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Araştırma Makalesi / Research Article

Theoretical Nitrous Oxide, Methane, Carbon Dioxide Emissions Calculations to the Atmosphere in Niğde, Turkey

Niğde, Türkiye'de Atmosfere Salınan Nitröz Oksit, Metan, Karbondioksitin Teorik Hesaplamaları

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ABSTRACT

One of the reasons for the formation of emissions in the world and Turkey is the livestock sector. Methane and nitrogen oxide are the two major greenhouse released into the atmosphere due to fertilizer management. If there is no good fertilizer management planning, animal fertilizer formed in animal husbandry enterprises poses a big problem for the environment and human health. Collection of fertilizer from shelters, method of collection, where to store fertilizer, and how to evaluate are among the most important problems. In this study, greenhouse gas emissions from animal husbandry in Niğde, Turkey were examined between 2016-2020. Different animal species were used in the study and the Tier-1 method defined by the IPCC was used to calculate greenhouse gas emissions. In addition, the potential for Global Warming that may occur from greenhouse gas emissions has been determined. As a result of calculations, N_2O (Nitrous oxide) emission was determined to be 1.1x10^3 tons/year and CH_4 (methane) emission to be 134x10^3 tons/year. The global warming potential created by these two emissions is 3152x10^3 tons of CO_2.

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ÖZ

Dünyada ve Türkiye'de emisyon oluşumunun nedenlerinden birisi de hayvancılık sektörüdür. Metan ve azot oksit, gübre yönetimi nedeniyle atmosfere salınan başlıca iki sera gazıdır. İyi bir gübre yönetim planlaması yoksa hayvancılık işletmelerinde oluşan hayvan gübresi çevre ve insan sağlığı için büyük bir sorun oluşturmaktadır. Gübrenin barınaklardan toplanması, toplanma yöntemi, gübrenin nerede depolanacağı ve nasıl değerlendirileceği en önemli sorunlar arasındadır. Bu çalışmada, 2016-2020 yılları arasında Niğde ili hayvancılıktan kaynaklı sera gazı emisyonları incelenmiştir. Çalışmada farklı hayvan türleri kullanılmış ve

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sera gazı emisyonlarının hesaplanmasında IPCC tarafından tanımlanan Tier-1 metodundan yararlanılmıştır. Ayrıca sera gazı emisyonlarından oluşabilecek küresel ısınma potansiyeli belirlenmiştir. Hesaplamalar sonucunda N_2O emisyon $1.1x10^3$ ton/yıl, CH_4 emisyonu $134x10^3$ ton/yıl olduğu belirlenmiştir. Bu iki emisyonun oluşturduğu küresel ısınma potansiyeli CO_2 ise $3152x10^3$ tondur.

1. INTRODUCTION

Fast- growing economic developments are increasing dependence on fossil resources around the world. This leads to energy shortages and environmental pollution crises [1]. Bioenergy, an alternative to fossil resources, is one of the best options for minimizing such negativity [2]. If biomass is discarded or not used properly, these wastes have a negative impact on climate change, not only on soil and water pollution but also on-air quality [3]. As biomass, it contains several organic substances and nutrients that can pollute the water environment if appropriate use of livestock faces [4].

Among agricultural activities, it is the livestock sector that has the most critical impact on the quality of the environment, and fertilizer management causes the main share of pollution. Livestock production is a significant contribution to most economies, and livestock products represent the highest value of agricultural production for most countries [5]. In recent years, the high intensity of livestock production has been accompanied by its separation from crop production, as existing livestock production techniques rely heavily on imported feed for economic profitability. The environmental impact of intensive fattening livestock is often related to fertilizer management systems and practices that do not apply current techniques. Given the intensification of animal husbandry, there is a need to develop technologies and strategies that address relevant environmental concerns [6].

Animal waste storage and evaluation methods, Turkey's water, and soil pollution in terms of treatment, and adverse conditions are mandatory to improve urgently. In developed countries, necessary measures are taken to prevent image, water, and soil pollution by implementing regulatory regulations and certain standards on the conditions for storing and evaluating fertilizer in livestock enterprises [7]. The fact that the conditions for storing and evaluating animal waste in our country, controlled by strict control mechanisms and effective work to eliminate deficiencies, have still not been done to a sufficient extent today, are the most important sources of problems in the livestock sector [8]. In our country, many studies have been conducted by researchers to examine the current state of animal waste storage and evaluation practices in cattle breeding enterprises, and problem-solving recommendations have been developed. These recommendations should be considered in the restructuring of animal waste storage and fertilizer evaluation conditions in enterprises [9].

