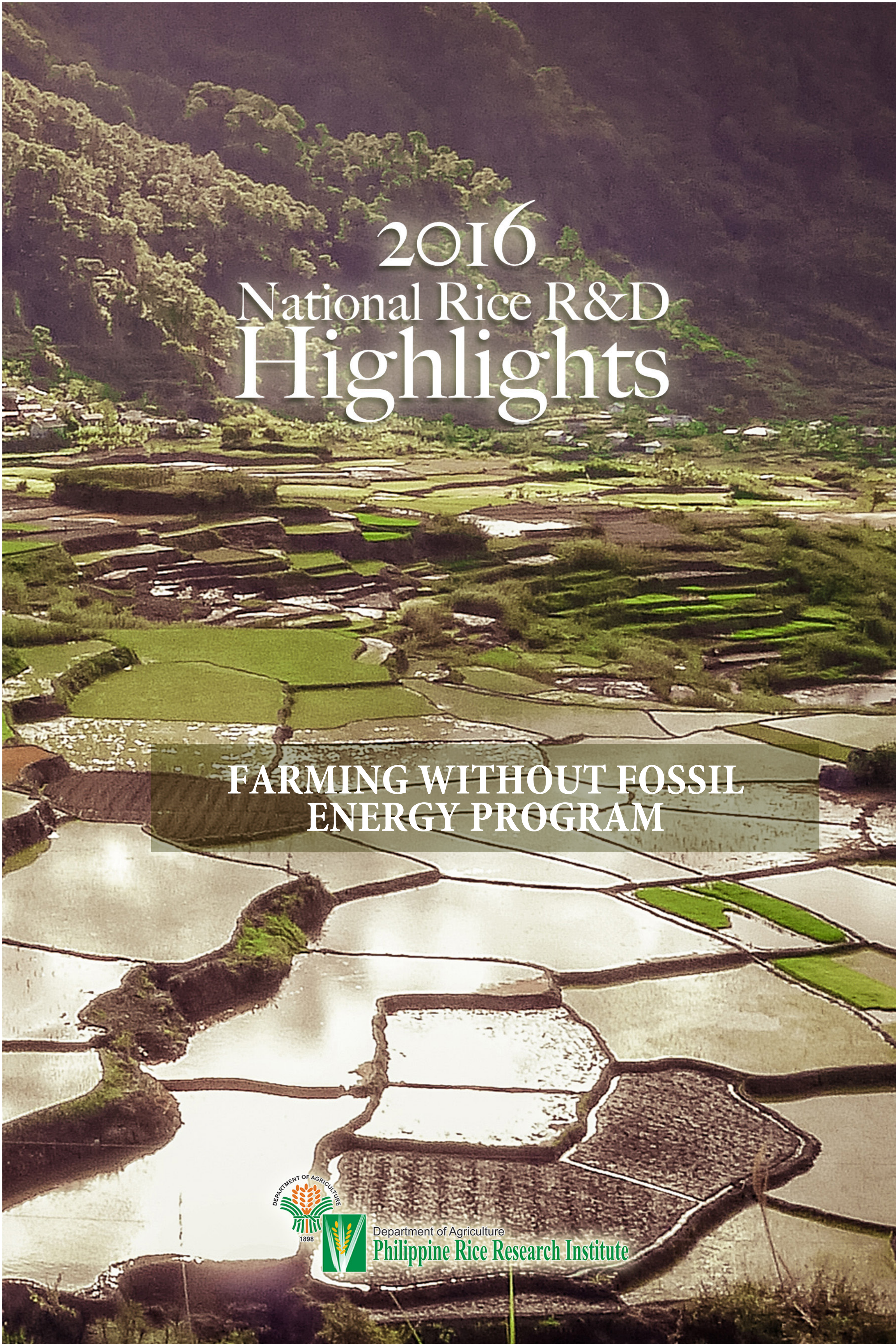

2016 National Rice R&D Highlights

FARMING WITHOUT FOSSIL ENERGY PROGRAM

Department of Agriculture
Philippine Rice Research Institute

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Farming Without Fossil Energy Program

Program leader:Eden C. Gagelonia

Executive Summary

Modern commercial farming practices such as the use of gasoline-powered farm equipment consumes a lot of fossil fuel. Nowadays, the prices of petroleum-based fuel is not stable, and the supply from the oil producing countries is not reliable in the years to come. Thus, in order to be prepared on this situation, renewable energy production from rice biomass and other farm sources should be derived to supply fuel, heat and electricity in mechanized production of rice.

The Farming without Fossil Energy Program aims to substantially or entirely remove fossil fuels in rice and rice-based farming by developing alternative energy sources and inputs to come up with sustainable and cost-effective rice and rice-based farming systems. It will explore the various alternative and renewable energy resources such as biomass waste, wind, sun, water and plants in order to develop processes and technologies to help reduce dependence, if not totally remove, on fossil fuels in rice and rice-based farming operations. In addition, the program will study how energy resource use in rice production can be more efficient by identifying available technologies that are resource-use-efficient.

The program composed of two projects as follows:

1. Development of renewable, alternative, diversified and decentralized energy resource systems for and from rice-based agriculture – these are technologies that will provide sustainable energy and fuel for farming activities as well as for electricity generation.
2. Adaptation of low external energy input technologies in rice-based farming – these are generated technologies that will contribute in reducing dependence from fossil energy use and resource-use-efficient in rice-based farming system.

The component studies of project 1 includes gasification for power generation and also for providing alternative fuel for internal combustion engines for water pumping application, and using hydrous bioethanol as alternative fuel for gasoline engine in mechanized farming.

Series of testing were done to evaluate the performance of the 100kwe rice husk gasifier. Results of testing showed that the system can continuously operate at 12 hours. However, tar deposit were observed in the intake manifold and possibly inside the combustion chamber. Thus more testing is needed to observe some problems during continuous operation and also to determine the maximum electrical power output of the system.

A fuel feeding device was retrofitted to gasoline engines (3.5hp and 6.5hp) and brush cutter where hydrous bioethanol was used as alternative fuel of the engines for farming operations. For 6.5hp retrofitted engine, the CO^2 emission using hydrous bioethanol is significantly lower than using gasoline fuel. For 3.5hp retrofitted engine, the calculated pumping cost using hydrous bioethanol is PhP2.8 per cu. m. of water.

A moving-bed downdraft rice husk gasifier for shallow-tube well pumping of water was designed and fabricated and performance evaluation showed that it was able to run for 2 hours (120 minutes) with 20-kg rice husk fuel consumption. Other parameters such as the volume of water discharge, and the gas quality entering the engine were gathered. However, it is recommended that further testing be conducted to evaluate the performance at 8-hr continuous operation which is usually the duration of water pumping in rainfed areas.

Project 2 "Adaptation of low external energy input in rice based farming" composed of 8 studies as follows: , pilot testing on the use of gasifier technologies for water pumping and grain drying, develop wind-solar hybrid system for irrigation, produce stable species of azolla as non-fossil fuel nitrogen source, identify the best non-fossil fuel-based sources from green manures, optimize the production of vermicast from farm wastes, establish a sustainable decentralize energy system model for small island, and determine the energy input-output of all operations in rice production by LCA. Expected outcome of these studies will help reduce dependence from the use of fossil fuel-based inputs and making the farming operations sustainable and environment-friendly.

