, based on the described model and the presented input data, it was possible to process a much more sophisticated and accurate estimate of N_2O and CH_4 emissions according to the IPCC methodology, tier 2 approach [22].

Emission estimations from rabbits were prepared for the first time. The activity data for inventory are new and not publicized yet. Domestic rabbit breeding in Slovakia produced an average of 0.31 Gg of N_2O emissions. The most emissions occurred during the storage of excrement in covered manure storage (0.19 Gg N_2O), which was claimed by most of the households. Solid storage with bulking agent addition produces only 0.0014 Gg N_2O emissions. This animal waste management system produces the least emissions in rabbit farming in Slovakia. If we look in more detail at the data in Table 2, the emission factors for all manure systems are almost the same, which means that only the higher frequency of use of manure systems impacted the total emissions. During excrement composting, 0.045 Gg N_2O was emitted, and from unconfined piles or stacks, 0.03 Gg N_2O. Emissions from municipal waste were not estimated due to missing emission factors for this activity. Emissions from rabbit grazing were estimated from 0.043 to 0.054 Gg N_2O per year (Figure 10).

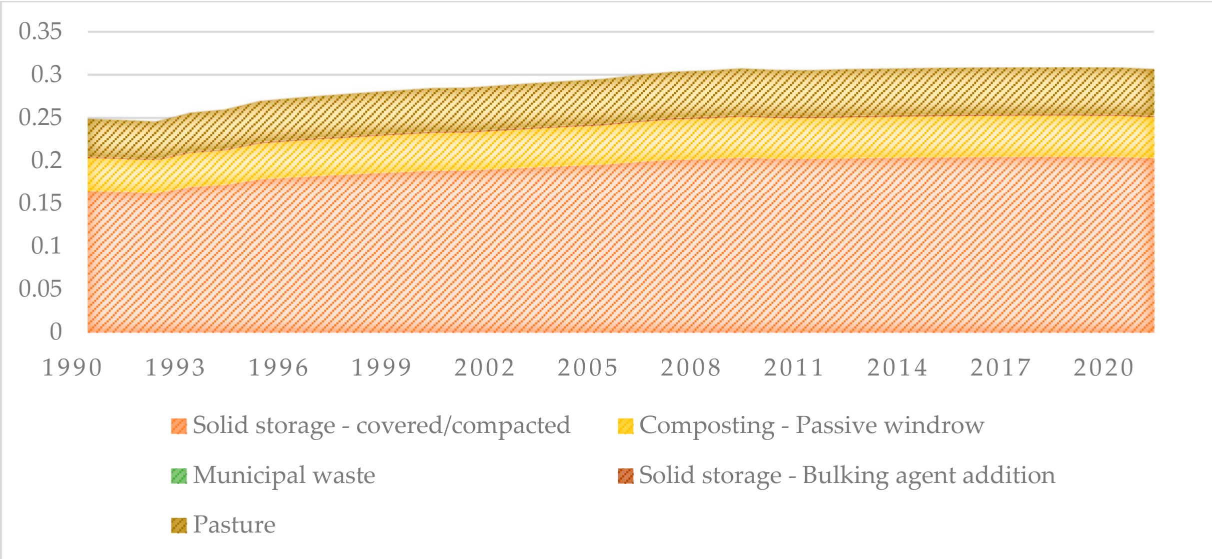


Figure 10. N_2O emissions in Gg per year from manure management and pasture.

Methane emissions from rabbit breeding (enteric fermentation and manure management) from 1990 to 2021 amounted to 0.51–0.63 Gg per year (Figure 11). Emissions were balanced according to the IPCC methodology, tier 2 approach, and the specific emission factor for Slovakia was estimated at the level of 0.001 kg CH_4 per animal. The default emission factor for manure management according to the IPCC methodology 2019 Refinement [22] is 0.08 kg CH_4 per animal, which is 99% higher than the nationally specific emission factor. Figure 9 shows the emission development in rabbit breeding in Slovakia from 1990 to 2021. In total, 91% of methane emissions were produced in households that keep rabbits for their own consumption. This is followed by the breeding of rabbits as pets (6%) and breeding for exhibition purposes (3%), displaying the make-up of emission development in rabbit breeding in Slovakia.

