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A Dataset of Nitrogen Flow Characteristics of Living Consumption of Rural Residents in China (2000–2020)

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Abstract: This study utilizes basic information on China's rural areas spanning the years 2000 to 2020. The study employs material flow analysis to quantify and assess nitrogen (N) inputs and outputs within the living system of Chinese rural residents, along with their corresponding environmental impacts. A comprehensive dataset detailing the N flow characteristics of rural residents' living consumption in China was compiled and calculated. This dataset encompasses key aspects such as the amount of N consumption in food, industrial daily necessities, and domestic fuels along with their respective input pathways. Additionally, the dataset explores the characteristics of reactive N emissions, sources of NH_3 volatilization, NO_x, and N_2O emissions, all of which stem from the domestic consumption patterns of rural residents in China over the two-decade period from 2000 to 2020. The compiled dataset is presented in a single .xlsx file with a size of 22 KB.

Keywords: rural residents; living consumption; reactive nitrogen emissions; sustainable development

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Dataset Availability Statement:

The dataset supporting this paper was published and is accessible through the *Digital Journal of Global Change Data Repository* at: https://doi.org/10.3974/geodb.2024.01.08.V1 or https://cstr.escience.org.cn/CSTR:20146.11.2024.01.08.V1.

1 Introduction

Nitrogen (N) serves as both a valuable resource and a formidable pollutant, presenting a challenge in terms of elimination[1]. The current scenario witnesses escalating ecological, human health, and climate change concerns attributed to excessive inputs and emissions of reactive nitrogen (Nr), particularly in developing countries[2–4]. Research indicates that over

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[2] Zhao, Y. Q., Tian, D., Liu, W. Dataset of nitrogen flow from the rural residents' consumption in China (2000–2020) [J/DB/OL]. *Digital Journal of Global Change Data Repository*, 2024. https://doi.org/10.3974/geodb.2024.01.08.V1. https://cstr.escience.org.cn/CSTR:20146.11.2024.01.08.V1.

70% of Nr emissions from terrestrial ecosystems are intricately linked to human living consumption activities[5]. China, as the world's largest developing country, has undergone significant transformations in the consumption structure of its rural residents due to rapid urbanization in recent years. However, the impact of these changes on N flow within the rural socioeconomic system and its repercussions on the ecological environment remain unclear. It is imperative to quantify and evaluate the sources and destiny of N in the consumption patterns of rural residents, along with its environmental effects. Such an analysis holds paramount theoretical and guiding significance, providing insights into the N balance of China's rural socioeconomic system and aiding in the formulation of effective measures for the prevention and control of N pollution.

Currently, most studies concerning the N cycle in residential life predominantly concentrate on spatial and temporal variations in the N footprint of urban food consumption systems through model simulations[6–12]. However, there exists a noticeable gap in the examination of N flow and its environmental impacts associated with the consumption patterns of rural residents.

This study addresses this gap by collecting statistical data from the China Rural Statistical Yearbook 2001–2021[13] and China Statistical Yearbook 2001–2021[14], encompassing the years 2000, 2005, 2010, 2015, and 2020 across 31 provinces, autonomous regions, and municipalities directly under the central government (excluding Hong Kong, Macao, and Taiwan). Additionally, relevant data from related research literature were incorporated. The objective of this study is to comprehensively account for and analyze the inputs and outputs of N, along with its changing characteristics in the living consumption of rural residents in China. This study sheds light on the impacts of N on rural ecological environments and proposes corresponding mitigation measures. This endeavor is geared toward aiding the strategy of rural revitalization.

2 Metadata of the Dataset

The metadata of Dataset of nitrogen flow from the rural residents' consumption in China (2000–2020)[15] is summarized in Table 1. It includes the dataset full name, short name, authors, year of the dataset, data format, data size, data files, data publisher, and data sharing policy, etc.

3 Methods

3.1 Data Sources

This study delves into the N sources and Nr emissions associated with the living consumption of rural residents in China for the years 2000, 2005, 2010, 2015, and 2020. The required data are categorized into two main groups. The first category comprises basic information data related to the living consumption of rural residents in China. This includes parameters such as the number of rural residents, per capita consumption of food and fossil fuels, firewood production, grassland area, per capita disposable income, and industrial daily necessities consumption. These data were primarily sourced from the China Rural Statistical Yearbook 2001–2021[13] and the China Statistical Yearbook 2001–2021[14]. The second category involves data on conversion factors used to calculate the production of N and its Nr emissions resulting from the living consumption of rural inhabitants. These data were predominantly derived from pertinent literature sources[3–5, 17–20].

