ZERO-WASTE RICE-BASED FARMING SYSTEM FOR SMALL-SCALE FARMERS

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ABSTRACT

*Small scale farmers in Asia till an average of one-hectare of farm. They are one of the poorest in society economically and physically. The best option to lift them up from poverty is to organize them to become strong and obtain more support from the government and philanthropists to start projects that will empower them. Individually, they need to learn the techniques to intensify, diversify and integrate to make their farm zero-waste and adapt to climate change and mitigate greenhouse gas emission. This paper will describe the different climate smart technologies that they could use in intensification, diversification and integration. These technologies also reduce greenhouse gas emissions compared to conventional farming practices. It is a balanced of natural and modern rice farming practices. The alternate wetting and drying (AWD), rice straw-based nutrient management and azolla production, mushroom growing and vermi composting, capillarigation, rice-duck system, sorjan system, high-yielding varieties, Continuous Rice Hull (*CtRH*) carbonizer with attachments, Ride-on tillage implement, Wind-pump system, Rice Husk Gasifier for village rice mills are just few of the climate smart and mitigating technologies. For examples the AWD reduces methane by 30-70%, early and compost rice straw incorporation has a lower emission, azolla production as carbon sequestration, mushroom growing and vermi composting aside from additional income of farmers it also helps reduce greenhouse gas emission. High yielding varieties, when cultivated with climate smart technologies or integrated crop management, can reduce methane by 83-93%. Generally, high yielding varieties have lower methane transport capacity (MTC). Capillarigation gives higher water use efficiency compared to conventional drip irrigation. The mitigated methane emission from ride-on tillage* *implement, wind-pump system and rice hull gasifier have 2.3 kg CO_2 eq, 0.1 Mg CO_2 eq per hectare, and 126 kg CO_2 eq per day, respectively. Although, we can mitigate greenhouse gases with the technologies we have introduced to the farmers, they will not have decent lives if they remain economically and physically poor. Thus, to complement these technologies and to help ensure a decent life for the farmers, strong support by the network of government, private sector and the academe is needed to empower them to organize and teach them to do agro-enterprise or farming as a business.*

Keywords: Intensify, diversify, integrate, organize, technologies, system

INTRODUCTION

The characterization of small farmers in Asia and the Pacific done by the Food and Agricultural Organization in the United Nations (FAO) found that they till an average land area of one hectare. They are very valuable because they are the largest part of the farming community in developing countries. If water is available, they intensify their farming system as a coping mechanism to optimize their land use to improve their household food security situation or to augment their income from agricultural activities. This special characteristic of agriculture holdings in Asia and the Pacific calls for special attention to be given to the small farmers in policies relating to the management of the food and agriculture sector, particularly those relating to supply of agricultural inputs, technology promotion, marketing linkages and availability and accessibility of credit (23rd Session, Siem Reap, Cambodia, 26-30 April 2010. Characterisation of small farmers in Asia and the Pacific).

In the Philippines for example, a national report shows that poverty incidence remains predominantly agricultural. An average rice farmer earns about $1,000 a year, which is below the poverty threshold. In this situation, being a meager, non-lucrative venture, many rural poor no longer see a future in agriculture and would not like their children to become farmers. The Rural Transformation Movement (RTM) was established to address these pressing issues. RTM is a social mobilization initiative that aims to pool together various experts, organizations, and resources to catalyze rural transformation in rural farming areas with PhilRice as the lead agency. Rural transformation refers to the process of enabling positive and relevant change in farmers' perceptions, attitudes, practices, and life chances with rice-based agriculture as the driver of inclusive, sustainable growth in rural, farming communities. A campaign to enhance farmers' and other stakeholders' mindset towards agro-enterprise was carried out. Some agro enterprises as added sources of income were identified and market tested. And lastly, efforts to enhance farmers' social capital through intensive partnership were delivered. The project shows a great potential as a development strategy towards enhancing farmers' well-being (Zagado, *et al*. 2017). The RTM promoted the zero-waste rice-based farming system to the farmers. Teaching the technologies that they could use. It was enhanced and now called the Rice Business Innovation System (Rice-BIS) Community.