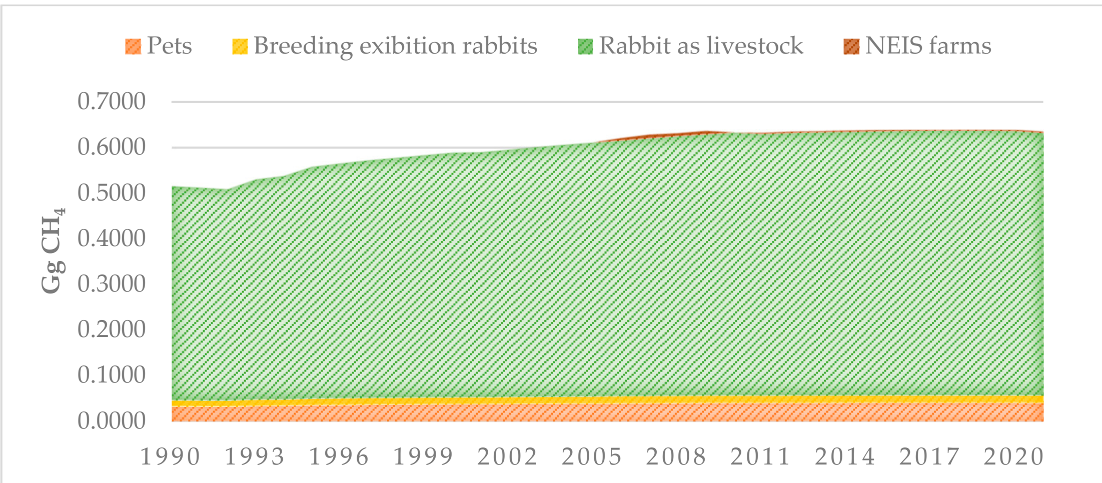


Figure 11. CH_4 emissions in Gg per year from manure management.

Proper nutrition is a prerequisite for successful rabbit breeding. A rabbit has a relatively large intake of feed, which passes through its digestive tract quickly.

The quality, quantity, and variety of feed affect the efficiency of animals. For rabbits, meadow hay, barley, oats, dry bread and pastries (without mold), and complete feed mixes are most suitable [32,33].

The animal feeding and health strategy aims to increase the production per animal in order to meet market demand for animal products while reducing the overall number of animals bred. This approach helps minimize the volume of animal waste generated. The strategy involves formulating diets that meet the specific nutritional requirements of animals for optimal growth and productivity. However, the impact of this strategy on gas emissions from animal manure has been rarely investigated. One study reported that including synthetic amino acids diet supplements, such as lysine, tryptophan, threonine, and methionine, in animal diets reduced ammonia and total nitrogen levels in freshly excreted manure by 28% [24,33].

Following the in vitro studies mentioned above, other researchers conducted in vivo animal health studies using composted green residues. In two trials conducted by Biagini et al., a total of 131 and 120 rabbits aged 35 days were fed a conventional diet supplemented with 0.0–1.0% composted green residues for two months. The study monitored the animals' live and slaughter performance, diet digestibility, and health status. Overall, the addition of composted green residues to the diet did not significantly affect growth performance, carcass quality, or meat characteristics [4].

Rabbit breeding encompasses a diverse range of breeds, varying in size from giant to small and even dwarf varieties. A breed refers to a group of animals that share the same genetic lineage and possess distinct characteristics and traits. These traits are inherited by the offspring as long as the external environmental conditions remain unchanged. As of 2017, a total of 305 domestic rabbit breeds were documented across 70 countries worldwide [34]. Among breeders in Slovakia, there is a notable presence of national breeds. These include the Slovak Grey Blue Rex and its dwarf variant, the Blue of Holic Rabbit, Nitra Rabbit (Ni), Zobor Rabbit, Zemplin Rabbit, Liptov Bold-Spotted Rabbit (LL), Zemplin Rex, Slovak Pastel Rabbit, Slovak Pastel Rex, as well as the Dwarf Slovak Pastel Rex. Additionally, breeds like Štrba Gepard Rabbit, Štrba Gepard Rex, Chrabrany Rabbit, and Saris Giant Rabbit are awaiting official recognition. These national breeds are frequently showcased at various breeding exhibitions held in the Czech and Slovak Republics [35–37]. The results indicated that the predominant farming method in rural areas involves housing with movement restrictions. Rabbits are bred for commercial purposes, such as meat production. The demand for rabbit meat or research purposes may result in increased breeding practices to meet these specific needs. If rabbit breeding practices are not well-regulated, it can contribute to overpopulation. Uncontrolled or indiscriminate breeding can lead to the propagation of genetic health problems. Breeding without proper consideration of the health and genetic background of the rabbits may result in an increased prevalence of hereditary diseases and a reduction in overall welfare. Without adequate breeding standards and regulations, there is a risk of unethical breeding practices, such as inbreeding, overcrowded housing conditions, or neglecting the well-being of the animals. This can have detrimental effects on the welfare of the rabbits involved. Implementing and enforcing breeding regulations that prioritize the welfare of the animals, including standards for housing, breeding frequency, genetic diversity, and responsible ownership, can help control and improve breeding practices [38,39].

