REFERENCES

1. Anderson, Tracy L. 2013. "One World, One Ocean, One Mission." Earth Common Journal 3 (1): 1-2.

2. Donre Quang Tri. 2023. Report on Results monitoring of Resources and Evironment in Quang Tri province 2019 - 2023. Dong Ha: Department of Natural Resources and Environment of Quang Tri province.

3. Donre. 2020. Report on Environmental Current of Quang Tri province, 2016-2020. Dong Ha: Department of Natural Resources and Environment of Quang Tri province.

4. GESAMP. 2008. Assessment and communication of environmental risks in coastal aquaculture. Rome: UN, UNEP, FAO, UNESCO-IOC, WMO, UNIDO, IMO, IAEA.

5. Hernando, M D, M Mezcua, A R Fernandez-Albá, and B Barcelo'. 2006. "Environmental risk assessment of pharmaceutical residues in wastewater effluents, surface waters and sediments." Talanta 69: 334-342.

6. Monre. 2016. Circulars 26/2016/ TT-BNTMT Regulation on Criteria of Risk Classification and Zoning. Ha Noi: Ministry of Natural Resources and Environment.

7. MONRE. 2021. Report on the National Sea and Island Environment in the 2016-2020 period. Ha Noi: Ministry of Natural Resources and Environment.

8. Phuoc, Le Van. 2023. Risk regional zonation of environmetal pollution on the sea and islands of Quang Tri. Dong Ha: The Department of Natural Resources and Environment of Quang Tri province.

9. Rana, Juwel, Patricia Luna Gutierrez, and John C Oldroyd. 2021. "Quantitative Methods." Global Encyclopedia of Public Administration, Public Policy, and Governance 1-6.

10. Z. Vryzas, C. Alexoudis, G. Vassiliou, K. Galanis, and E. Papadopoulou-Mourkidou. 2011. "Determination and aquatic risk assessment of pesticide residues in riparian drainage canals in northeastern Greece." Ecotoxicology and Environmental Safety 74: 174–181.

1. INTRODUCTION

Open burning of rice straw in the fields is a method of cleaning the fields after harvest, preparing for the next crop in Vietnam. Emissions from the burning of rice straw contribute greatly to air pollution in Vietnam, negatively affecting human health, contributing to increasing the greenhouse effect and acid rain. The results of calculating the air pollution load [01] due to open burning show that in 2020, open burning of rice straw in Vietnam emitted 905,544.6 tons of $PM_{2.5}$, 1,017,802.2 tons of PM_{10}, 104,773.8 tons of SO_2, 97,289.9 tons of NO_2, 170,631.6 tons of NO_x, 2,596,892.0 tons of CO. By 2030, open burning of rice straw in Vietnam will emit 258,062.1 tons of $PM_{2.5}$, 290,053.3 tons of PM_{10}, 29,858.4 tons of SO_2, 27,725.7 tons of NO_2, 48,626.6 tons of NO_x, and 740,062.4 tons of CO.

During the period 2022-2025, the Vietnam Association for Conservation of Nature and Environment (VACNE) has coordinated with the Global Alliance for Pollution and Health (GAHP) to implement the project "Reducion of risks of open burning practices and unsafe use of pesticides to the environment and human health in Vietnam" funded by the UK Department of Environment, Food and Rural Affaire (DEFRA).

Within the framework of this project, some demonstration models on straw open burning alternatives were implemented, including rice-straw composting, rice-straw fermented for cattle feed, and straw mushroom production in Chau Thanh district, An Giang province [02],[03], models of in-field microbiological decomposing straw in Khanh Thanh commune, Yen Khanh district, Ninh Binh province [04] and in Song Ray commune, Cam My district, Dong Nai province [05].

The implementation of the above mentioned open burning alternative models brings many economic benefits (i.e. enhancing the value chain of the rice production sector), social benefits (i.e. creating new jobs, improving farmers' lives) and environmental benefits (i.e. reducing environmental pollution, reducing greenhouse gas (GHG) emissions).