Table 1 Metadata summary of the Dataset of nitrogen flow from the rural residents' consumption in China (2000–2020)

Items	Description
Dataset full name	Dataset of nitrogen flow from the rural residents' consumption in China (2000–2020)
Dataset short name	NLivConRuralChina
Authors	Zhao, Y. Q. E-1061-2018, School of Geography and Tourism, Zhengzhou Normal University, zyongqiang@126.com Tian, D., Urban Planning and Design Institute of Nanjing University Co., LTD, nptd08@163.com Liu, W., School of Economics and Management, Zhengzhou Normal University, liuwei@zznu.edu.cn
Geographical region	31 provinces in China (excluding Hong Kong, Macao and Taiwan)
Year	2000, 2005, 2010, 2015, 2020
Data format	.xlsx Data size 22 KB
Data files	5 tables, including the amount of N consumed, its input pathways, Nr emissions and its emission characteristics from the domestic consumption of rural residents in China
Foundation	The Scientific and Technological Project of Henan Province of China (222102320122)
Data publisher	Global Change Research Data Publishing & Repository, http://www.geodoi.ac.cn
Address	No. 11A, Datun Road, Chaoyang District, Beijing 100101, China
Data sharing policy	(1) ***Data*** are openly available and can be free downloaded via the Internet; (2) End users are encouraged to use ***Data*** subject to citation; (3) Users, who are by definition also value-added service providers, are welcome to redistribute ***Data*** subject to written permission from the GCdataPR Editorial Office and the issuance of a ***Data*** redistribution license; and (4) If ***Data*** are used to compile new datasets, the 'ten per cent principal' should be followed such that ***Data*** records utilized should not surpass 10% of the new dataset contents, while sources should be clearly noted in suitable places in the new dataset[16]
Communication and searchable system	DOI, CSTR, Crossref, DCI, CSCD, CNKI, SciEngine, WDS/ISC, GEOSS

3.2 Algorithm

The material flow method is employed in this study to calculate and analyze the source, fate, and N flow within the living consumption system of rural residents in China. The fundamental guiding principle of this approach is the law of mass balance, which posits that the change in the internal storage capacity of a system is equal to the difference between the amount of input and output system material. This principle is mathematically expressed by the following equation:

$$\sum_{h=1}^{m} IN_h = \sum_{g=1}^{n} OUT_g + \sum_{k=1}^{p} AC_k \tag{1}$$

where, IN_h and OUT_g represent the N inputs and outputs, respectively, while AC_k represents the N accumulations. Here, h=1–m represents the N input terms (e.g., food consumption, consumption of industrial daily necessities), g=1–n represents N output terms (e.g., NH_3 volatilization, N_2O emissions), and k=1–p represents N accumulation terms.

3.3 Methodology

In this study, the methodology revolves around the utilization of basic information data collected on the living consumption of Chinese rural residents and N conversion coefficients derived from relevant research literature. Drawing inspiration from the methodologies employed by Cai *et al.*[18], Gu *et al.*[5] and Zhao *et al.*[17], a comprehensive framework for analyzing the N flow in the living consumption of rural residents was established. This study adopts a bottom-up approach, accounting for and evaluating the N sources and Nr emissions within the living consumption system of rural residents in China for the years 2000, 2005, 2010, 2015, and 2020. The material flow analysis method serves as the principal analytical tool. Refer to Section 3.1 for details regarding data acquisition and the sources of emission factors essential for the calculations. Specifically, the N inputs in rural residents living consumption mainly encompass food consumption N (including grain, meat and poultry products, vegetables, fruits, and aquatic products), industrial commodities consumed N, and domestic fuel combustion N by rural residents (including natural gas, gas and biomass fuels). N outputs include NH_3, N_2O, and NO_x, as well as direct discharge and leakage of N-containing wastewater released by rural residents after food consumption and human metabolism, domestic waste treatment, and fuel combustion emissions.

4 Data Results and Validation

4.1 Data Composition

The dataset, archived in .xlsx format, comprises one data file with a size of 22 KB. The data comprehensively cover the structure of N consumption in various aspects of rural residents' lives in China. This includes the breakdown of N consumption in food, industrial daily necessities, and household fuels, as well as the corresponding Nr emissions from rural residents' living consumption. The dataset also encompasses details on the sources and emissions of NH_3 volatilization, NO_x, and N_2O.