I. Development of Renewable, Alternative, Diversified and Decentralized Energy Resource System for and from Rice-Based Agriculture

Project Leader: EC Gagelonia

Biomass, which can be derived from plant materials like rice and other crops including farm wastes, is a potential source of energy for rice mechanization. This energy source can be considered as carbon-neutral since the CO_2 emitted by this material when burned is counterbalanced by consuming an equivalent amount of CO_2 during their growth stage. Biomass includes rice plant itself and its by-products such as rice husk, straw, and its surrounding weeds in the farming environment. They are usually considered as nuisance in the community due to the large volume and spaces they occupy in the field and in rice mills which makes it necessary for them to be eradicated to take advantage of other farming and business opportunities. Tapping these wastes for beneficial use can provide the energy and power needed to fuel both stationary and agricultural machines used in the farm.

Currently, biomass can be converted into different forms of fuel either solid, liquid, gas, or their combination. Heat can be derived directly by burning biomass with excess air. It can also be burned with limited amount of air to produce char which can be used as soil amendment materials and the heat generated can be utilized to produce steam to provide mechanical power. When burning biomass with limited amount of air, combustible gases such as carbon monoxide (CO), hydrogen (H2), and methane (CH4) are produced. On the other hand, sugar-rich biomass materials such as those living in rice environment like nipa, coconut, sugar, and many others can be processed through fermentation and distillation to extract the bioethanol content which can be used as replacement or supplementary fuel for spark-ignition engines; whereas, oil-based biomass like coconut, jatropha, and others can be converted into biodiesel through methyl esterification that can be used as replacement for diesel as fuel for compression-ignition engines.

With four component studies, wherein the technologies being developed will automatically reduce consumption of fossil fuel in rice-based farming by utilization of biomass as alternative fuel. It is contemplated that the fuel and energy that can be derived from rice wastes and its by-products can be used to fuel varieties of sizes and kind of internal combustion engines that will power stationary and mobile machines for land preparation, irrigation, harvesting, threshing, drying, transport, and milling. With this idea, farmers can be encouraged to produce fuel from their farm which they can subsequently use for their farming activities and they can even sell some for their livelihood. Once this is realized, a sustainable and cost-effective rice farming can be achieved.

Performance Testing And Evaluation of 100-kW Rice Husk Gasifier

MJC. Regalado, JA. Dela Cruz, AT. Belonio, JA. Ramos, EC. Gagelonia

PhilRice through REMD started its rice husk energy R&D for electric power generation in the early 2000's. In 2013, a 100-kWe rated capacity rice husk gasifier (Fig. 1) was developed. The moving-bed, downdraft gasifier system consisted of: 1.) 1.2 meter diameter reactor; 2.) 30-cm diameter by 3-m long counter-flow, impact-type wet scrubber; 3.) two 60-cm diameter by 50cm thick horizontal, packed bed of rice husks as the primary filter; 4.) 50cm by 50cm by 10cm thick foam as the secondary filter; and 5.) 75cm diameter by 245cm long holding tank for producer gas storage. A 3-hp, single-phase, high-pressure ring blower located between the secondary filter and the engine gas manifold was used in drawing the gas from the reactor. The prime mover used to drive the generator is an 8-cylinder spark-ignition engine running at 2000 rpm rated speed. The engine was cooled with circulating water from a 1.73m^3 cooling tank. The generator is a brushless, 3-phase synchronous generator with 100 kW rated power at 1800 rpm, 220 volts, 328 amperes and 60 hertz. Rice husk was fed into the reactor using a 5in cup by 15cm spacing bucket elevator, which was driven by a 2-hp, 220-single phase electric motor and has a capacity of 227 kilograms per hour. Char was removed from the water-filled bin using a 0.5hp screw conveyor with throughput rate of 50kg/h wet char. Gradual removal of char was done by manually scraping it with a rotating sweeper to ensure continuous operation of the gasifier. The gasifier-engine-generator system was planned to be installed at PhilRice Negros for powering a submersible water pump and supplementing electricity supply in the farm. But it was retained at REMD to first carry out a series of tests to optimize its operation and performance.

Findings:

1. The engine, running on producer gas as fuel, was found to operate optimally at fourth gear transmission setting and matched the 1800rpm generator speed. At this speed, voltage output was 220 volts at 60 Hz. Previously, the engine was operated at 3rd gear drive, but this was found excessive for the engine when it ran continuously for 2 hours.

2. Temperatures monitored using thermocouple sensors and digital thermometer showed that the reactor temperature ranges from 600°C to 710°C. The temperature of the gas leaving the reactor measured at the gas outlet varied from 349°C to 429°C. The temperature of gas leaving the scrubber ranged from 38.5°Cto 44.5°C, and after the filter, it ranged from 31.5°C to 39.9°C. The temperature of the gas entering the engine varied from 32°C to 39.9°C.

3. The producer gas output from the gasifier contained the following main component gases: 1.) carbon monoxide, 9.47 to 12.23%; 2.) methane, 2.64 to 3.46%; and 3.) hydrogen, 7.64 to 9.62%. Moreover, its heating value ranged from 722 to 930kcal/m^3. The other component gases are shown in Table 1.

5. Sound level of the engine at 4th gear, measured 1 m away, was 89 decibels. While this is slightly lower compared with that of gasoline-fueled engine, the noise level is dangerous with prolonged exposure.

6. Trial results (Table 2) have shown that the system can operate continuously for 12 hours. Rice husk consumption was 48kg per hour with 24kWe power output. The electrical load consisted of 12 pieces of 1 kWe light bulbs and three units of nichrome wire resistance loads, each having a 4-kWe rating, for an aggregate of 24kWe. However, at 4th gear setting, we found that tar had built up at the intake manifold and possibly inside the combustion chamber, thus making the engine difficult to start. We surmised that, when the engine was running at 4th gear, pyrolysis instead of gasification was taking place inside the reactor. Low engine speed caused a weak draft inside the reactor, resulting in slower suction of producer gas by the engine, a condition which favors pyrolysis.

Figure 1. The 100-kWe rice husk gasifier.

Table 1. Composition of producer gas from the rice husk gasifier with engine operating at fourth gear.

Sampling	CO (%)	CH_4 (%)	H_2 (%)	CO_2 (%)	C_nH_m	O_2	Heating Value (kcal/m^3)
1	12.23	3.46	9.62	13.58	0.15	3.91	930
2	10.47	3.09	8.98	12.47	0.16	5.67	834
3	9.47	2.64	7.64	10.43	0.13	7.66	722
4	9.74	2.86	7.83	10.29	0.16	7.92	761

Table 2. Performance of the gasifier at 4th gear drive.

PARAMETER	VALUE
Gear Setting	4th
Operating Time	4 hours
Fuel consumption rate	46 kg of rice husk per hour
Load	24 kW_e (12 pcs. 1-kW_e bulb, 3 pcs. Nichrome wire @ 4 kW_e)
Reactor Temperature	600 - 710
Gas Temperature (°C)	
After the Reactor	346 - 429
After the Scrubber	38 - 45
After the Filter	32 - 43
Before the Engine	32 - 40
Water Temperature (°C)	
Bottom Tank	34 - 48
Top Tank	36 - 48
Engine water cooling tank (°C)	39 - 57
Engine Sound Level at 1 m.	87 dB

Pilot Testing of Retrofitted Engine for Mechanized Rice Farming Operation

KCVillota, ATBelonio, MLRafael, PRCastillo, ECGagelonia and MJCRegalado

Most internal combustion engines that power the agriculture sector utilize either gasoline or diesel as fuel. These resources are both costly and contribute to the global environental problems. Current research thrusts focus on replacing these petroleum-based fuels with eco-friendly renewable energy from organic matter such as bioethanol and biediesel. The Philippine Biofeuels act of 2006 mandates that gasoline sold at the pumps be blended with 10% bioethanol and 2% biodeisel for diesel.