From animal fertilizers, gases such as water vapor (H_2O), carbon dioxide (CO_2), ammonia (NH_3), hydrogen sulfide (H_2S), carbon monoxide (CO), and hydrogen (H_2) are emitted into the atmosphere. In addition, methane (CH_4) gas is released by the degradation of the organic substances contained in these fertilizers by anaerobic bacteria. Livestock production systems, directly and indirectly, contribute to atmospheric anthropogenic greenhouse gases through emissions of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). The most important greenhouse gases caused by the livestock sector are methane and nitrous oxide [10]. CH_4, mainly from enteric fermentation and manure storage, is a gas that has 28 times more impact on global warming than CO_2. N_2O, which results from manure storage and use, is 265 times more effective on global warming than carbon dioxide. At a time when global warming is an undeniable danger, greenhouse gas emissions are gases that are effective in creating global climate change [11]. Although the use of nitrogen fertilizers is a necessity in terms of meeting the needs of the growing world population, it is known that the effectiveness of nitrogen use leads to significant environmental problems. The use of nitrogen fertilizers leads to deterioration of soil and water quality, pollution of underground and above-ground water sources, air pollution, and biodiversity reduction, as well as increasing greenhouse gas emissions. For this reason, methods of increasing the effectiveness of nitrogen fertilizers through the use of slow and controlled release fertilizers, nitrification, and the use of urease inhibitors are proposed to reduce nitrogen pollution [12]. Increasing concerns with the increase in CH_4 and N_2O gas emissions have led scientists to start focusing on emission sources and accelerate their prevention and mitigation work.

Du Toit et al. [13] calculated greenhouse gas CH_4 and N_2O emissions from South African pigs, ostriches, horses, donkeys, mules, and poultry from 2010 data. They stated that a total of 25.7 Gg CH_4 and 2.25 Gg N_2O emissions occurred [13]. Moeletsi and Tongwane [14] have estimated greenhouse gas emissions from fertilizer management for South Africa. The Intergovernmental Panel on Climate Change (IPCC) guidelines on different deceleration levels have also been used in forecasting. As a result, they found that carbon dioxide produced 3104 Gg methane and 2272 Gg nitrous oxide emissions in the equivalent of global warming [14]. Paik et al. [15] determined the emission values of livestock and poultry production in Korea according to the IPCC Tier 1 and Tier 2 approach with comprehensive data on live animal and poultry populations for the years 1990 to 2010. Methane emissions range from 1.85 Gg to 3.99 Gg for non-dairy cattle and 1.36 Gg to 1.72 Gg for dairy cattle. The study also stated that nitrous oxide emissions were 1.17 to 2.48 Gg for non-dairy cattle and 0.79 to 1.2 Gg for dairy cattle [15]. Kara et al. [11] the greenhouse gas emissions produced by livestock activities for Konya, Turkey were calculated according to IPCC 2006 guidelines. In the study, they determined total fertilizer-induced methane emissions as 1110.14 Gg [11]. Ersoy and Uğurlu [16] stated that Turkey's total greenhouse gas emissions from animals are 33 million tons of CO_2 and that the emission value can be reduced by 1.13% as a result of biogas production. It was also stated that 4% of the electricity needs per capita can be met by the production of biogas [16]. Yaylı and Kılıç [10] have determined the global warming potential caused by enteric fermentation and manure management of dairy cattle enterprises in Turkey and Bursa by Tier-1 method. As a result, the global warming potential in Turkey is 53.5 TG CO_2 and Bursa is 0.70 TG CO_2 [10]. Ceyhan et al. [17] calculated the carbon footprint of a dairy sheep farm in Niğde, Turkey using the Tier 1 method to determine the potential for global warming. The total emissions of this farm from both sources, such as N_2O and CH_4, are 85535.2 CO_2 [17]. Nasiru et al. [18] estimated N_2O emissions from different livestock using the Tier 1-2-3 approach according to the manure management system for five continents. According to the Tier 1 approach, the emission value dominated by farm animals was 2453 Gg N_2O emissions [18]. Sarah et al. [19] calculated greenhouse gas emissions from livestock in Central Java, Indonesia, covering 2010-2015 using the IPCC 2006 Tier 1 method. CO_2 emissions were determined as 1546.26, 1658.38, 1775.99, 1708.46, 1,745.37, and 1817.52 Gg respectively according to the years. In the study, approximately 1-6% CH_4 emission per year can be prevented by anaerobic digestion [19]. Tongwane and Moeletsi [20] have investigated the causal factors of cattle emissions for South Africa. Regional CH_4 emissions required for N_2O emissions generated by cattle manure have been identified. 35.37 million tons of CO_2 equivalent (CO_{2e}) was obtained from the total emissions for 2019 [20]. Greenhouse gas emissions can occur in many different ways as a result of animal husbandry activities. Emissions directly generated by livestock activities occur through enteric fermentation and manure management in animals. As a result of enteric fermentation, methane gas (CH_4) emissions are released, while animal manure emissions are methane (CH_4) and nitrous oxide (N_2O) gases [11].