The purpose of this study is to assess the potentials of GHG emission reduction due to open burning alternatives. The applied methods are rapid assessment based on investigation, survey, data collection and application of GHG emission factors [06].

2. METHODOLOGY

2.1. Study Subjects

This study focused on some straw open burning alternative models, including:

- Three technical models utilizing rice straw in some selected communes of Chau Thanh district, An Giang province such as rice straw mushroom production, rice straw composting and rice straw fermented for cattle feed.
- One model of in-field decomposing straw in Khanh Thanh commune, Yen Khanh district, Ninh Binh province.
- One model of in-field decomposing straw in Song Ray commune, Cam My district, Dong Nai province.

2.2. Study methods

2.2.1. Data collection

Data were collected in the selected communes, Chau Thanh district, An Giang province including area of rice cultivation, mass of rice straw generated, mass of straw transported and used for the open burning alternative models.

Assessment of greenhouse gas emission reduction of rice straw open burning alternative methods in some selected areas in Vietnam

PHÙNG ANH ĐỨC[1], PHÙNG CHÍ SỸ[1]
NGUYỄN NGỌC SINH[2], NGUYỄN ANH TUẤN[2]
HOÀNG VĂN PHÚC[3], NGUYỄN THỊ VÂN HÀ[4], LƯƠNG HỮU THÀNH[5]
[1]Environmental Technology Center
[2]Vietnam Association of Conservation of Nature and Encironment
[3]Nguyen Tat Thanh University
[4]Institute of Natural Resource and Environment of Ho Chi Minh City
[5]Institute of Agrcultural Environment, MARD

Abstract

Rice straw open burning has been quite popular in Vietnam and caused pollution and greenhouse gases emission. There have been several alternative methods to replace the open burning including rice-straw composting, rice-straw fermented for cattle feed, straw mushroom production and models of in-field microbiological decomposing straw. This study aims to investigate GHG reduction of the straw open burning alternative models in Vietnam, including An Giang, Ninh Binh and Dong Nai provinces. Results showed that, the models contribute to reducing GHG emissions in selected communes in Chau Thanh district, Khanh Thanh, Song Ray communes including 64.3, 328.1, 45.1 tons, respectively. If the research results of the models are replicated, GHG emissions in Khanh Thanh, Song Ray communes can be reduced by 3,065.9, 3,635.6 tons/year, respectively. The potentials for GHG emission reduction in 2022 in Chau Thanh, Yen Khanh, Cam My districts are 2,644.2, 8,772.6, 821.8tons/year, respectively. Those in An Giang, Ninh Binh, Dong Nai provinces are 5,530.5, 112,885.1, 56,140.0 tons/year, respectively. By 2030, the potentials for GHG emission reduction in Chau Thanh, Yen Khanh, Cam My districts will be 13,098.9, 14,474.8, 1,355.9 tons/year, respectively. Those in An Giang, Ninh Binh, Dong Nai provinces will be 27,358.6, 56,410.9, 26,853.1 tons/year, respectively.

Keywords: *Open burning alternatives, greenhouse gases, potential reduction.*
JEL Classifications: *Q51, Q53, Q55.*
Received: *2nd August 2024;* ***Revised:*** *22nd August 2024;* ***Accepted:*** *16th September 2024.*

Data were collected in Khanh Thanh commune, Yen Khanh district, Ninh Binh province and Song Ray commune, Cam My district, Dong Nai province, including area of rice cultivation, mass of rice straw generated, rate of straw in-field decomposting.

2.2.2. Emission factors

This study applied the emission factor (EF) to estimate the total GHG emission from rice straw open-burning and compare them with those from the open burning alternative models (See tables 1).

The GHG emission from the models will be calculated based on the total GHG emission from harvesting, rolling and transporting the rice straw plus the GHG emission of applied open burning alternative models.

Total GHG emission from straw burning is calculated as follows:

GHG emission (kg/year) = MB×CF×EF_i (1)

of which MB: Straw production (ton dry weight/ha), CF: burning efficiency = 0,80%, EF_i: emission factors (kg/ton of burned straw).