4.2 Data Products

(1) Structure of food consumption n and its generation by Chinese rural residents in 2000, 2005, 2010, 2015, and 2020 (Table 2): the results indicate that the proportion of food consumption N accounted for 43.2% and exhibited a declining trend over the years. Notably, there was a 36.5% reduction in 2020 compared with 2000. Regarding the consumption structure, the proportion of food consumption N was 65.9%, also demonstrating a decreasing trend. However, within this structure, the N consumption of meat, poultry, egg, and dairy products, as well as aquatic products, exhibited an increasing trend with average annual growth rates of 8.0% and 14.2%, respectively.

Table 2 The structure of nitrogen in food consumption and its production (Tg)

Food	2000	2005	2010	2015	2020
Grain	2.37	1.88	1.47	1.18	1.11
Livestock and poultry products	0.43	0.48	0.44	0.55	0.57
Aquatic products	0.09	0.10	0.09	0.11	0.14
Vegetable	0.26	0.23	0.19	0.16	0.15
Melon and fruit	0.03	0.03	0.03	0.04	0.04

(2) Structure and production of N consumption in industrial daily necessities for rural residents in China (Table 3): the findings reveal that the proportion of N consumed by rural residents in industrial daily necessities is 31.5%. This category has undergone a period of rapid growth, with consumption in 2020 registering a staggering increase of 572.6% compared with 2000. Examining the consumption structure, synthetic industrial product N constitutes 89.5%, while biosynthetic industrial product accounts for 10.5%. Notably, the per capita consumption of industrial N products by rural residents in China now surpasses the per capita consumption of food N. Given that industrial products are rich in carbon and N, there is an urgent need to intensify efforts toward recycling and harmless treatment of these products.

(3) Structure and production of fuel consumption N by rural households in China (Table 4): fuel consumption N by rural households accounted for 25.3%, demonstrating a gradual increase with an average annual growth rate of 1.5%. Analyzing the consumption structure reveals that straw and livestock manure serve as the primary sources of N in domestic fuel

consumption, collectively contributing a substantial 97.9%, while other sources constitute a mere 2.0%. These findings underscore the critical importance of increasing the proportion of clean energy used in the daily lives of rural residents. This would help prevent and control atmospheric N pollution in rural areas.

Table 3 The structure of nitrogen in industrial daily necessities and its production (Gg)

Types		2000	2005	2010	2015	2020
Artificial synthesis	Plastic	14.4	27.3	52.4	98.8	148.1
	Coating/paintings	72.8	135.9	343.0	652.1	1,036.5
	Chemical fiber	146.6	315.3	584.6	978.3	1,376.8
	Syntheic rubber	1.1	2.4	3.8	6.8	10.6
	Syntheic dyes	6.8	7.7	9.1	11.7	15.8
	Chemical medicines	6.9	15.0	26.7	42.4	41.0
	Dynamite	58.0	101.0	149.6	167.3	226.7
	Reagents	7.9	11.6	33.0	95.1	158.7
	Chemical pesticide	8.0	13.6	26.4	47.3	30.2
	Synthetic detergents	3.9	6.1	8.9	16.6	16.1
	Nitrate	47.9	81.8	122.6	154.1	143.6
Biosynthetic products	Agricultural raw materials	13.1	13.8	13.7	13.6	12.5
	Raw materials for livestock and poultry products	61.8	67.4	73.8	92.8	111.3
	Forest product raw materials	65.1	68.7	99.6	95.1	132.3

Table 4 Nitrogen structure of household fuel consumption and its production (Gg)

Types	2000	2005	2010	2015	2020
Fossil fuel_NH_3	1.8	1.9	1.9	0.8	0.4
Fossil fuel_NO_x	9.7	11.3	14.1	12.9	12.8
Straw fuel	825.8	862.2	881.2	907.8	974.2
Firewood	12.7	12.9	13.4	16.1	24.6
Livestock and poultry manure fuel	549.8	514.8	469.9	505.5	469.9

(4) The amount of Nr emissions from the living consumption of rural residents in China: the results, as illustrated in Figure 1, indicate that 25.4% of the N produced by the domestic consumption of rural residents in China is discharged into the atmosphere and water environment in the form of Nr, amounting to an annual emission of approximately 1.43 Tg. The primary source of Nr emissions is NH_3 volatilization, contributing to 50.1%, followed by Nr discharged into surface water bodies at 31.0% and NO_x at 15.8%. Additionally, N_2O contributes 2.0%, while Nr discharged into groundwater bodies accounts for only 1.1%. The overall Nr emissions exhibit fluctuations but show a decreasing trend at an average annual rate of 1.3%. These findings suggest that changes in the consumption structure of rural residents in China have significantly alleviated the N load in the rural environment.