THE ZERO-WASTE RICE-BASED FARMING SYSTEM

The zero-waste rice-based farming system components are shown in Fig. 1. They are all connected and making a cycle or a system. It is zero-waste because everything is recycled and consumed. When the rice plant is harvested, the grains are milled to produce the rice and the rice bran and rice hull. Rice bran can be used as feed and rice hull can be used as energy. On the other side the rice straw can be used as energy or incorporated as rice straw to act as fertilizer or can be used as substrate for mushroom production. The waste from livestock or ruminants can be combined with the mushroom wastes for vermi-composting. This compost can now be used as fertilizer. If you are a rice grower, you can also integrate fish or duck with azolla. This system if done by a farmer, he will have additional income, his risk will be distributed and generally he will be less vulnerable to extreme weather impacts. He will also have multiple sources of nutrition that cannot be obtained from rice. This system will also reduce the greenhouse gases emission and it will capture more carbon dioxide from the atmosphere as explained below.

GREENHOUSE GASES MITIGATING TECHNOLOGIES IN THE ZERO-WASTE RICE-BASED FARMING SYSTEM

Alternate-Wetting and Drying (AWD) – This water management technology sometimes called controlled irrigation can be used to increase the efficiency of farm inputs and at the same time help the plant grow healthier. It uses an observation well to know the right timing of irrigating the field during the crop growing period. Reduces water used in rice production by 16-35% without decreasing grain yield. Aids in proper seed germination and seedling survival, tillering, and grain uniformity. Increases the efficiency of the plants in using soil nutrients and applied fertilizers. Keeps a good balance of available nutrients in the soil. Helps in controlling weeds. Minimizes golden apple snail attack since there is an excellent water level control. Significantly reduces cost in pump irrigated areas. Stabilizes soil and plant base, hence helps minimize crop lodging. Facilitates farm mechanization especially in the harvesting and hauling of harvests. Reduces farm inputs such as oil, fuel, and labor. Provides for timely water needs of farms at the tail-end of an irrigation system (http://www.pinoyrice.com/keycheck6-water-management/what-is-controlled-irrigation/). Thru this technology, there will be multiple aerations of the paddy fields that eventually reduce methane emission by 30-70% (sander *et al*., 2012) as shown in Table 1. This technology can be used by a small-scale rice farmer who's using water pump and also irrigators association for additional irrigated areas. In the Philippines, the AWD became the banner technology in the national dissemination of rice production technologies that are resource use efficient from 2014 to 2017. Results showed that the use of AWD has been very promising in reducing the frequency of pump irrigation from 2-3 times a week to once a week for small-scale farmers with land holding area of one hectare or less (Regalado *et*. 2017).