Total GHG emissions from machinery straw rolling, transportation, open burning alternatives are calculated as follows:

GHG emissions = Mass of rolled straw × EF_i (2)

of which: EF_i is emission factors (kg/ton rice straw), i changes from 1 to 7.

3. RESULTS AND DISCUSSIONS

3.1. Technical models utilizing rice straw in Chau Thanh district, An Giang province

3.1.1. Reduction of GHG emissions due to the open burning alternatives models in selected communes, Chau Thanh District

The mushroom production models were implemented in 4 communes (Can Dang, Vinh An, Vinh Binh, Binh Thanh, Vinh Hanh), the composting models were implemented in 07 communes (Can Dang, An Chau, An Hoa, Vinh Hanh, Vinh An, Vinh Nhuan, Vinh Loi), the straw fermented models for cattle feed were implemented

Table 1. GHG emission factors [03], [06], [07]

No	Activities	Unit	CO_2	CH_4	N_2O	CO_{2e}
01	Straw burning (EF_1)	kg/ton rice straw	1,489.5	2.7	0.07	1,577.9
02	Machinery straw rolling (EF_2)	kg/ton rice straw				4.378
03	Transportation (EF_3)	kg/ton rice straw				740.0
04	Straw mushroom production (EF_4)	kg/ton rice straw				222.0
05	Ricestraw composting (EF_5)	kg/ton rice straw		4.0	0.24	171.5
06	Ricestraw fermented for cattle feed (EF_6)	kg/ton rice straw				60.0
07	Decomposting wet straw/ stubble (EF_7)	kg/ton rice straw/stubble		4.0	0.24	171.5

Note: CH_4 and N_2O emission were converted to CO_2 equivalent (CO_{2e}) by applying global warming potentials (GWP) such as: $1CO_2 = CO_{2e}$; $1CH_4 = 25\ CO_{2e}$; $1N_2O = 298\ CO_{2e}$.

in 5 communes (Vinh Nhuan, Vinh Loi, An Chau, An Hoa, Vinh An) in Chau Thanh district, An Giang province. Based on the mass of rice straw used for the alternative models [02], emission factors in table 1, one can estimate the GHG emissions reduction due to the alternatives models in the selected communes of Chau Thanh District (See table 2).

Table 2.GHG emissions reduction due to the open burning alternatives in the selected communes of Chau Thanh District

Alternative models	Emisson factor ($kgCO_{2e}$/ton rice straw)	Mass of rice straw used for models (ton/year)	GHG emission (kg/year)
1. Straw open burning	1,577.9	177.6	224,188
2. Open burning alternatives			159,904
Machinery straw rolling	*4.378*	*177.6*	*778*
Transportation	*740.0*	*177.6*	*131,424*
Straw mushroom production	*222.0*	*88.0*	*19,536*
Rice straw composting	*171.5*	*32.0*	*5,488*
Rice straw fermented for cattle feed	*60.0*	*57.6*	*3,456*
3. GHG emissions reduction			64,286

Table 2 shown that the open burning alternative models will reduce 64,286 kg CO_{2e}/year or 64.3 tons CO_{2e}/year.

3.1.2. Potentials of GHG emission reduction in Chau Thanh district and An Giang province

According to research results [03], the mass of straw generated in 2022 in Chau Thanh district is 146,669 tons/year, in An Giang province is 1,451,908 tons/year. From 2014 to 2022, about 37-40% of straw in Chau Thanh district was collected and transported to households for reuse. The collection and reuse rate increased by about 5%/year [08]. The mass collected for reuse in Chau Thanh district is 58,667 tons/year, in An Giang province is 290,382 tons/year. Among those, about 70% of the straw volume is used to produce straw mushrooms (15%), for fermented feeds (5%), for composting (50%) and for stump cover of vegetables and orchards (the remaining 30%) (See Table 3).