In this study, N_2O, CH_4 emissions that may occur from livestock activities were determined for Niğde, Turkey between 2016 and 2020. Data in the IPCC 2006 guide was used to calculate greenhouse gas emissions. In addition, the CO_2 equivalence of global warming potentials that can be caused by emissions has been calculated.

2. MATERIALS AND METHOD

Niğde is located in the southeast of Turkey's Central Anatolia Region and the Cappadocia region. Its altitude is 1229 m and its population for 2020 is 362.071. The number of animals belonging to Niğde in 2016-2020 is given in Table 1 [21]. This study aims to estimate the global warming potential of emissions from enteric fermentation and manure management in 2016-2020 decayed from different animals in Niğde, Turkey. N_2O and CH_4 emissions were calculated using the default emission factors in the guidance published by the IPCC using the Tier-1 method developed by the IPCC (Intergovernmental Panel on Climate Change). The CO_2 equivalents of CH_4 and N_2O gases were examined and the global warming potentials of different animal species were determined.. When calculating N_2O, CH_4, and CO_2

emissions, the global warming potentials of these gases were taken as 310, 21, and 1 as the equivalent of carbon dioxide, respectively [16]. In the calculations, the Turkish Statistical Institute (TUIK) used the number of animals in the province of Niğde in 2020. According to IPCC 2006 guidelines, it was found that animals in Turkey were more appropriate to be evaluated within the Eastern European country category in terms of their physical characteristics, and the emission factor values, which are the most important criteria in calculations, were selected according to this criterion [22].

Table 1. Number of animals in Niğde, Turkey

Animal	2016	2017	2018	2019	2020
Dairy Cattle	107680	109490	129422	129703	141354
Other Cattle	34224	38414	43047	42303	45402
Water Buffalo	18	7	8	13	11
Sheep	425675	480906	498827	517343	614809
Goat	74714	70574	74142	72485	81328
Horse	408	449	455	368	378
Donkey+Mule	2292	2084	2134	2075	1807
Turkey	13003	11993	10814	10872	10305
Duck+Goose	11981	12641	12509	13520	16231
Meat Chicken	425000	405000	400400	204000	550000
Egg Chicken	631448	745806	725381	666246	559208

Table 2. Formulas and parameters used to determine the theoretical amount of N_2O and CH_4

$Ne_{x,t} = 0.365xN_{r,t}xM_t$	(1)
$N_2O_d = 1.5714\ x\left[\sum_s\left[\sum_t\left(N_txNe_{x,t}xMS_{t,s}\right)\right]xEf_{3,s}\right]$	(2)
$N_2O_g = 1.5714x(N_{v-ms} * Ef_4)$	(3)
$N_{v-ms} = \sum_s\left[\sum_t\left[N_txNe_{x,t}xMS_{t,s}\ x0.01(Fg)_{t,s}\right]\right]$	(4)
$CH_{4_{ent}} = Ef_tx\ \ N_tx\ 10^{-6}$	(5)
$CH_{4_{man}} = \sum_t Ef_tx\ N_tx10^{-6}$	(6)