The 10% bioethanol blended with gasoline is anhydrous ethanol. At this level, the gasoline engine can operate without any negative effects on its performance. However, increasing the anhydrous ethanol blend using pure hydrous ethanol will require an engine different from those available in the local market. Brazil has been one of the trailblazers of this technology as they have perfected the flexible-fuel technology that enables their engines to run with any blend of anhydrous ethanol and gasoline or even pure hydrous bioethanol.

Presently, PhilRice developed a fuel feeding device to feed hydrous ethanol fuel into the intake manifold of the engine, by passing the carburetor.

With this, spark-ignition engine which one of the common power sources of farm equipments were able to run solely on 80-95% hydrous bioethanol fuel.

Activities:

- Retrofitted of gasoline engines for hydrous bioethanol fuel.
- Installed retrofitted engine to different rice farming implements.
- Conducted long season use of retrofitted engine as power source for different farming implements.
- Conducted cost analysis of retrofitted engine with hydrous bioethanol fuel.

Findings:

1. The hydrous bioethanol retrofitted engines were successfully used and tested as power source of different rice and rice-related farming machines. Performance data was gathered and analyzed.

   - A 3.5-hp retrofitted engine was used as power source for a 2" water pump and was tested for irrigating a rice field of about 500 m2 at PhilRice, Nueva Ecija for one cropping season.
   - Hydrous bioethanol fuel was tested to a brush cutter which cleaned the levees of 2.5 ha of rice fields.
   - A 6.5-hp retrofitted engine was used as power source of a pump boat in Infanta, Quezon which transported nipa sap in 20-liter containers for one season production of "lambanog".

2. The fuel economy of the tested engines using hydrous bioethanol was 27-29% higher than when using gasoline.

3. Some of the parts of cylinder of retrofitted engine showed signs of corrosion as an effect of using hydrous bioethanol fuel.

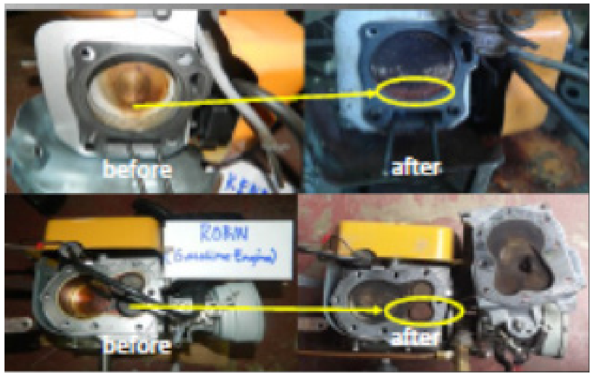

Figure 2. Observed parts of the engine that corroded using hydrous bioethanol.

4. Preliminary data showed CO2 emission with hydrous bioethanol from fermented nipa sap as fuel of an engine could be reduced by about 150%.

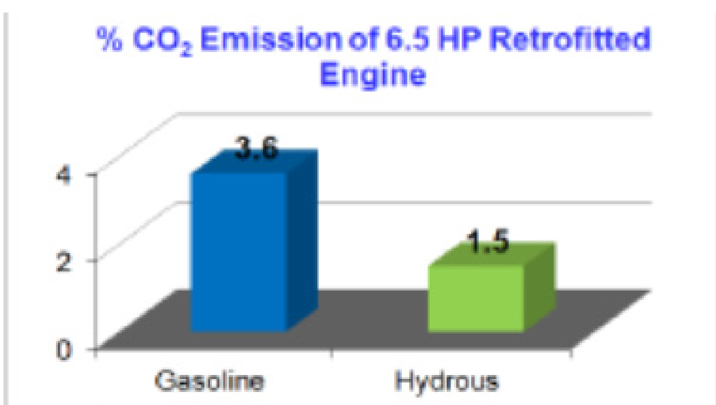

Figure 3. Observed reduction on CO2 using hydrous bioethanol.

Pilot testing of a moving-bed downdraft rice husk gasifier for shallow-tube well pumping of water

PRCastillo, ATBelonio, JARamos, ECGagelonia and MJCRegalado

One of the major problems in rice production and postharvest operations alike is the cost of energy in providing power for various agricultural mechanization tasks. During the cropping season, farmers need irrigation water the most for their field usually for 2- to 3-day period. Failure to provide the water required during crop maintenance often results in reduced rice yield which is translated to low income for farmers. As reported in the Asia Rice Forum Seminar (Belonio, et.al. 2013), it requires around 0.8 to 1.0 liter per hour of diesel just to pump water to irrigate a hectare of rice fields. This is more so during the dry cropping season when the period required to irrigate the field is longer and the amount of water needed by rice plants is more.

It is envisioned that with the use of the rice husk gasifier technology for pumping water, rice farmers will be able to cope with the problem on the high cost of fuel for their farm machines. Farmers can make use of the rice husks from their harvested paddy as fuel for pumping water rather than just burning them in the field or throwing them along roadsides. As a technology developer for rice machinery, PhilRice has developed a moving-bed downdraft rice husk gasifier for shallow-tube well pumping of water using rice husks as fuel. The technology has been tested in terms of running time, rpm of suction blower and pumps, noise level of the engine, volume of water discharge, and quality of the gas entering the engine. Making it available to farmers can develop their awareness and curiosity on this technology facilitating its adoptability, which may result in reduced dependency on fossil fuel by farmers and, if widely adopted, minimize the country's dollar outflow associated with fossil fuel importation.

Findings:

- A moving-bed downdraft rice husk gasifier for shallow-tube well pumping of water was designed and fabricated with the following components: a 40cm-diameter conical reactor, a gas conditioning unit adopted from the existing 10kWe gasifier, a 16-hp Continental gasoline engine (looks similar to 16hp B&S engine), a suction blower, a 1-in. water pump, and a 4in. self-priming water pump.

- The gasifier-pump system was able to complete 2 hours of continuous operation. It was able to run for 2 hours (120 minutes) with 20kg rice husk fuel consumption. Other parameters such as the RPM of suction blower, of the 1in. water pump as well as that of the 4in. self-priming pump, the minimum and maximum engine noise level, the volume of water discharge, and the gas quality entering the engine were gathered.

- The compositions of gas (Table 3) entering the engine were determined using the Gasboard 3100P syngas analyzer. The producer gas output from the gasifier contained the following main component gasses: (1) carbon monoxide (CO) - 13.36 to 18.89%; (2) methane (CH4) - 2-27 to 4.12%; and (3) hydrogen (H2) - 6.26 to 10.19%. Its heating value ranges from 773-1160 Kcal/m3. Other component gases are shown in the table below.

- Using the producer gas from burned rice husks, the suction blower, the jet pump and the 4-in. water pump operated at a minimum speed of 1501, 1102, 1575 rpm and a maximum speed of 2017, 1563, 3614rpm, respectively. Maximum rotational speed of the suction blower and of the jet pump was observed at 40 minutes of operation and at 80 minutes of operation for the 4in. water pump.

- The engine's minimum and maximum noise level is 85.5 and 98.0dB, respectively. Maximum noise level was observed at 40 minutes of operation.

- During the 2-hour continuous operation, a water discharge of $44m^3$/hr was collected after 20 and 40 minutes of operation using the 4in. self-priming water pump. The water discharge decreased to $30.46m^3$/hr at 60 minutes of operation and further decreased to $15.84m^3$/hr at 80 minutes of operation and increased to $33m^3$/hr at 100 minutes of operation. The fluctuation in water pumping reading observed was due to the effect of engine performance as it is ran using the producer gas from burning rice husks as fuel.