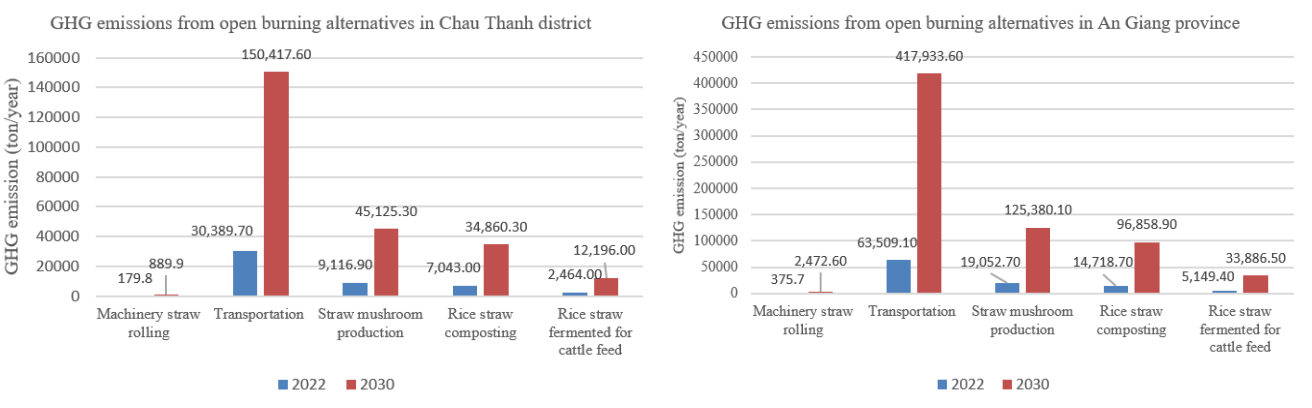
Based on rice cultivation area [10], it is forecasted that by 2030, the mass of straw generated in Chau Thanh district will be 143,039 tons/year, and in An Giang province will be 1,411,938 tons/year. Rice straw collection rate in 2030 should increase to 60% (85,823 tons/year) in Chau Thanh and 40% (564,775 tons/year) in An Giang, respectively [08], and the rate of mushroom: compost: feed model was planned as 35:50:15 in 2030 (See Table 3).

Based on the potential volume of straw that can be collected to produce straw mushrooms, compost, and animal feed in 2022 (Chau Thanh district 41,067 tons/year, An Giang province 203,267 tons/year) and forecast to 2030 (Chau Thanh district 85,823 tons/year, An Giang province 564,775 tons/year) (Table 3), the GHG emission factor (Table 1), CO_{2e} emissions in 2022 and 2030 from open burning alternatives in Chau Thanh district and An Giang province can be estimated (Figure 1).

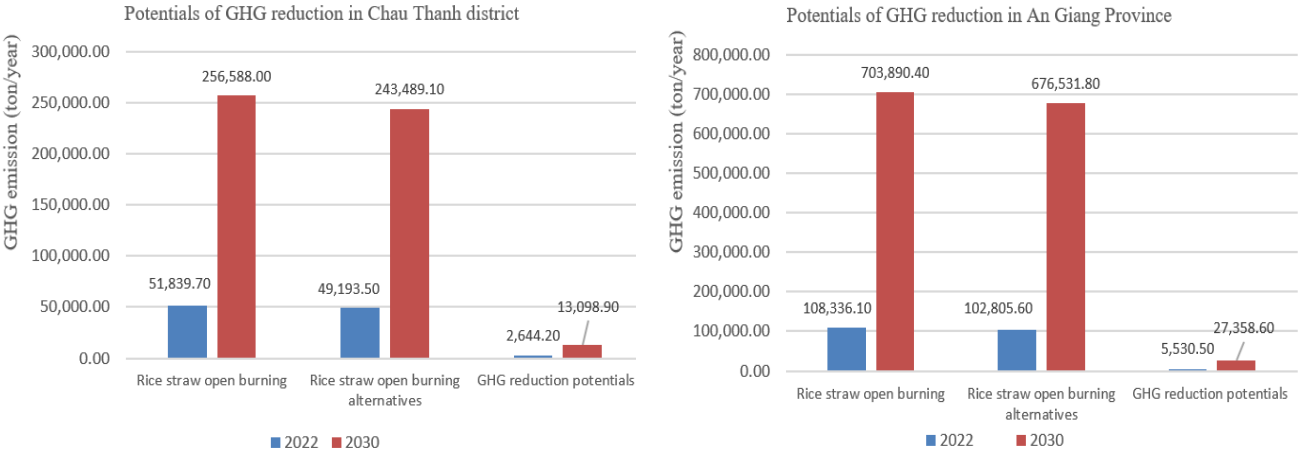
Table 3. The mass of straw generated in Chau Thanh district and An Giang province