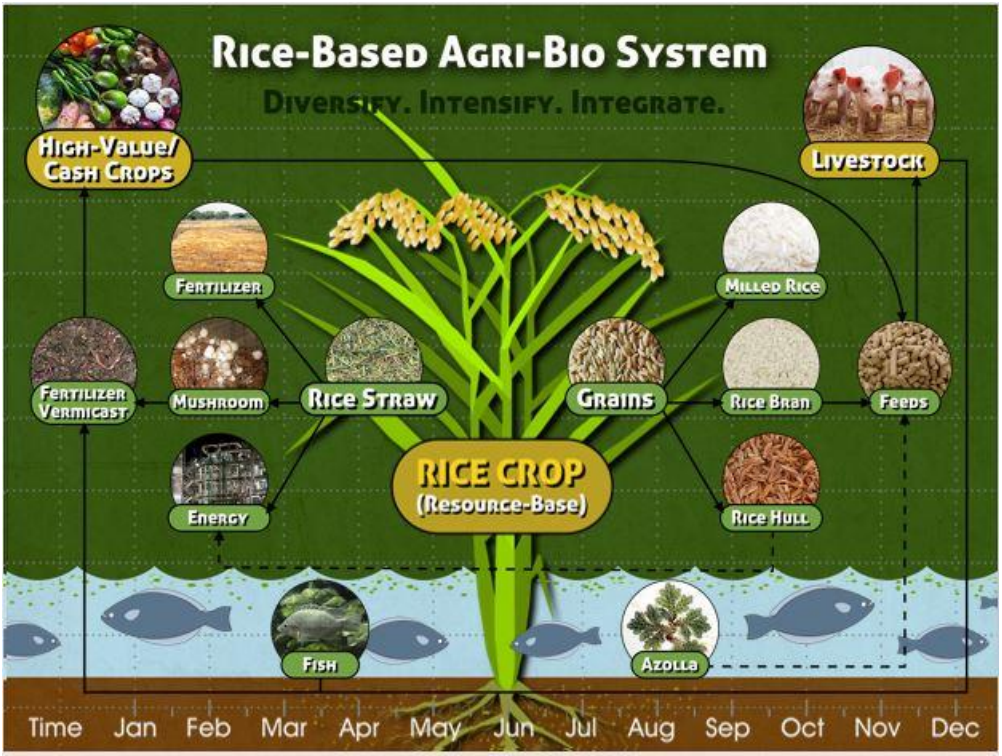

Fig. 1. Zero-waste rice-based farming system with its components.

Rice straw-based nutrient management and azolla production – In the rice-rice cropping system, rice straw is the main farm waste and having high C:N ratio, its reincorporation into the paddy soils increases methane emission (Table 2a). It is advisable to incorporate the rice straw back while the soil is in its dry condition. Otherwise, management of rice straw in the flooded soils should be done earlier or rice straw and stubbles should be decomposed first before it is to be incorporated. The greenhouse gas emission of the different rice straw management and its abatement cost showed that the best rice straw management that had reduced GHG with reasonable counter CO_2 cost is the early stubble and rice straw incorporation (Launio, *et al.*, 2016).

Table 1. Total seasonal methane (CH_4) emission from paddy fields in Nueva Ecija, Philippines

Treatment	CH_4 (kg CH_4 ha^{-1})		Year	Source
	DS	WS		
CF	90	-	1998	Corton *et al.* 2000
AWD	7	-		
CF	95	221	2017	Pascual *et al.* 2017
AWD	48	283		
CF	70	329	2014-2016	Sibayan *et al.* 2018
AWD	42	351		

CF- continuous flooding; AWD- alternate-wetting and drying. DS- dry season; WS- wet season

Table 2a. Methane emission of raw and composted rice straw incorporation

RS incorporation	GHG EF *kg/ton yield*		at 5 tons yield/ha
raw Rice straw and stubbles incorporation			
CH_4 (WS)	129.77		648.85
CH_4 (DS)	36.99		184.95
composted RS and stubbles incorporation			
CH_4 (WS)	13.37		66.85
CH_4 (DS)	2.1		10.5

Table 2b. Azolla production and Nitrogen content

Azolla spp	*Azolla* fresh weight (kg)	
	2017 DS	2017 WS
A. filiculoides 1001 *A. caroliniana* 3005	105.0 276.0	138.5 135.0
A. mexicana 2024	106.1	146.0
A. microphylla	273.5	147.0
A. microphylla harvested in observation/ demo plots (360 m^2)	615.7	1,435.8
TOTAL harvested	**1,376.3**	**2,002.3**
N content (%) from fresh Azolla	2.48	3.72
Post harvested:		
Azolla composted in compost pit	1,068.6	1,792.8
Fresh compost weight (kg)	328.0	461.0