Figure 4. Actual field testing of the gasifier-pump at PhilRice's Palayamanan area using STW source.

Table 3. Gas composition of the producer gas entering the engine.

Sampling	Gas Reading, %						Heating Value, Kcal/m^3
	CO	CH_4	H_2	CO_2	C_nH_m	O_2	
1	13.36	2.27	6.26	9.22	0.09	5.93	773
2	17.42	2.81	10.19	11.74	0.07	2.24	1040
3	17.84	3.97	8.11	12.33	0.16	1.78	1108
4	17.67	2.86	9.44	11.04	0.09	2.65	1031
5	16.64	3.80	7.62	11.49	0.17	3.09	1051
6	16.43	2.43	9.51	11.57	0.10	2.86	964
7	16.29	3.79	7.70	12.30	0.19	2.73	1044
8	18.89	4.10	8.46	11.73	0.15	2.13	1160
9	17.36	4.12	8.13	12.6	0.19	2.25	1117

Design and Development of Universal Fuel Feeding Device

KC Villota, AT Belonio, ML Rafael, PR Castillo, EC Gagelonia and MJC Regalado

A fuel feeding device for variable load was conceptualized and assembled. This is to allow use of hydrous bioethanol as alternative fuel for small spark-ignition engines that power mobile agri-machines like microtiller and laboy tiller. The device will feature provision to real-time regulates the engine throttle to provide the power corresponds with the workload of the engine without impeding the operation.

Activities:

- Fuel feeding design development including preparation of working drawings.
- Fabricated prototype and installed to spark-ignition engine for functionality test.
- Conducted series of preliminary tests to evaluate the functionality of the first prototype.
- The first prototype of the fuel feeding device was installed to a small spark ignition engine and tested in different mobile agri-machines.

Findings:

- The first prototype (Figure 5)of fuel feeding device for variable load was already designed and assembled. The assembly is consists of fuel pump for suctioning of fuel from fuel tank, DC battery as power source for the pump, and PWM switch to control the flow of fuel in the fuel injector which supplies fuel to the engine. Fuel injector is connected before the intake manifold of the engine, by-passing the carburetor.
- Preliminary testing of the fuel feeding device shows that the system functions accordingly. A varying fuel flow rate from the injector was observed at different settings of PWM switch.
- The first prototype of fuel feeding device was successfully installed in a 6.5hp spark ignition engine and tested in dry area without and with variable load (Mobile Agri Machines). Preliminary data was gathered and analyzed.

  a. The fuel consumption of the retrofitted engine increases as attached to microtiller. Without load (disengaged in the machine), the engine consumes an average rate of 2.25L/h and 2.7 L/h with variable load (attached to microtiller).

  b. Preliminary test results of microtiller (mobile agri-machines) powered by 6.5hp retrofitted engine was based on the settings of the PWM switch which restricts the amount of fuel flow.

  c. It was observed that at almost full setting on the PWM switch the engine continuously operates and frequently stops as adjusted to lower settings.

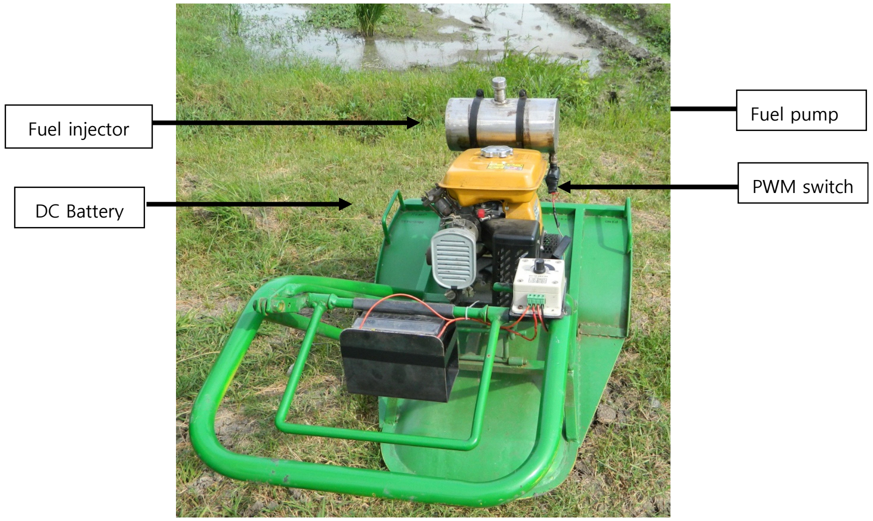

Figure 5. First prototype of Universal fuel feeding device installed to 6.5hp Spark Ignition Engine for Microtiller (Mobile Agri Machines).

II. Adaptation of Low External Energy Input in Rice-Based Farming

Project Leader – JA Ramos

Conventional farming requires high energy inputs which mostly came from fossil fuel-based sources. But this has been the practice of most farmers as the use of such resources like inorganic fertilizer, diesel fuel and pesticides are very convenient for them. In the issue of limiting fossil fuel resources, its unstable global supply, and unpredictable domestic pricing, there is always an option of getting alternative energy supply from other sources, on top of it would be those that are available locally. In a project "Adaptation of low external energy input in rice based farming" the use of energy resources found within the farming system is studied. Ultimately, this will help reduce dependence from the use of fossil fuel-based inputs and making the farming operations sustainable and environment-friendly.

With eight components under the project, each endeavors to develop technology or technique that lower the input of external energy in a particular operation in the rice based farm. Among the goals of the project are, to pilot test the use of gasifier technologies for water pumping and grain drying, develop wind-solar hybrid system for irrigation, produce stable species of azolla as non-fossil fuel nitrogen source, identify the best non-fossil fuel-based sources from green manures, optimize the production of vermicast from farm wastes, establish a sustainable decentralize energy system model for small island, and determine the energy input-output of all operations in rice production by LCA.

Harnessing Wind and Solar Energy for Crop Irrigation in Ilocos Region

MG Galera, CT Dangcil, ND Ganotisi, MLO Quigao, MU Baradi, MJC Regalado, AT Belonio

With the increasing burden on natural oils and coal for production of energy, wind power and other sources of renewable energy offer an efficient alternative. With the strong institutional support from Philippine Renewable Energy Act and the National Renewable Energy Program, tapping these resources are promising. Hence, a hybrid wind-solar pump system was installed at the station's experimental farm for capacity and output evaluation.

Activities:

- Different types of pumps were tested for water discharge and water consumption.
- The area that the pump system can irrigate for an entire season by type of crop was estimated.

Findings:

- Three pumps were tested, 0.5hp submersible, 1.5hp top-mounted, and 12VDC pump with potential pump discharges of 9.22, 5.67, and 6.40m^3/day, respectively. Investment costs for using the three different pumps were PhP100,560, PhP138,560, PhP85,160 for the 0.5hp, 1.5hp, and 12VDC, respectively.
- Testing of the system showed that the 0.5hp water pump consumes 28 amperes per hour but pumping should be sustained up to 10 hours only to limit within 50% battery discharge for longer life.
- The hybrid wind-solar has an average 53A daily charging capacity, taking 5 to 6 days to fully recharge the battery from 50% depletion. Considering the 0.5 hp, the pump has 9.22 m^3/day that could irrigate roughly 1,900 m^2 or 700 m^2 of tomato or rice crop with an average water requirement of 4.83 and 13.31mm/day, respectively. For longer battery life, pumping should be sustained up to 10 hours only to limit within 50% battery discharge.
- To use the pumped water efficiently, the pump system was coupled with the low-cost drip irrigation system to irrigate rice-based crops.
- The system is now operational and was evaluated for irrigation of rice (400 m^2) during WS 2016..