Straw utilization	Chau Thanh District (ton/year)		An Giang Province (tone year)	
	2022	2030	2022	2030
Total mass of straw generated	146,669	143,039	1,451,908	1,411,938
Total mass of straw collected	58,667	85,823	290,382	564,775
Total mass of straw used for the alternative models	41,067	85,823	203,267	564,775
- Straw mushroom production	*8,800*	*30,038*	*43,557*	*197,671*
- Rice straw composting	*29,334*	*42,912*	*145,191*	*282,388*
- Rice straw fermented for cattle feed	*2,933*	*12,873*	*14,519*	*84,716*

Calculation of GHG emissions from open burning of rice straw is based on formula (1) in section 2.2.2 above. The mass of rice straw used to calculate GHG emissions from open burning is equivalent to the mass of rice straw used for open burning alternatives (i.e. straw mushroom production, composting, animal feed fermentation). Calculation of potentials of GHG reduction is based on the difference between the GHG emissions generated from open burning of rice straw and the GHG emissions generated from open burning alternatives (see Figure 2).



▲ *Figure 1. GHG emissions from the open burning alternatives in Chau Thanh and An Giang Province*



▲ *Figure 2. Potentials of GHG reduction due to the open burning alternatives in Chau Thanh and An Giang Province*

The results of Figure 2 show that the potential for GHG emission reduction due to the implementation of open burning alternatives in 2022 in Chau Thanh district is 2,644.2 tons/year, in An Giang province is 5,530.5 tons/year. Those by 2030 in Chau Thanh district will be 13,098.9 tons/year and in An Giang province will be 27,358.6 tons/year.

3.2. Model of in-field decomposing straw in Khanh Thanh commune, Yen Khanh district, Ninh Binh province

3.2.1. Reduction of GHG emissions due to the open burning alternative models in Khanh Thanh commune

Based on the mass of rice straw/stabble used for the alternative models (i.e. in-field decomposting) [04], emission factors in table 1, one can estimate the GHG emissions redution from the alternatives models in Khanh Thanh commune (See table 4).

Calculation of potentials of GHG emission reduction is based on the difference between the GHG emission generated from rice straw open burning and the GHG emission generated from in-field composting (see Figure 3).

The results of Figure 3 show that the potentials for GHG emission reduction due to the implementation of in-field decomposting in 2022 in Yen Khanh district is 19,436.0 tons/year, in Ninh Binh province is 112,885.1 tons/year. Those by 2030 in Yen Khanh district will be 8,772.6 tons/year and in Ninh Binh province will be 56,410.9 tons/year.

Table 4. GHG emission reduction due to the alternative models in Khanh Thanh commune

Alternative models	Emisson factor ($kgCO_{2e}$/ton rice straw/ stubble)	Mass of rice straw/ stubble used for decomposting (ton/ year)	GHG emission (kg/year)
Straw open burning	1,577.9	233.26	368,061
Decomposting straw/stubble	171.5	233.26	40,004
GHG reduction potentials due to in-field decomposting straw/stubble			328,057

Table 4 shown that, the reduction in GHG emission due to in-field decomposting will be: 328,057 kg of CO_{2e}/year or 328.1 tons of CO_{2e}/year.