Sources of NH_3 volatilization, NO_x, and N_2O and their emissions from the domestic consumption of rural residents in China: the primary source of NH_3 emissions from the domestic consumption of rural residents in China is human food metabolized excreta, constituting the largest share at an annual average of 513.1 Gg N, accounting for approximately 72.0%, while other sources collectively contribute around 28.0% (Figure 2). This highlights the significance of addressing and improving the disposal capacity of human fecal and urinary excreta in the prevention and control of NH_3 volatilization in rural residential areas in China.

As depicted in Figure 3, the primary contributor to NO_x emissions from rural residents was straw combustion, representing the largest share at 51.4%. Following this, livestock and poultry manure combustion contributed 33.4%, garbage treatment emissions constituted

8.7%, and household fossil fuel combustion accounted for 5.4%, with firewood contributing only 1.1%. Consequently, the key strategy for reducing NO_x emissions in rural residents' lives involves increasing the proportion of consumption of fossil fuels and clean energy.

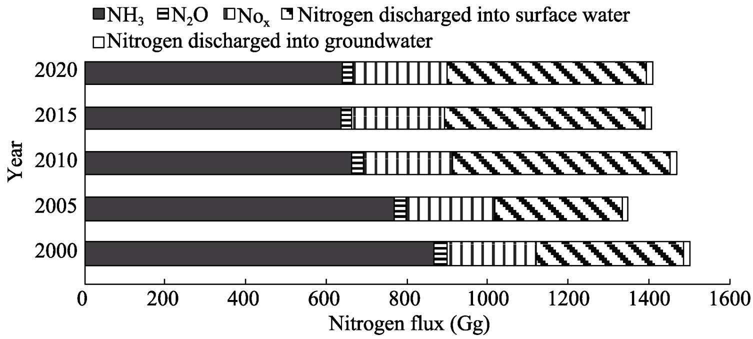

Figure 1 Nr emissions from living consumption of rural residents in China (Gg)

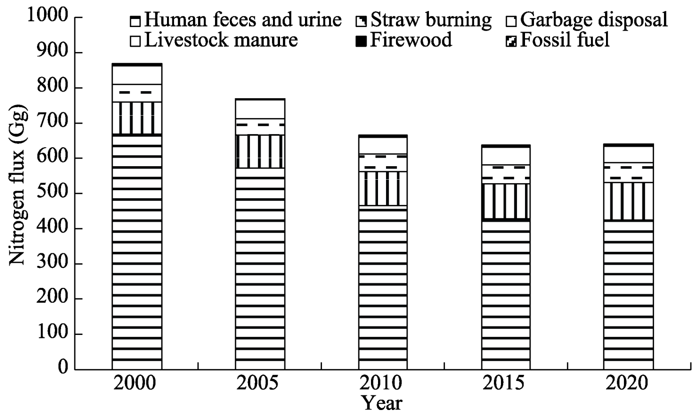

Figure 2 Sources and emissions of NH_3 from living consumption of rural residents in China (Gg)

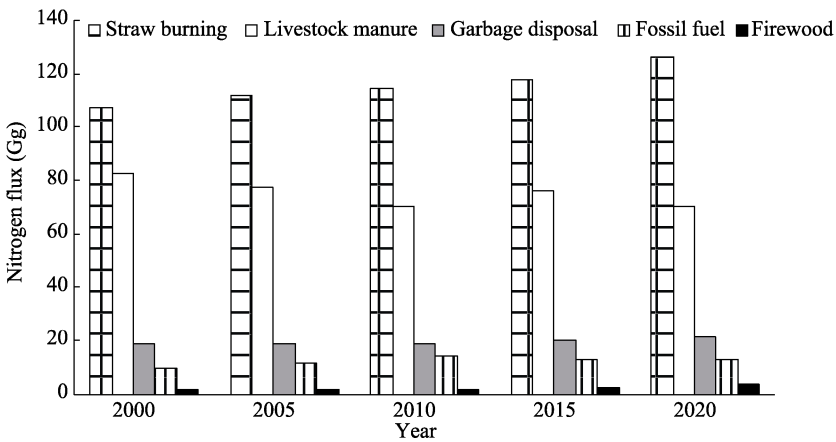

Figure 3 Sources and emissions of NO_x from living consumption of rural residents in China (Gg)

In Figure 4, the distribution of N_2O emissions reveals that human feces and urine excretion constitute the largest contributor at 37.3%. Following this, straw combustion contributes 31.0%, while fecal combustion and garbage treatment collectively account for 17.5% and 13.7%, respectively. In contrast, firewood contributes less than 1.0%. This analysis suggests that efforts to reduce N_2O greenhouse gas emissions from the living consumption of rural residents should primarily focus on improving the treatment capacity of human fecal and urine excretion and minimizing the use of straw fuel.