Table 4. Evaluation Result of the Hybrid Wind-Solar System

Pump tested	0.5 Hp	1.5Hp	132W, 12VDC
Battery capacity, Ah	600		400
Water table, m	3.50	3.50	3.50
Ampere charging/day, A/day	53		
Average Ampere usage, A	28.0	80.0	9.8
Total time to operate, hrs	12.61	4.41	25.82
Days to replenish the 50% depleted battery charge	5.66	5.66	3.77
Daily discharge, m^3/day	9.22	5.67	6.40
Total discharge every year, m^3	3,365.62	2,069.12	2,337.27
No. of days to operate in a year*	64.48	64.48	96.73
Investment cost, Php	100,560.00	138,560.00	85,160.00
*assuming the system runs 100% of the total number of cycle (charging-discharging) in a year			

Improving the performance of flatbed drying operation through adoption of continuous flow rice husk gasifier as heat source and an s-type vane tube axial fan air moving device
JA Ramos, MJC Regalado, AT Belonio, and EC Gagelonia

One of the drying facilities in the deck of farmers, seed growers, and cooperatives is the flatbed dryer wherein thousand units were dessiminated in recent years by DA through its mechanization support program. It is a more popular version among farmers and seed growers because of its simplicity and cheaper cost. However, the inherent problem of grain exposure over ash and soots through the use of direct furnace remains an issue. The use of indirect fired furnace on the other hand is the better option to resolve the problem but here involves another constraint which is cost effectiveness. The best alternative so far is the use of gasifier technology as the heat source for the drying system. With this, ash and soots are limited while cost is comparable to that of the available direct furnaces.

Activities:

- Modificaiton of gasifier prototype which focused on proper timing of char discharging and shortening the time of ignition.
- Validation test as to the functionality of the parts being modified.

Findings:

- A prototype of gasifier purposely for flatbed dryer has been fabricated recently (Figure 6). This has been installed already to the dryer. Series of tests have been made as regards to operation and some constraints have been encountered. One of which was the relatively long period of igniting the rice hull prior to drying operation. It is a very important consideration in the drying operation if it is to be shorten some more. It has been observed during the tests that it took 20 to 30 minutes to stabilize the production of gas which migth be due to the burning of rice hull that starts from the base of the reactor towards its center. While the air is more limited at the center, it tends to slow down the burning of rice hull in that part of the reactor.
- This has been addressed by providing a layer of perforated screen at the bottom of the reactor which holds the rice hull (Figure 7). In this way, the delivery of air from the top of reactor may be evenly spread towards its bottom covering the whole surface area of the reactor. It also limits the loading of char prior to ignition of rice hull.
- It has also been observed the escape of smoke and soot from the bottom of reactor during ash discharging and once the layer of char becomes so thin the gas is depleted which resluts to weakening of flame. This was addressed by extending the chute of ach discharger submerge to a container of water which served as the trap for smoke and at the same time cooler for the char being discharged from the reactor (Figure 8).

Figure 6. Prototype of continuous flow rice hull gasifier.

Figure 7. Perforated screen at bottom of reactor.

Figure 8. Char dispenser

Evaluation and utilization of alternative and potential non-fossil fuel based (nFFB) nitrogen nutrition for rice farming.
EF Javier, XXG. Sto. Domingo, and AJ. Espiritu

Past results of organic fertilizer trial in flooded rice soils had indicated that farm wastes could be a good and direct basal applied nutrient supplement (Javier 2009), and the proper timing of organic fertilizer incorporation should be followed for best efficient nutrient use (Javier and Tabien, 2003). However, the nitrogen supply from these organic fertilizers was good only for 28 to 30 days after transplanting (Javier 2009/2014 Q&A series). The observed low yield of organically fertilized rice plants in irrigated ecosystem therefore can be attributed to insufficiency of nitrogen approaching the early panicle initiation stage of the rice growth. Hence this research project aims to evaluate and optimize alternative fossil fuel free nitrogen sources like Azolla sp and other green manure as top dress to increase rice yield production.

Activities:

- Green house trials/Experiments
  - a. Collections and growing out of Azolla spp, Sesbania, and Aeschynomene for the proposed trials.
  - 1. 40 Azolla spp, 12 Sesbania, and 9 Aeschynomene spp were tested for heat tolerance/high RH tolerance (year 2016), saline soils and acidic soils (2017)
  - 2. Collection and seed production of other green manures: Indigofera tinctoria (tayum), Cochorus olitorius (saluyot), Vigna radiata (native mungbean) in a separate field in preparation for planting in the fallow period for the field trial.
  - b. Assessments of best organic basal fertilizers to increase and sustain high biomass N of Azolla spp for its growth as well the growth of rice plants (year 2016).
  - c. Four best varieties of Azolla that had tolerated the high climatic condition of the Maligaya, Azolla spp were applied to different medium (basal organic input). Replacing the inorganic basal into organic; three (3) Azolla varieties were seeded in different soils applied with different organic basal fertilizers at the common rate of 30 kg N/ha: Rice straw (RS), Rice straw with EM (RSEM), chicken manure (CM), vermicompost (Vc), commercial organic fertilizer (COF), green manure (WSF).

- Field Trial/Experiments
  - a. Adaptability assessment and optimization of the pre-screened bio fertilizers in the actual field conditions

(2015WS-2018).

b. Two different rice varieties: inbred (PSB Rc82) and hybrid (Bigante plus) were planted in a plots basally incorporated with different nFF alternative N source: Azolla microphylla, Indigofera tinctoria (tayum), Cochorus olitorius (saluyot), Vigna radiata (native mungbean), Sesbania and Aeschynomene. Control (unfertilized) and the key check no. 5 of Palay Check System will serve as check. All treatments were laid out in factorial split-plot design with four replications.

- Integration of nutrient management emanating from the results of green house and field trials (2017-2020).
  a. Combination of basal organic fertilizer (farm wastes e.g. rice straw, dungs or manures, vermicomposts, Azolla compost) and different green manure as top dress nutrient supplement.

Findings:

- Green house experiments
  a. On screening for hot temperature and high relative humidity:
  1. Six (6) Azolla accessions (A. pinnata var. pinnata 20, A. caroliniana 3522, A. mexicana 2024, A.caroliniana 3005 and A. filiculoides 1001 and A. microphylla) were identified to adapt in high temperature condition and relative humidity under the screen house condition
  2. Four (A. mexicana 2024, A.caroliniana 3005 and A. filiculoides 1001 and A. microphylla) out of six was subjected to field condition under the vegetable production (c/o DEV 0014-001) whose trellis was used to shade the production of the 4 Azolla spp.
  3. A. microphylla was the only species that thrived in an open lowland field conditions. The other 3 spp can survive high RH but not direct sunlight. This has been mass produced to support some S&T researchers, and as give aways to farmers during the Lakbay Palay
  b. On giving good nutrients to Azolla for higher biomass N:
  1. with full NPK (120-40-60), Azolla microphylla can give 72.3 kg N/ha or an energy equivalent of 5784 MJ/ kg N; with half of the inorganic NPK (60-20-30), the Azolla microphylla can only give 64.6 kg N/ ha or an equivalent energy value of 5168 MJ/ kg N produced

  2. Azolla caroliniana (2.8%) have the highest % N content when grown in CM-applied soils, followed by Azolla pinnata (2.5%) in soils basally applied with RS, Azolla pinnata (2.0%) in Vc-applied soils. Considering their growth in each basal organic fertilizer application, Azolla caroliniana can add up to 20 kg/ ha biomass N in CM-applied soil, followed by Azolla pinnata (13 kg/ha), and Azolla microphylla (9 kg/ha) both in the Vc-applied soils (Table 5).