Azolla is a very good alternate organic N topdress for rice. The ability to fix atmospheric nitrogen at substantially higher rates has led to the exploitation of the organism as bio-fertilizer. Application of *Azolla* in rice paddy fields has a positive role in improving the soil fertility index. The ability of nitrogen fixation is due to the presence of the symbiotic cyanobacterium *Anabaena* that occurs in the dorsal leaf cavities of the *Azolla* fronds (Peters and Meeks, 1989). The total N fixed in *Azolla* in the field has been estimated to be 1.1 kg N ha^{-1} day^{-1} and this fixed nitrogen is sufficient to meet the entire nitrogen requirement of rice crop within a few weeks (Lumpkin and Plucknett, 1980). The rapid and substantially higher rates of nitrogen fixation coupled with production of high biomass (Table 2b) through carbon sequestration by the *Azolla* have made the organism an outstanding agronomic choice to supply or recycle Nitrogen and carbon dioxide back into the farm (Javier *et. al*., 2017).

Mushroom growing and vermi composting– Mushroom and vermi composting are directly link because after harvesting the mushroom the substrate can be used immediately for vermi composting. In the Philippines and other countries there is an increasing demand for mushroom. This is because it is an alternative source of healthy nutrients, medical compounds, and dietary supplement. Apart from its health and nutritional benefits, mushroom is a cash crop with immediate economic benefit. Others say, it revives and tightens the connection between nature and people (Rizal G. Corales *et. al*, Philippine Rice Research Institute 2018). In Vietnam, Social entrepreneur Trang Tran is teaching Vietnamese farmers how to use rice straw as a substrate to grow gourmet mushrooms, helping to reduce greenhouse gas emissions and give farmers a new source of income (https://fellowsblog.ted.com/how-we-can-curb-climate-change-by-turning-waste-into-gourmet-mushrooms-e0aa92992089).

Capillarigation – Capillarrigation system is an efficient and affordable micro-irrigation system that enhance productivity especially when water is limited. It is patterned from drip irrigation system but uses capillary wicks as media for dispensing water. Fabrication of drippers is easy and can be done by farmers. The cotton yarn was selected as the best wick material with the most uniform wicking flow rate (Orge R. F and Sawey D. A, 2017). The potential to reduce greenhouse gas is reflected indirectly through higher water use efficiency (Table 3).

Table 3. Dry Season 2016 test results of capillarigation system for pepper

Irrigation Method	Cost ($/sq.m) 1$=P50	Emitter discharge mL/hr	Yield (kg/plant)	Water Use Efficiency (kg/L)
Capillary	0.34	30-40	9.02	36.6
Drip	0.87	1200	10.95	9.9

CtRH carbonizer with attachments – The latest prototype offers potential for use not only in carbonizing rice hull but also other biomass wastes that can be commonly found in the farm. Likewise, the machine's capability to recover the heat generated during its operation offers a lot of potential benefits in the farm not only in terms of increasing farmers' income and productivity but also as a climate change adaptation strategy with some mitigation potential (Orge and Abon, 2012).

Rice – duck or fish integration – Integrated rice-duck farming system is a cultivation associated with ducks or fish raised simultaneously at the same parcel of land. This system enables the poor farmer to obtain not only rice as main crop but also subsidiary products like ducks meat and eggs or fish. Other benefits reported were reduced cost of weeding, insecticide and chemical fertilizer. The ducks eat weed seeds and insects, thus, keep the paddy field pest free. Likewise, ducks' or fish feces dropped on paddy soil serve as source of nutrients to rice crops. Thus, it helps reduce production input cost. At PhilRice experiment station, the rice + duck production system (0.15 ha) was planted with *Laila* which is considered as Special Quality Rice (SQR) variety. Seventy-five (75 heads) 15-day old Mallard ducklings were released in the rice field at 10 DAT. The ducks were given with rice brankangkong mix as supplemental feeds two times a day, one in the morning and in the afternoon. The ducks were withdrawn from the field at heading stage of the rice crop. The rice yield attained was 750kg equivalent to 5.0t/ha grain yield. The income from the rice production was $375 at $0.50/kg price of SQR. The number of ducks withdrawn from the field was 68 heads with an average weight of 550g/head having a 10% mortality rate. The projected income from the ducks based on pullet price of $3/head was $204. The total gross income that can be generated from the 0.15 ha area was $1158 per year which means that ducks provided an additional income of around $120 /season (Rizal G. Corales *et al.*, 2018).