$Ne_{x,t}$: Annual N excretion for t type; kg N /animal year
$N_{r,t}$: N excretion rate; kg N / (1000 kg mass day)
M_t : Animal mass for t type; kg/animal
N_2O_d : Direct N_2O emission for Turkey; kg N_2O yr^{-1}
N_{v-ms}: Amount of manure nitrogen lost due to evaporation; $kgNyr^{-1}$
Ef_3 : Direct emission factor from Turkey manure management; N_2O-N/kgN
N_2O_g : Indirect N_2O emission for Turkey; kg N_2O yr^{-1}
N_t : Number of animals of t type/species
Ef_4 : Factor for N_2O emissions from atmospheric nitrogen deposition; kgN_2O-N
$MS_{t,s}$: The fraction of total annual nitrogen excretion by type/species in Turkey
$(Fg)_{t,s}$: % of managed manure nitrogen for type/species evaporated as NH_3 and NO
CH_{4ent} : CH_4 from enteric fermentation; Cg CH_4 yr^{-1}
CH_{4man} : CH_4 from manure management; Cg CH_4 yr^{-1}
Ef_t : Emission factor for animal type; kg CH_4 $head^{-1}$

The amount of direct N_2O emission was calculated by equations 1 and 2. Indirect N_2O emissions from volatilization, which are in the forms of NH_3 and N_2O, can be calculated theoretically using equations 3-4.

Solid manure storage was chosen as the manure management system for the nitrogen excretion fraction, which differs according to each animal species. The default value for N_2O emission from atmospheric nitrogen deposition is 0.01 kg N_2O-N (kg NH_3-N+NO_x-N)$^{-1}$, which is given in the IPCC 2006 guideline. Enteric CH_4 emissions were calculated using equation 5. Methane emissions from manure management were found with the help of equation 6. Since temperature is an important criterion for calculating methane gas emissions, the average monthly temperature data of Niğde were obtained from the General Directorate of Meteorology of Turkey [23].

Table 3. Parameters used for direct N_2O calculation

Animal	$N_{r,t}$[kg N.(1000 kg animal)$^{-1}$ day^{-1}]	M_t (kg)	$MS_{t,s}$(%)	Ef_3 [kg N_2O-N.(kg N)$^{-1}$]
Dairy Cattle	0.35	550	100	0.02
Other Cattle	0.35	391	100	0.02
Water Buffalo	0.32	380	100	0.02
Sheep	0.9	48.5	100	0.02
Goat	1.28	38.5	100	0.02
Horse	0.3	377	100	0.02
Donkey+Mule	0.3	130	100	0.02
Meat Chicken	1.1	0.9	100	0.001
Egg Chicken	0.82	1.8	100	0.001
Turkey	0.74	6.8	100	0.001
Duck+Goose	0.83	2.7	100	0.001

Table 4. Enteric fermentation emission factors

Animal	Ef_4
Dairy Cattle	99*
Other Cattle	58*
Water Buffalo	55
Sheep	8
Goat	5
Horse	18
Donkey+Mule	10

*According to IPCC 2006 guidelines

Table 5. Manure management methane emission factor varying with temperature values

Animal	Emission Factor kg CH_4 head^{-1} year^{-1}		
	<15ºC	15°C - 25°C	>25°C
Dairy Cattle *	2	2	3
Other Cattle *	1	1	1
Water buffle*	4	5	5
Sheep	0.1	0.15	0.2
Goat	0.11	0.17	0.22
Horse	1.09	1.64	2.19
Donkey+Mule	0.6	0.9	1.2
Meat Chicken	0.01	0.02	0.02
Egg Chicken	0.01	0.02	0.02
Turkey	0.01	0.02	0.02
Duck+Goose	0.01	0.02	0.02

*According to IPCC 2006 guidelines

3. THE RESEARCH FINDINGS

In this study, N_2O, CH_4, and CO_2 emissions from animal husbandry were calculated. According to the physical characteristics of animals, it has been characteristically recognized as an Eastern European country, and all values have been selected and calculated from the relevant tables of the IPCC 2006 guide. Nitrous oxide (N_2O) values for different animal species covering the years 2016-2020 were calculated in two different ways: direct and indirect emissions. The emissions obtained as a result of the calculation are given in Figure 1. A total of 948.93 tonnes of direct N_2O emissions were generated between 2016-2020 Dec. When evaluating the percentage changes of direct N_2O emissions by year, total emissions amounted to 17.3% in 2016, while this figure increased to 22.3% in 2020. The percentage change between 2018 and 2019 is similar. In 2016-2020, the indirect N_2O emission value is 145.27 tons. Indirect N_2O increased by 31.9% between 2016-2020 of total emissions. 86.7% of N_2O emissions from fertilizer management are directly and 13.3% are indirect.