- Field trials/experiment
  a. Adaptability assessment and optimization of the pre-screened bio fertilizers in the actual field conditions (2015WS-2018).
  1. The average yield obtained in Bigante Plus™ yielded 4.9 t/ha (DS) and 5.9 t/ha (WS) while PSB Rc82 yielded 4.7 t/ha (DS) and 5.6 t/ha (WS) regardless of the green manure tested.
  2. The yield increase in the WS was due to the application of A. microphylla as top dress to specified treatment plots.
  3. In DS 2016, yields were 300 to 400 kg/ha lower than in the previous years but during the WS 2016, yields increased up to 900-1000 kg/ha higher than the previous season.
  b. The target yield to increase grain production in a non-fossil fuel free alternative N sources was not realized this year due to:
  1. Insufficient amount of green manure applied into the soils due to typhoons Karen and Lawin
  2. The purpose of relay-cropping of green manure in between 2 rice-rice cropping seasons was not successful. Planting GM plants during the dry-to-wet transition period, and the wet-to-dry transition period of rice-cropping was inhibited by the soil properties particularly to heavy clay soil series and the water regime in the trial site. This kind of relay cropping (rice-green manure cropping pattern) is more suitable in other lighter soil series, and well-drained soil condition.

Table 5. Total biomass nitrogen given by the different Azolla sp. As affected by different basal medium. DS 2016, PhilRice CES, Maligaya, Science City of Munoz, Nueva Ecija.

Organic based Basal Medium	Biomass Nitrogen, kg/ha (= equivalent energy saved, MJ/kg N)		
	Azolla pinnata	*Azolla caroliniana*	*Azolla microphylla*
Control	4.46	2.55	0.96
	-357.03	-204.08	-76.46
Inorganic (30-30-30 kg NPK/ha)	2.9	1.36	1.48
	-231.74	-108.81	-118.45
Rice straw (RS)	7.17	4.43	8.58
	-573.92	-354.74	-686.1
Rice straw with EM (RSEM)	5.21	6.84	4.72
	-417.01	-547.35	-377.87
chicken manure (CM),	5.32	13.15	6.89
	-425.89	-1052.1	-551.04
green manure (WSF)	2.39	1.48	4.13
	-191.48	-118.38	-330.51
vermicompost (VC)	5.8	4.22	6.62
	-463.68	-337.72	-529.3

Optimization of efficient production and quality of vermicompost using different substrates

EF. Javier and VIG. Mapa

Rice straw is one of the major wastes that are beneficial in many ways. Incorporation of rice straw in the rice field is one of the best practice to retain the nutrients from rice straw. But many of the farmers are still burning their rice straw not considering the benefits from it. With vermicomposting, the rice straw can be composted faster, transforming it into a beneficial microorganisms- and humus-rich fertilizer. However, nutrient content and overall quality of vermicompost varies with different materials and substrates add to it. In order to standardize or at least establish a guide on the nutrient contents of vermicast from a specific material, the sources, materials and the process need to be characterized toward a high quality vermicast with higher nutrient content than the other commercial organic fertilizer.

Activities:

- Dry season (2016 DS) : Optimization of main substrates and additives for best quality vermicast

  a. Optimization on vermicompost quality using partially decomposed rice straw (PDRS)
  b. Optimization on vermicompost quality using mushroom waste (MW) spent

General procedure (for both cycle):

a. Combination with other three substrates such as carabao manure, Azolla, and Sesbania at different ratio.
b. Serve as feeds to vermi worms and turn it into vermicast.
c. Data gathering: Weight of vermicast; chemical analyses: pH, moisture, N, P and K content; micronutrient (Cu, Zn, Fe, and Mn) of vermicasts; weight of harvested vermi worms

- Wet Season (2016 WS): Validation of the different ratio of substrate relative to rice straw compost and mushroom spent (rice straw based inoculum for mushroom).
  a. PDRS as the main substrate, in combination of three substrates such as carabao manure, Azolla, and Sesbania at different ratio.
  b. Serve as feeds of vermi worms and turn it into vermicast.
  c. Data gathering: Weight of vermicast; chemical analyses: pH, moisture, N, P and K content; micronutrient (Cu, Zn, Fe, and Mn) of vermicasts; weight of harvested vermi worms

Findings:

- Partially decomposed RS (PDRS) gave higher vermicast harvest and higher nutrient elements than when mushroom waste was used as substrate. (Table 1).

- Generally, all the substrate mixes in the study gave higher vermicast yield: 6.55kg (by the PDRS) and 4.93kg (by the MW) than the check MRF commercial vermicast substrate) that yielded only 3.45kg (Table 6).

- Average nitrogen content of vermicast from the PDRS from 1.04 to 2.74% N, while MW ranged from 1.12 to 1.50% N (Table 2 and 3). This may be attributed to the utilization of nutrients in the mushroom spent by the mushrooms plantlets.

- Although the ratio did not show significant differences in the different additives, the harvested vermicast with high N content was those with Sesbania, and those with high P content were those with carabao manure, and statistically most of the treatments have high K, owing that the base substrate was the partially decomposed rice straw. The addition of A. microphylla gave vermicast of high Fe and Mn (Table 7 and 8).

- With these results, only those with higher potential of high vermicast yield and higher chemical components will be short listed and be established for the 3rd screening.

Table 6. Comparisons of 3 main substrates regardless of other additives applied to each substrate. 2016. PhilRice CES, Maligaya Science City of Muñoz, Nueva Ecija. (Data were analyzed by Statistical analysis for agricultural research, STAR at 5% level of significance for mean comparison).

Main Substrate	Harvested vermicast (kg)	pH	% N	% P	% K	Fe, ppm	Mn, ppm	Zn, ppm	Cu, ppm
Partially decomposed RS	6.55	6.90	1.91	0.03	0.72	65.90	362.54	11.21	52.05
Mushroom spent/waste	4.93	6.96	1.29	0.04	0.32	79.32	241.04	61.93	7.85
MRF commercial vermicast	3.45	7.37	1.37	0.04	0.61	68.44	262.35	42.08	108.48

Table 7. Vermicast yield and chemical properties as affected by different substrates regardless of their ratio to partially decomposed rice straw (PDRS). 2016. PhilRice CES, Maligaya Science City of Muñoz, Nueva Ecija. (Data were analyzed by Statistical analysis for agricultural research, STAR at 5% level of significance for mean comparison).

Substrate regardless of ratio	Harvested vermicast (kg)	pH	%N	% P	%K	Fe, ppm	Mn, ppm	Cu, ppm	Zn, ppm
Partially decomposed rice straw	6.45	6.64	1.59	0.02	0.52	36.82	451.39	17.80	23.85
PDRS + Carabao Manure (CM)	6.43	7.53	1.62	0.04	1.04	54.32	297.79	13.79	68.90
PDRS + Sesbania	6.78	6.25	2.74	0.01	0.72	46.27	380.57	4.63	52.53
PDRS + *A. microphylla*	6.40	6.42	1.89	0.02	0.58	142.73	524.60	5.62	46.01
PDRS + Carabao Manure (CM) + Sesbania	8.32	7.06	2.10	0.04	0.73	53.03	297.82	9.48	62.26
PDRS + Carabao Manure (CM) + *A. microphylla*	5.83	7.27	1.73	0.04	0.82	71.20	319.01	10.21	58.88
PDRS + Carabao Manure (CM) + Madre de Agua	8.07	7.32	1.73	0.040	0.88	43.4	263.17	10.67	68.87
PDRS + 5%EMAS	2.23	6.86	1.09	0.023	0.102	32.51	262.96	35.50	6.66
MRF best substrate (control)	3.47	8.06	1.48	0.040	1.08	55.5	219.98	19.38	94.85
Average of substrate on test	6.55	6.90	1.91	0.03	0.72	65.90	362.54	11.21	52.05
MRF best substrate (control)	3.47	8.06	1.48	0.040	1.08	55.5	219.98	19.38	94.85

Table 8. Vermicast yield and chemical properties as affected by different substrates regardless of their ratio to partially decomposed rice straw. 2016. PhilRice CES, Maligaya Science City of Muñoz, Nueva Ecija. (Data were analyzed by Statistical analysis for agricultural research, STAR at 5% level of significance for mean comparison).