During the project implementation, the expert team provided microbial products to decompose rice straw/ stubble on an area of 400 hectares of rice/year, those generate 2,180 tons of rice straw/stubble per year. The GHG emitted due to in-field decomposting will be 373.9 tons of CO_{2e}/year. The GHG emitted due to burning is (2,180x1,577.9 = 3,439.8 tons/year. The GHG emission is reduced: 3,439.8 - 373.9 = 3,065.9 tons/year.

3.2.2. Potentials of GHG emission reduction in Yen Khanh district and Ninh Binh province

Based on data on rice cultivaton area in Yen Khanh district and Ninh Binh province in 2022 [09], the plan until 2030 [10], the straw generation factor, the average ratio of in-field decomposting straw/stubble mass [04], it is possible to estimate the mass of straw/stubble generated and that decomposed in the field (see table 5).

3.3. Model of in-field decomposing straw in Song Ray commune, Cam My district, Dong Nai province

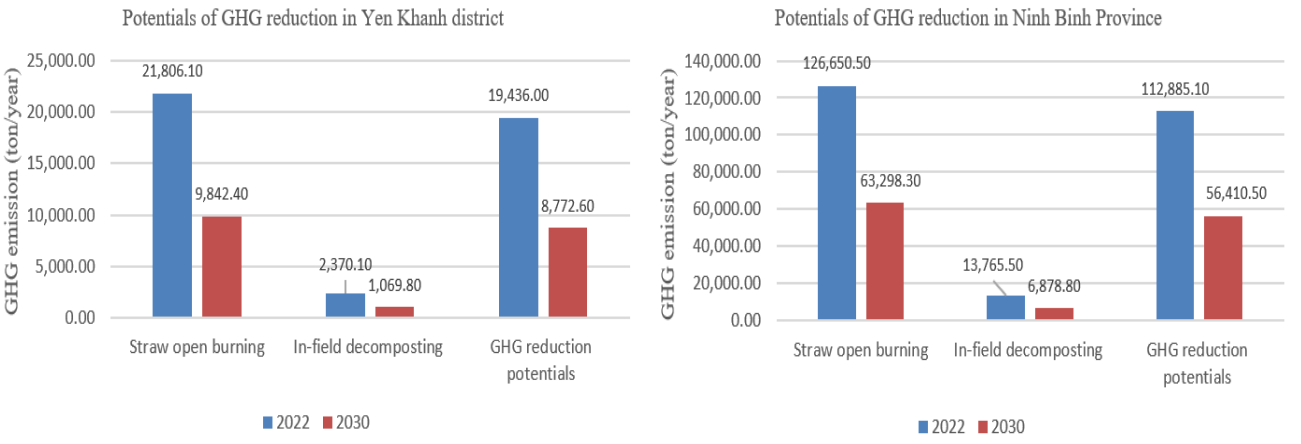
3.3.1. Reduction of GHG emissions due to the open burning alternative models in Song Ray commune

The in-fiels decomposting models were implemented in 3 sessions from August 2023 to September 2024 for 20 households with total area of 5.3 ha in Song Ray commune.

Based on the mass of rice straw/ stabble used for the alternative models (i.e. in-field decomposting) [05], emission factors in table 1, we can estimate the GHG emissions redution from the alternatives models in Song Ray commune (See table 6).

Table 5. The mass of straw generated in Yen Khanh district and Ninh Binh province

Straw utilization	Yen Khanh district (ton/year)		Ninh Binh province (tone year)	
	2022	2030	2022	2030
Total mass of straw generated	41,877.8	31,188.2	243,228.1	200,549.1
Total mass of straw/stubble decomposed	13,819.7	6,237.6	80,265.3	40,109.8



▲ *Figure 3. Potentials of GHG reduction due to the open burning alternatives in Yen Khanh and Ninh Binh province*

Table 6. GHG emission reduction due to the alternative models in Song Ray commune

Alternative models	Emisson factor ($kgCO_{2e}$/ton rice straw/stubble)	Mass of rice straw/stubble used for decomposting (ton/year)	GHG emission (kg/year)
Straw open burning	1,577.9	29.15	45,995.8
Decomposting wet straw/stubble	171.5	29.15	909.0
Potential of CO_{2e} emission reduction due to in-field decomposting straw/stubble			45,086.8

Table 6 shown that, the reduction in GHG emission due to in-field decomposting models will be 45,086.8 kg of CO_{2e}/year or 45.1 tons of CO_{2e}/year.