4. Conclusions

Rabbits are popular companion animals due to their small size, adorable appearance, and perceived ease of care. Their popularity as pets has increased over the years, leading to higher demand for rabbits from breeders. Rabbits are bred for show and exhibition purposes, where breeders aim to produce rabbits that meet specific breed standards. This demand for rabbits with desirable traits and appearances may contribute to increased breeding practices. The obtained data on the number of rabbits, on the recovery and storage of waste from their breeding, and the results on methane and N_2O emissions, are unique. Only a few studies derivate information about breeding conditions and their impact on the environment. Our survey fills in missing information and increases the complexity and accuracy of Slovakia's greenhouse gas emissions at the national level. These results are important for supplementing statistical data and subsequently improving the quality of inputs in the field of national inventories of greenhouse gases and inventories of pollutants. The results of the presented article will be processed into emission inventories and will be reported under the Convention on Long-Range Transboundary Air Pollution (CRLTAP) [40] and Directive No. 2016/2284 [41] on the reduction of national emissions of certain air pollutants and Regulation of the EP and the Council on the management of the Energy Union No. 2018/1999 in Article 26(2) [42]. The survey brought interesting results implemented into the emission calculations. The questionnaire was designed in such a way that as much information as possible was obtained about the conditions of breeding in households, farms, manure management systems, and storage of rabbit excrement. It emerged from the survey that approximately 4,161,764 rabbits are bred in Slovakia. Rabbits are bred 365 days a year in the housing system. The majority of rabbits in commercial farms are kept in cages. The information was implemented in the emission estimations. On the contrary, the survey of households shows that free-range bred rabbits are paradoxical in cities. The results show that approximately 25% of households' compost excrement from rabbit breeding and 53% of households store excrement in covered manure storage, which they subsequently use by incorporating it into the soil as fertilizer. Waste from rabbit farming also ends up in municipal waste, with up to 13% of households reporting it.

Emissions were estimated based on the tier 2 approach according to 22. The results show that raising rabbits in households and farms in Slovakia produces an average of 0.51 Gg of methane and 0.13 Gg of nitrous oxide per year. During the presence of free-range rabbits, 0.001 Gg of nitrogen oxide emissions is produced. Greenhouse gas emissions from rabbit farming make up 7% of the total emissions from animal farming, ranking it third in production behind sheep. A comparison of emissions by animal species is available in Figure 12.

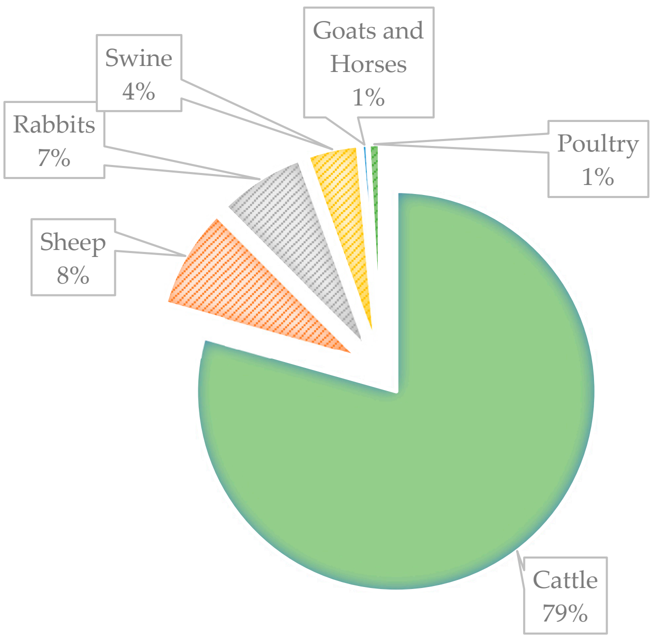


Figure 12. Comparison of greenhouse gas emissions with other livestock species.

The comparison shows that this category produces a significant amount of greenhouse gas emissions than originally expected, and therefore it will be a priority to implement this category in the national report on emissions for Slovakia. The improved emissions estimation will be implemented dynamically into the national emission inventory for the whole time series starting in 1990, which is the base year for emission estimations under the Paris Agreement. Consensus on representative national data on rabbit breeding and numbers is missing at the country level, which confirms the uniqueness of this study. With the article, we also want to point out that it is necessary to collect these data annually at the state level.

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