Substrate regardless of ratio	Harvested vermicast (kg)	pH	% N	% P	% K	Fe, ppm	Mn, ppm	Zn, ppm	Cu, ppm
Mushroom Waste (MW)	7.35	7.12	1.36	0.048	0.23	62.03	253.13	56.10	4.36
MW + Carabao Manure (CM)	6.73	7.16	1.12	0.04	0.43	79.97	201.91	66.75	10.90
MW + 5%EMAS	3.58	7.17	1.26	0.05	0.24	57.57	222.39	55.16	3.84
MW + *A. microphylla*	4.48	6.43	1.50	0.04	0.20	103.36	334.21	59.00	5.81
MW + Carabao Manure (CM) + 5% EMAS	3.86	7.17	1.22	0.04	0.39	78.59	214.92	68.60	10.15
MW + Carabao Manure (CM) + *A. microphylla*	4.75	6.89	1.33	0.04	0.35	75.61	221.51	59.80	8.40
MRF best substrate (control)	3.42	6.68	1.25	0.032	0.14	81.37	304.72	64.77	13.63
Average of substrate on test	4.93	6.96	1.29	0.04	0.32	79.32	241.04	61.93	7.85
MRF best substrate (control)	3.47	8.06	1.48	0.040	1.08	55.5	219.98	19.38	94.85

Pilot Testing of an Improved Ricehull Gasifier Engine – Pump System for Rainfed Lowland Farm

AS. Juliano, JA Ramos, JP Miano

Water is certainly one of the major resources in farming. Pumping water from underground or from open sources such as lakes, rivers, and streams could be very costly, especially with the increasing cost of fuel. To lower the high cost of pumping water, PhilRice developed two models of rice hull gasifier engine-pump system (RHGEPS) that is efficient and reliable where rice hull biomass is used as fuel (instead of gasoline fuel) to pump water from a source with features that are compact, light-weight, mobile, and affordable for the small farmers. The RHGEPS-1 with 6.5Hp gasoline engine and 3 inch diameter pump for small plots, and the RHGEPS-2 with 16Hp gasoline engine and 4 inch diameter pump for large plots.

Prior to full commercialization, pilot testing is necessary to identify potential problem and deficiencies of the machine. This study is being conducted to pilot test the units in farmer's fields near PhilRice branch stations specifically in rainfed lowland condition with abundant rice hull biomass in order to evaluate further the performance of the machine and fine tune according to farmer's preference.

Findings:

- To secure availability and adequate supply of fuel (rice hull), storage space for fuel, adequate depth of water in the STW, availability of skilled operators, and potential of effective utilization, two locations (PhilRice Batac and PhilRice Mindoro) were identified for pilot testing of improved RHGEPS.

- Revision of the design was completed based on the recommendation of the previous study. In order to safeguard the operation components were reoriented to hide moving parts (pulley and belts) and engine starting part positioned outside to facilitate the starting of engine. Tests for checking the functionality were conducted.

- One unit RHGEPS-2 (improved model) was fabricated by the accredited manufacturer and one unit RHGEPS-1 was assembled at the REMD shop.
- The two RHGEPS models undergone and passed the functionality test before the delivery to the farmer cooperator in Mindoro and Batac, Ilocos Norte.
- The two models were already delivered in Mindoro and Ilocos Norte branch stations. For RHGEPS -1, Engineer and operator were trained during testing.

Pilot testing will be started this December 2016 to the farmer cooperator (Lorenzo delos Santos of Dingras, Ilocos Norte) for the RHGEPS-1.

Indigenous N Accumulation from Biomass of Sporulating Azolla Growing along the Cropping Cycle of Irrigated Lowland Rice
CLC Mondejar & GO San Valentin

The nitrogen fixation of azolla – anabaena is equal to the rhizobium – legume symbiosis. The azolla – anabaena association can fixes about 1.2 kg of nitrogen per hectare daily (Talley et al. 1977; Lumpkin and Pucknett, 1980). Azolla being a fresh water fern demonstrates to be the best alternative source of nitrogen for lowland rice production. Azolla can grow together with rice in the paddies. Several studies have proved a significant increase in rice yield in proportion to azolla biomass applied (DA-UPLB-NAAP, 1988; Kannaiyan, 1987; Kulasooriya et al. 1987; Zhuang-ta et al. 1987).

The rice paddy could provide the place for growth of azolla. Azolla can grow together with rice in the paddies. However, the water regime of the flooded rice system is not always favorable for vegetative production of azolla. Rice paddies are generally drained and allowed to dry two to three weeks before harvesting. The usual rice cropping cycle involves a fallow period in which soil become dry until low saturation. In this case, azolla becomes desiccated. Vegetative propagation of azolla has limitation since azolla dies when it dries. Production through spores ensures the continued survival of azolla in rice paddies.

During the implementation of study on azolla spore production of PhilRice under the Farming without Fossil Energy (FFE) program, observations from different farmer's field in CALABARZON and Bicol Region showed persistence of some azolla species in alternate flooded and drained during the year-round cropping cycle (Mondejar & San Valentin, 2015). The persistence of azolla appears to be associated with the production of spores and favorable condition that induce the spore production of a given azolla strain. The growth cycle of azolla from 'spore-to-spore' was validated in the observation conducted in PhilRice Los Baños. The environmental conditions and growth characteristics such as such as growth rates, sporulation index and germination rate, contributing to the continuous existence of azolla in a specific location is the subject of the previous study at PhilRice. Methods of producing spores and growing azolla from spore are some of the accomplishments of the study. These methods are validated in this study.

The study mainly aim to account the nitrogen contribution of sporulating azolla selected during the previous study as a step in determining the possibility of producing rice independently in irrigated lowland rice ecosystem to inorganic fertilizer by using persistent azolla with reduce labor of the farmers in reinoculating the biofertilizer.

Findings:

- Azolla were propagated in the field using spores and azolla sporelings pre-germinated in the nursery. A total of 30g of dried spores was used during pre-germination. The spores germinated after 8 days. Germination of spores were tested also with direct inoculation in the field. In a 1 x 1m sub-plot in the field, a total of 50g of dried spores were inoculated. Similarly, the spores germinated in the field after 8 days. After two months, azolla fully covered a 5 x 5m plot with a total of of ~25kg fresh biomass after two months. The doubling time of azolla used is six day. Azolla mexicana # 2024 was used in the evaluation. The sporelings were used as starting inoculum in the –N, -P, -K omission plots.
- Soils were sampled from the field after land preparation to be used for initial indigenous N of the soil. The following treatments were established in the field at UPLB Agripark with four replications using split-plots as experimental design;

T1 – control, no application of fertilizers
T2 – used of azolla but basal only or one application during land preparation
T3 – used of inorganic fertilizers (120 – 40 – 30)
T4 – used of inorganic fertilizers (120 – 0 – 30, no P)
T5 – used of inorganic fertilizers (0 – 40 – 30, no N)

T6 – used of azolla as basal and inorganic P & K (0 – 40 – 30)
T7 - half of the N requirement comes from azolla and half from inorganic N, with P & K (60 – 40 – 30)

Average grain yield and yield parameters will be gathered. Rice plants will be harvested on the 1st or 2nd of December.