High yielding rice varieties – In literatures, many studies have proven that the higher the yield the lesser is the Methane Transport Capacity (MTC) as shown in Fig. 2. With the new breeds of high-yielding varieties including hybrids we can now promote these varieties to be adopted by farmers. In the Philippines new varieties even the inbred is now comparable to hybrid yields. Coupled with Integrated Crop Management (ICM) best practices from seed selection to nutrient and water management and crop establishment, methane emission can be reduced by 83-93% as shown in Table 4 (Asis C. A. *et al.*, 2014). The promotion of these varieties with ready ICM for farmers adoption has to be further strengthened to help contribute in food security and mitigate climate change.

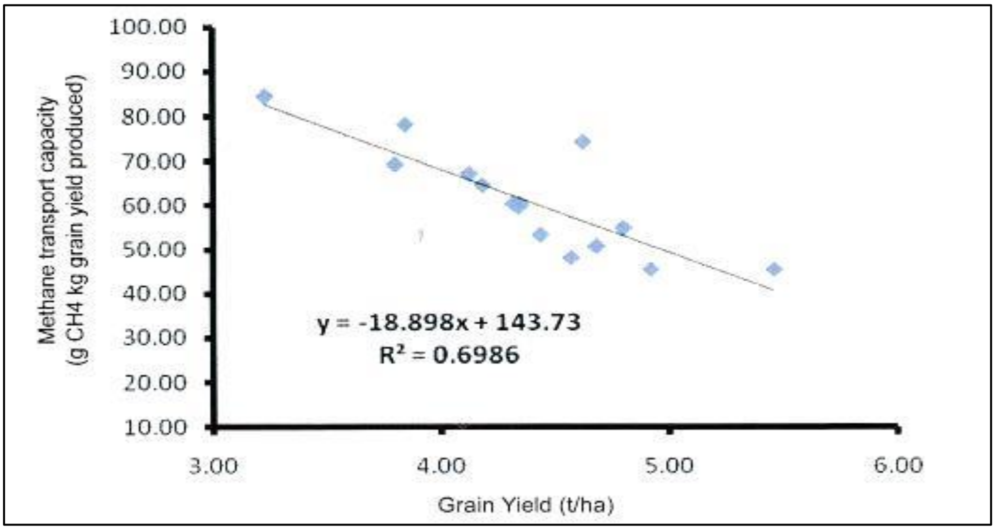

Fig. 2. Relationship between Grain Yield and Methane Transport Capacity.

Table 4. Best practices to reduce methane emissions

Mitigating Options to Reduce Methane Emissions	
Options	Potential Reduction
Direct Seeding Technology	16-54%
Mid-Season Drainage	43%
Fertilizer Management	25-72%
Reduced Tillage	33%

Sorjan system – Sorjan production system is a common farming system in the flood-prone communities in Java, Indonesia. PhilRice developed and assessed three modified sorjan models to help increase food source, and income of rice farmers in the context of crop diversification, intensification and integration. The sorjan production model 3 is more diversified than the other models. The 1160 square meter area generated an average annual income of $550.61 (Table 5) equivalent to around $45.88 monthly. The advantage of this highly diversified and intensified sorjan model can produce an income almost $4184.19 over the income of rice production alone. Moreover, the intensified and diversified nature of income sources enhances income stability by providing the much needed income to sustain the daily needs including food security.