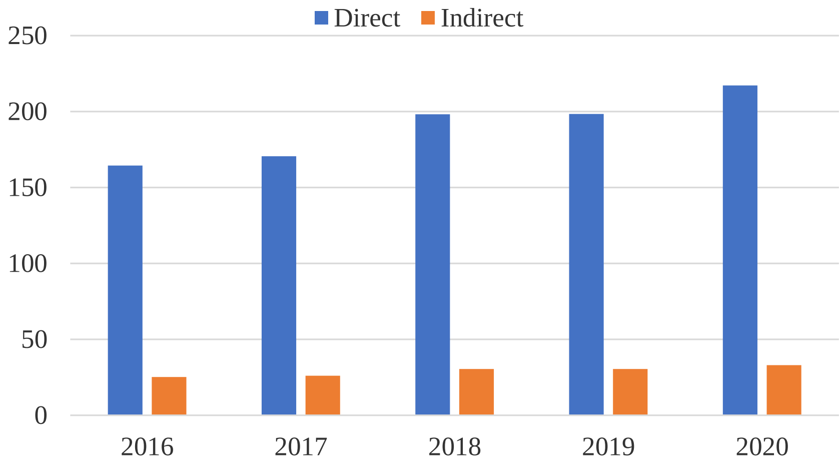

Figure 1. *Indirect and direct N_2O emissions*

CH_4 emissions related to enteric fermentation and manure management for the years 2016-2020, taking into account animal species, are given in Figure 2. The total enteric fermentation methane value was obtained as 132.26 x 10^3 tons, and the methane value formed by manure management was obtained as 1.79 x 10^3 tons. Enteric fermentation values could not be calculated because there is no data on the factors of enteric emission for chicken, turkey, goose - duck.

According to the years, CH_4 emissions were the highest in 2020 and the lowest in 2016. In 2016, the emission value due to enteric fermentation was 23.79 x 10^3 tons, while in 2020 this value was 28.77 x 10^3 tons. CH_4 emissions from manure management in 2018 and 2019 are almost the same. The total CH_4 emission calculated according to both methods is 134.06 x 10^3 tons. 98.7% of CH_4 emissions are caused by manure management, while enteric fermentation accounts for 1.3%.

The CO_2 potential generated by N_2O and CH_4 emissions for 2016-2020 is given in Figure 3. According to Figure 3, a total of 3152000 tons of CO_2 was caused by 2813000 tons of CH_4 , and 339000 tons of N_2O. Considering the total N_2O potential, 86.7% is caused by direct N_2O emissions, while 13.3% is due to indirect N_2O emissions. 98.6% of the global warming potential due to CH_4 is due to enteric fermentation and 1.4% to the fertilizer management system. When the global warming potential is examined according to years, it has occurred mostly in 2020 and at least in 2016. From 2016 to 2020, the global warming potential due to N_2O increased by 31.9% and the increase due to CH_4 increased by 21%.