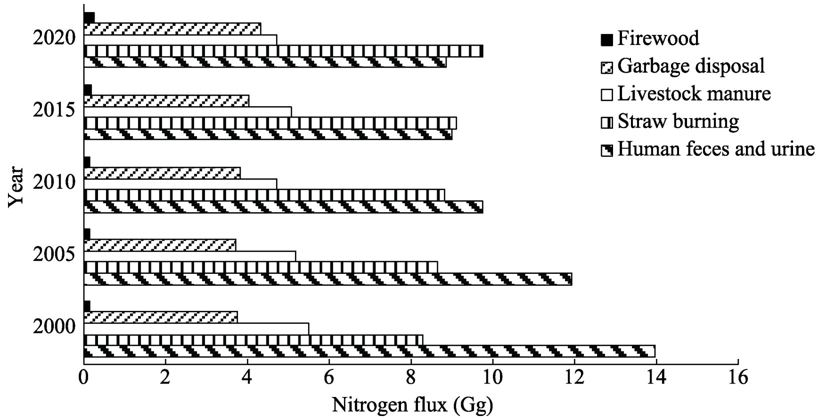

Figure 4 Sources and emissions of N_2O from living consumption of rural residents in China (Gg)

The discharge of Nr into water bodies is primarily attributed to human feces, urine, and domestic residues, with an annual discharge of approximately 458.5 Gg N. This discharge accounts for 32.1% of the total Nr discharged, with a substantial proportion of 96.6% being released into surface water bodies, while the remaining percentage is discharged into groundwater bodies.

4.3 Data Validation

To validate the data on food consumption N, industrial product consumption N, domestic fuel consumption N, and Nr emissions from 2000 to 2020, the method proposed by Gao *et al.* [10] was employed. The validation results indicate that the calculation error falls within the range of 7.1%–22.5%, all of which are deemed acceptable. Furthermore, the food consumption N by rural residents in this study closely aligns with the estimated results from published literature[12], affirming the reliability of the accounting results presented in this study.

5 Discussion and Conclusion

Utilizing material flow analysis and the law of mass balance, this study successfully established a comprehensive framework for analyzing N flow within the domestic consumption of rural residents. Employing bottom-up calculations based on national-level statistical information, this study generated a dataset capturing the N flow in the domestic consumption of rural residents in China for the period 2000–2020. Through uncertainty analysis and comparison with data from related studies, the results exhibited a high degree of credibility. This dataset holds substantial reference significance, offering valuable insights into the input and output characteristics of N consumption by rural residents in China. The findings provide a solid foundation for formulating strategies aimed at managing and regulating rural N pollution.

Data analysis revealed the following key insights. (1) Food and industrial daily necessities emerged as the primary sources of N in the domestic consumption of Chinese rural residents. These areas should be the focal points for effective management and control of N in the domestic consumption of rural residents. (2) The food consumption of N by rural residents in China continues to be primarily dominated by grain consumption. However, a discernible trend indicates a year-by-year increase in the consumption of meat, poultry, eggs, milk products, and aquatic products. (3) Currently, the proportion of fossil fuels in the consumption of household fuels by rural residents is relatively low. (4) A significant portion, 25.4%, of the N produced by rural residents' domestic consumption is discharged into the surrounding environment in the form of Nr. Enhancing the disposal capacity of human fecal and urinary excreta and increasing the proportion of clean energy consumption are critical priorities for the prevention and control of N pollution in rural areas. This dataset serves as a valuable resource for research and decision-making related to N balance and sustainable N management in China's rural socioeconomic system.

Author Contributions

Zhao, Y. Q. designed the algorithms of dataset. Tian, D. contributed to the data processing and analysis. Liu, W. designed the algorithms, performed data validation. All authors wrote the data paper.

Conflicts of Interest

The authors declare no conflicts of interest.

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