If this model is replicated in Song Ray commune with a total rice growing area of 470 hectares, the mass of straw generated will be 2,585 tons/year. The GHG emitted due to in-field decomposting will be 443.3 tons of CO_{2e}/year. The GHG emitted due to burning will be 4,078.9 tons/year. The GHG emissions could be reduced 4,078.9 - 443.3 = 3,635.6 tons/year.

3.3.2. Potentials of GHG emission reduction in Cam My district and Dong Nai province

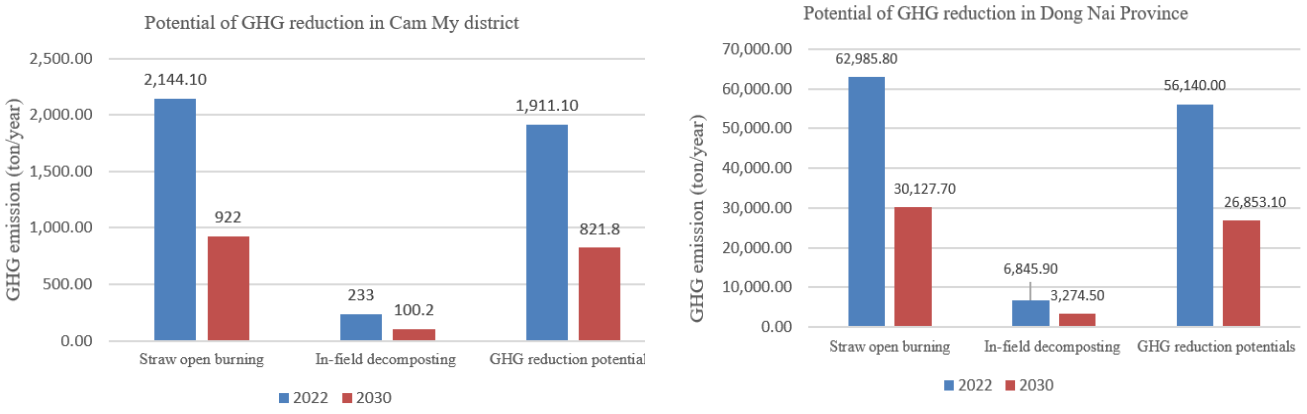
Based on data on rice cultivaton areas in Cam My district and Dong Nai province in 2022, the plan until 2030 [05][10], the straw generation factor, the average ratio of in-field decomposting straw/stubble mass, it is possible to estimate the mass of straw/stubble generated and that decomposed in the field (see table 7).

Calculation of GHG reduction potential is based on the difference between the GHG emission generated from open burning of rice straw and the GHG emission generated from open burning alternatives (i.e. in-field composting) (see Figure 4).

The results of Figure 4 show that the potential for GHG emission reduction due to the implementation of in-field decomposting in 2022 in Cam My district is 1,911.1 tons/year, in Dong Nai province is 56,140.0 tons/year. Those by 2030 in Cam My district will be 821.8 tons/year and in Dong Nai province will be 26,853.1 tons/year.

Table 7. The mass of straw generated in Cam My district and Dong Nai province

Straw utilization	Cam My district (ton/year)		Dong Nai province (tone year)	
	2022	2030	2022	2030
Total mass of straw generated	4,117.7	2,921.5	120,962.2	95,467.7
Total mass of straw/ stubble decomposed	1,358.8	584.3	39,917.5	19,093.5



▲ *Figure 4. Potentials of GHG reduction due to the open burning alternatives in Cam My and Dong Nai province*

4. CONCLUSION

Some straw open burning alternative models were implemented, including rice straw mushroom production, rice straw composting, rice straw fermented for cattle feed in the selected communes, Chau Thanh district, An Giang province, models of in-field microbiological decomposing straw in Khanh Thanh commune, Yen Khanh district, Ninh Binh province and in Song Ray commune, Cam My district, Dong Nai province.