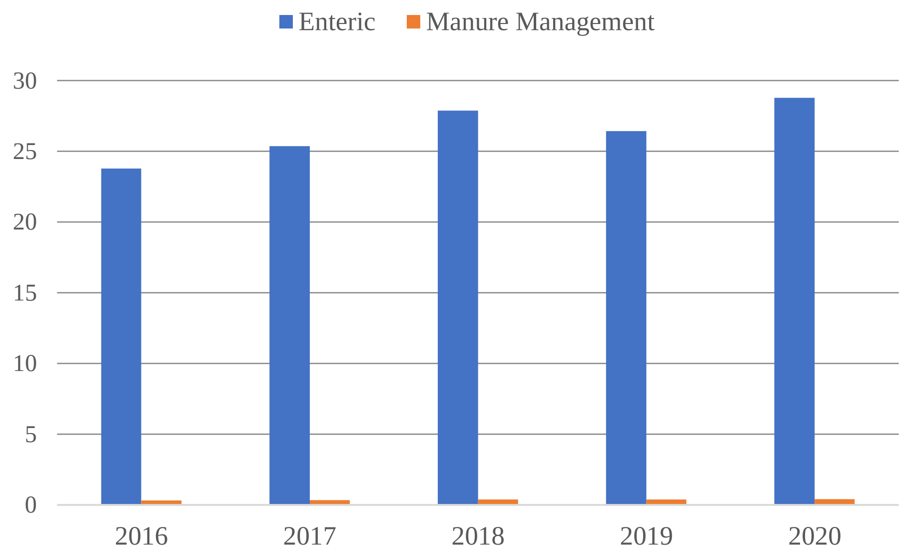

Figure 2. *CH_4 emission due to enteric fermentation and manure management*

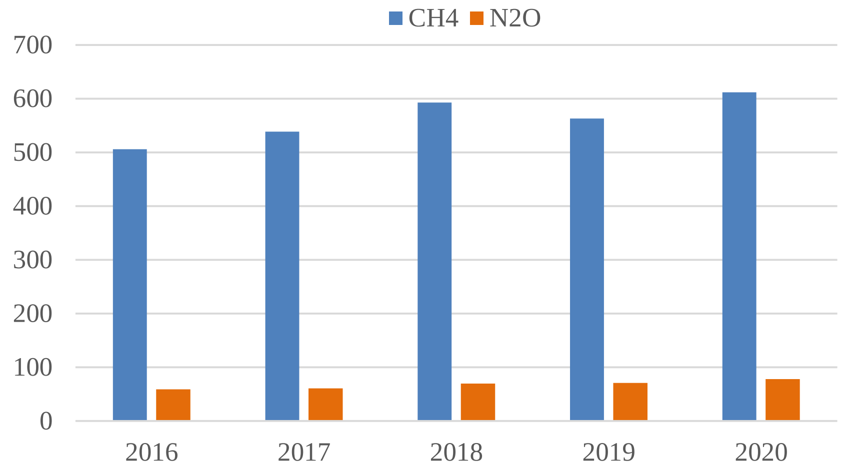

Figure 3. *CO_2 from N_2O and CH_4 emissions*

4. CONCLUSION

Reducing or preventing the impact of greenhouse gases from the livestock sector is very important in terms of contributing to the slowing down of global warming that threatens our future. Reducing greenhouse gases also provides for an increase in efficiency at enterprises.

In this study, N_2O and CH_4 emissions that may occur from livestock activities in Niğde, Turkey between 2016 and 2020 were determined.

The Tier 1 approach included in the IPCC 2006 guidelines was used to calculate greenhouse gas emissions. In addition, the CO_2 equivalence of global warming potentials that can be caused by emissions has been calculated.

N_2O has been calculated as direct and indirect emissions according to different animal species, including the years 2016-2020.

It was found that direct N_2O emission was 948.93 tons and indirect N_2O emission was 145.27 tons. Total enteric fermentation CH_4 value was 132.26 x 10^3 tons, and CH_4 value generated by manure management was 1.79 x 10^3 tons. While the total CH_4 emission due to enteric fermentation and manure management system was 24.10x10^3 tons in 2016, this value reached 29.18x10^3 tons in 2020. Enteric fermentation values could not be calculated for meat and laying chicken, turkey, goose, duck because there is no relevant data for enteric emission factor values.

The CO_2 value created by N_2O and CH_4 emissions is a total of 3152x10^3 tons. When the global warming potential between the years 2016-2020 has been evaluated, it occurred mostly in 2020 and at least in 2016. From 2016 to 2020, the global warming potential due to N_2O increased by 31.9% and the increase due to CH_4 increased by 21%.

CONFLICTS OF INTEREST

No conflict of interest was declared by the authors

AUTHORS' CONTRIBUTIONS

Kazım KUMAŞ: Data collection, data curation, investigation. Ali Özhan AKYÜZ: Conceptualization, methodology, validation, analysis, writing-review and editing, supervision.

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