Table 5. Income generated from Sorjan production model 3 from 1160 square meter

Production Model Component	Year 2015	Year 2016	Year 2017	Average	
	Annual Income PhP [$]	Annual Income PhP [$]	Annual Income PhP [$]	Annual Income PhP [$]	Monthly Income PhP [$]
Vegetables	10884 [239.19]	14543 [306.22]	16248 [322.36]	13891.67 [290.62]	1157.64 [24.22]
Fish	0 [0]	0 [0]	700 [13.89]	700 [14.64]	58.33 [1.22]
Rice	9280 [203.94]	9860 [207.61]	9396 [186.42]	9512 [199.00]	792.67 [16.58]
Taro	0 [0]	320 [6.74]	4110.6 [81.55]	2215.3 [46.35]	184.61 [3.86]
Total	20,164.00 [443.14]	24,723.00 [520.57]	30,454.60 [604.21]	26,318.97 [550.61]	2,193.25 [45.88]

Note: Conversion to USD ($) is based on the average prevailing annual rate.

Ride-on tillage implement – The ride-on tillage implement can accomplish all major land preparation operations such as plowing, harrowing, and leveling. The newly designed implement is a good alternative for preparing the rice field that could shorten time of preparation because of faster performance than the customarily used attachment. It is good replacement to carabao as a draft animal which commonly emits more GHG emission from its enteric fermentation and its manure. The handtractor was proven to mitigate GHG emission as shown in Fig. 3 if it will replace the carabao in rice production (Bautista EG, *et al.*, 2008).

Wind-pump system – The wind-pump system could be used for smaller areas of rice crop. It can also be used for irrigation of high-value crops that does not require total flooding. The system mitigated GHG emission by replacing the fossil fuel with naturally available source of energy (Bautista EG. *et. al*., 2015).

Rice Husk (RH) gasifier for village rice mills – When small scale farmers are organized and formally formed a registered group, they can buy and process their own produced without being dependent to rice traders. In this case, they can put up their own rice processing center and use Up-Draft rice husk gasifier to power their village rice mills. The mitigation effect of the RH gasifier system was related to the electricity required to power its everyday operation and from RH by-product which was disposed and burnt in open field. In Fig. 4, The rice mill factory emitted around 166 kg CO_2 eq d^{-1} due to its electricity requirement and 125 kg CO_2 eq due to RH by-product from everyday operation. However when the RH gasifier system supplied electricity to rice mill, it emitted 88 kg CO_2 eq d^{-1} and 77 kg CO_2 eq d^{-1} for its electricity and RH disposal, respectively. Therefore, using the RH gasifier system could mitigate a total of 126 kg CO_2 eq d^{-1}. (Bautista EG. *et al*., 2014).

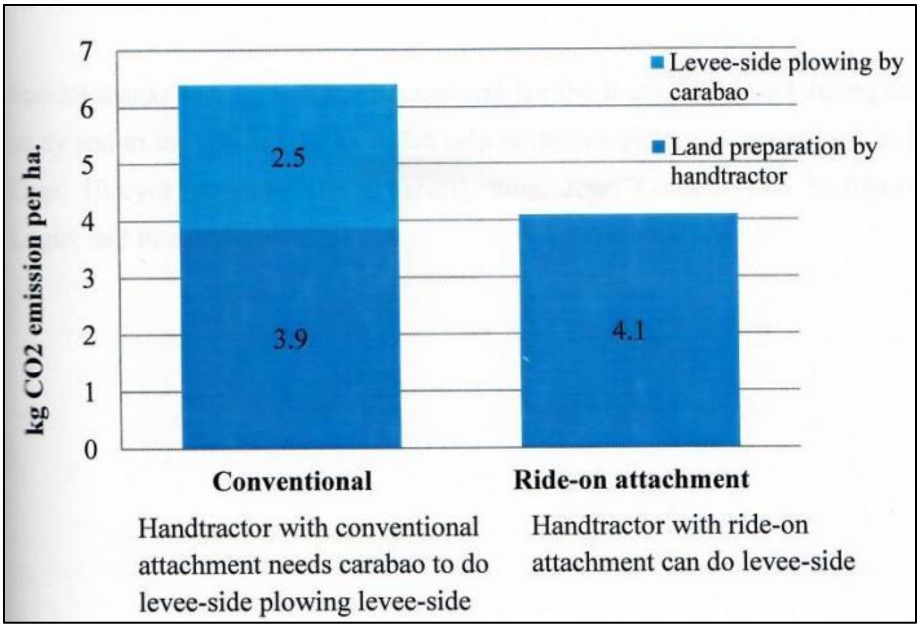

Fig. 3. Emission from handtractor with conventional and ride-on attachment.