In addition to economic, social and environmental benefits, implementing the models contributes to reducing GHG emissions in selected communes in Chau Thanh district, Khanh Thanh, Song Ray communes, including 64.3, 328.1, 45.1 tons, respectively.

If the research results of straw/stubble decomposition in the fields are replicated, the potentials of GHG emission reduction in Khanh Thanh, Song Ray communes can be 3,065.9, 635.6 tons/year, respectively. The reduction potentials in 2022 in Chau Thanh, Yen Khanh, Cam My districts are 2,644.2, 19,436.0, 1,911.1 tons/year, respectively. Those in An Giang, Ninh Binh, Dong Nai could be 5,530.5, 112,885.1, 56,140.0 tons/year, respectively. By the year of 2030, the potentials of GHG reduction in Chau Thanh, Yen Khanh, Cam My districts will be 13,098.9, 8,772.6, 821.8 tons/year, respectively. Those in An Giang, Ninh Binh, Dong Nai province will be 27,358.6, 56,410.9, 26,853.1 tons/year, respectively.

The research results show that implementing open burning alternatives significantly reduces GHG compared to open burning, so it is recommended that authorities increase propaganda on the benefits of alternative solutions, provide technical guidance and preferential funding to replicate these models, contributing to GHG emission reducing to achieve the goal of net zero.

Acknowlegement: Part of the research presented in this article was funded by the UK Department for Environment, Food and Rural Affairs (DEFRA) through the project "Reduction of risks of open burning practices and unsafe pesticide use to the environment and human health in Vietnam" implemented by the Global Alliance for Health and Pollution (GAHP) in collaboration with the Vietnam Association for Conservation of Nature and Environment (VACNE) ■

REFERENCES

1. Phung Chi Sy, Phung Anh Duc, Nguyen Thi Hai (2024). Assessment of the current status and forecast of air pollution load due to open burning of straw in Vietnam (in Vietnamese). Environment Magazine, ISSN:2015:9600, Vietnamese Edition I-2024, Pp 30-35.

2. Phung Anh Duc, Phung Chi Sy, Nguyen Thi Van Ha, Pham Ngoc Xuan (2024). Alternative solutions of rice straw open burnig in An Giang Province. Environment Magazine, ISSN:2015:9600, Eglish Edition I-2024,Pp 16-22.

3. Nguyen Thi Kim Chi, Nguyen Van Nhan, Nguyen Thi Van Ha (2024). Aseessment Environmental and Social Impacts for the Rice Straw Utilization Technical Models to Proote Circukar Economy for Rice Production in Chau Thanh District- An Giang Province. JST: Engineering and Technology for Sustainable Development, Volume 34, Issue 1, March 2024

4. Nhan Van Community Capacity Development Center (2023). Assessment of the current status of air pollutant emissions from open burning of rice straw and proposed solutions for rice straw treatment in the fields - Pilot study in Ninh Binh, 113 pages.

5. Nguyen Tat Thanh University (2024). Research on building a model for treating rice straw in the field using microbial products - A case study in Song Ray commune, Cam My district, Dong Nai province, 141 pages.

6. Decision 2626/QD-BTNMT dated October 10, 2022 of the Ministry of Natural Resources and Environment announcing the list of emission factors for greenhouse gas inventory.

7. Nguyen Thi Van Ha (2022). Estimated CO_2-eq generated from different models of straw uses in An Giang province. Ho Chi Minh City University of Natural Resources and Environment.

8. Chau Thanh District Agriculture and Rural Development Division (2022). Agriculture sector results report in 2022.

9. General Statistics Office. Vietnam Statistical Yearbook 2022.

10. Decision No. 326/QD-TTg dated March 9, 2022 of the Prime Minister on the allocation of national land use planning targets for the 2021-2030 period, with a vision to 2050, and the 5-year national land use plan for 2021-2025.