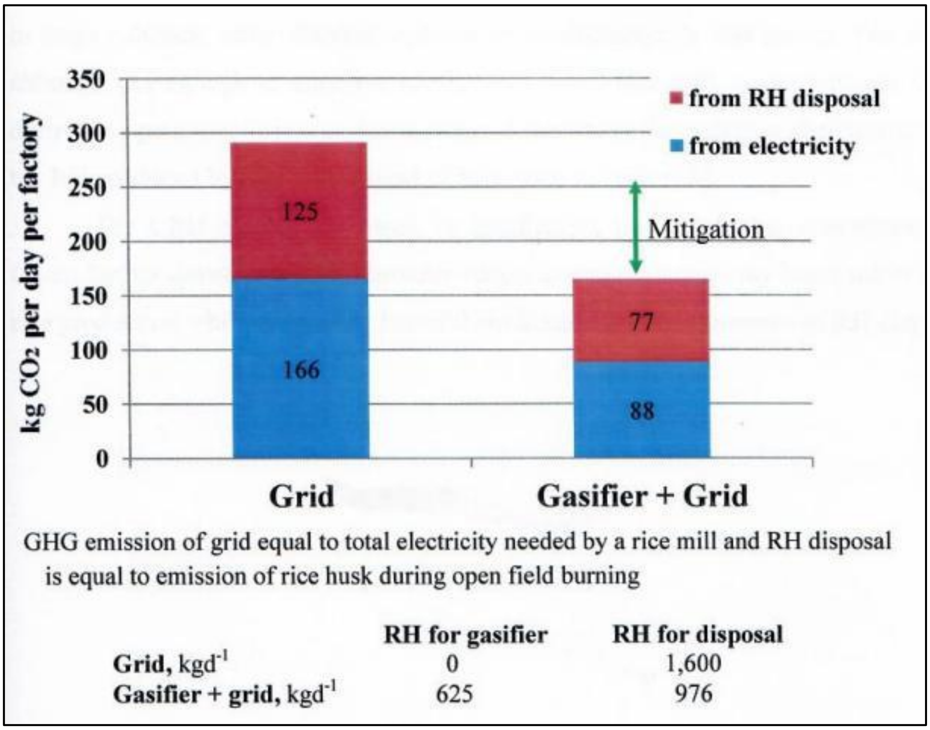

Fig. 4. Emission from 8 t h^{-1} rice milling factory.

CONCLUSION

There are a lot of climate smart technologies already available for farmers. These are efficient and environmentally friendly and require political will to be promoted and adopted by farmers. It can reduce greenhouse gases emissions and at the same time mitigate climate change effect. It will increase productivity and income of the farmers.

A good study is to quantify specifically the greenhouse gas emission of the zero-waste rice- based farming system. We assume that it should be negligible since all the carbon produced is sequestered and put back into the soil.

A model that is in pilot stage in the Philippines to help the small-scale farmers increase their income is the Rice Business Innovation System (RiceBIS) Community. The zero-waste rice-based farming system is being adopted to empower the farmers. In the Philippines it is common that the farmers' produce is sold to traders and the price is dependent in the hands of the traders. In this case, we need to help the farmers not only in their production concerns but also on how they deal with market and business development service providers. There should be a paradigm shift to the thinking of the farmers that farm is a production unit only. They should think that farming is an Agro-Enterprise or business. They should learn what to sell, how to sell, and whom to sell. Farmers should organize their farming activities and take advantage of business and marketing opportunities. In this scenario of organizing the farmers by themselves, they need enabling support from network of public and private institutions and the academe. As a group they will be stronger, more efficient and precise in farming that leads to mitigation of GHGs, more bargaining power, and at the end because of increase income they could easily adapt to climate change and become resilient and sustainable.

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