Sustainable and Energy Self-Sufficient Community in Small Islands of the Philippines
EC Gagelonia, JA Ramos, BD Tadeo, M Rafael, MJC Regalado

Renewable energy sources are currently one of the most, if not the only suitable option to supply electricity in fragmented areas or at certain distances from the grid. Indeed, renewables are already contributing to the realization of important economic, environmental and social objectives by the enhancement of security of energy supply, the reduction of greenhouse gases and other pollutants and by the creation of local employment which leads to the improvement of general social welfare and living conditions.

Basically, the fuel that can be derived from biomass can be used as source of heat and power. Once power is available, it can be utilized to drive agricultural machines for mechanized operation and/or to produce electricity for powering farmstead equipment and for lighting purpose. It is contemplated that the fuel and energy that can be derived from rice wastes and its by-products can be used to fuel varieties of sizes and kind of internal combustion engines that will power stationary and mobile machines for land preparation, irrigation, harvesting, threshing, drying, transport, and milling. With this idea, farmers can be encouraged to produce fuel from their farm which they can subsequently use for their farming activities and they can even sell some for their livelihood. Once this is realized, a sustainable and cost-effective rice farming can be achieved.
Throughout the past decades, bioenergy and other renewable energies have been the subject of several international declarations and commitments on sustainable development (FAO, 2005)

As a long-term strategy, the Philippines is exploring and developing renewable energy sources. Based on current projections of the Department of Energy, renewable energy is estimated to meet up to 40 percent of the country's primary energy requirements over the ten-year period beginning in 2003. Although its share will decline in relation to the total figure, it is estimated to grow at an average annual rate of 2.4 percent in absolute terms. Biomass, micro-hydro, solar and wind will remain the largest contributors to the total share of renewable energy in the energy mix with an average share of 27.5 percent.

Thus, this study is implemented to establish a sustainable decentralize energy system model for small island.

Activities:

- Identification of site (island) according to set criteria. Visited the island and held a meeting with the municipal council regarding the collaborative project.

- Resources and needs assessment. The planning and development officer presented the profile of the municipality. From there, the source of income and livelihood was identified including the present needs in the municipality. Sources of biomass was also determined.Visited some of the barangays, in particular the rice areas and the main livelihood in the municipality.

- Conducted GPS mapping of available source of biomass energy in the municipality.

Findings:

- Identified municipality of Alabat for the collaborative project on establishing sustainable and energy self-sufficient community in small islands in the Philippines. A meeting was held to present about the program "Farming Without Fossil Energy" of PhilRice. Dr. Bernardo Tadeo also presented Biomass Gasification in the Philippines for power generation. An agreement was set and Memorandum of Agreement between LGU-Alabat and PhilRice was signed.

- The three main livelihood in Alabat is coconut farming comprising of 2,977ha, rice with 325ha and citrus, 50ha. Alabat island composed of 19 barangays with 2 barangays (Bacong and Angeles) engaged in rice farming. Most of the coconut trees is used for the production of coco sugar. We visited 2 households engaged in production of coco sugar and familiarized on how coco sugar is being processed. In processing of coco sugar, the source of heat they used is LPG, thus technologies utilizing biomass as source of heat is needed:
- Data on the available agri-residue energy was gathered (Table 9).

- GPS map on the sources of biomass energy was generated.

- Conducted exploratory adoption of the gasifier and continuous type rice husk carbonizer (Figure 9) as source of heat in granulation of coco sugar.

- Fabricated a customized design of the continuous-type rice hull carbonizer for the household coco sugar processor.

Table 9. Available agri-residue energy in Alabat.

Biomass	Area, ha	Number of trees, bearing	Produce, MT	Available, MT	Potential Power, MW	Potential Power, KW
Coconut	3,615.00	519,340.00	5,711.70			
Husk				1,175.47	0.21	214.36
Shell				616.86	0.07	71.89
Cocofrond				1,144.62	0.17	169.78
Rice, Rainfed	210.00		1,092.00			
Rice, Irrigated	237.00		1,516.80			
Rice Total	447.00		2,608.80			
Rice Husk				557.63	0.06	59.18
Rice straw				1,304.40	0.12	122.33
Secondary forest	1,526.00	152,600.00				
Trimmings			51,769.67	8,283.15	0.96	964.26
Others (Residential, Commercial, etc)	171.77					
Total	5,588.00				1.60	1,601.80

Figure 9. Exploratory adoption of continuous type rice husk carbonizer as source of heat in granulation of coco sugar.

Field evaluation of the environmental impact and sustainability of rice production system through LCA

EG. Bautista, MJC. Regalado, JA. Ramos

Rice fields had been identified as essential source of 40% anthropogenic methane and biogenic emission that causes climate change. The Philippines as an agricultural country primarily depend on rice production to feed the population and also one of the most affected regions by climate change as it has been severely experiencing natural calamities such as floods, stronger typhoons, and droughts. These phenomena become more devastating in the tropics than in other climatic zones (UNFCC 1999). There are many factors that challenged the capability of farmers and researchers to produce more rice and at the same time reduce GHG emission.

Modern farm inputs utilization such as fertilizer, high-yielding rice variety, pesticides and farm machinery substantially increased the rice productivity and reducing the cultivation cycle and increased the possibility of a higher yield potential. The government had given emphasis to introducing high-yielding varieties, development of irrigation facilities, and provision of loans and subsidies to encourage farmers to produce more yields. Paddy production meets a total of 16.52 million metric tons which was improved due to sustained used of hybrid and high quality inbred rice seeds (PhilRice 2008). But modern methods and machine utilization in rice production also increases our dependent on fossil energy that increases degradation of our environment.

Therefore, it is very challenging task to increase rice production for the increasing population using modern and advanced technologies considering the risks of producing more GHG emission in the rice fields. Production intensification with lower GHG emission level is the greatest challenge in rice agriculture. In terms of cultivation environments and agricultural practices, rice production in the Philippines is very diverse and basically different from those in temperate countries such as Japan. The tremendous utilization of energy from fossil fuel, chemical fertilizer, pesticides, machinery and electricity during intensive production resulted to remarkably increased GHG emission thus resulted to global warming which became the most serious problem of humankind today.

In order to deal with these challenges, it needs to find out the factors that contribute to release of GHG emission involved in rice production. Understanding the sources of emissions lead to better understanding of effective mitigating methods and will become the basis on how to manage it. This study will assess the energy input /output of rice production with reduced tillage and conventional tillage and evaluate the productivity of hybrid and inbred rice relative to the production inputs that affects the

environment through GHG emissions.

Using the RCBD statistical design in three replications, all rice production inputs including human labor, machine operation, fossil fuel, fertilizer, pesticide and other elated input were monitored throughout the production period. Treatments were rice variety (inbred, hybrid), crop establishment (transplanted and direct seeded) and land preparation (reduced tillage and conventional tillage). Reduced tillage was used to became mechanized farming by utilizing mechanical means of operations while conventional tillage was manual labor using the traditional way of operations. The following are treatments adopted in the field experiment;

Treatments: 1. Reduced tillage, transplanted, Inbred
Treatments: 2. Reduced tillage, transplanted, Hybrid
Treatments: 3. Reduced tillage, direct seeding, hybrid
Treatments: 4. Reduced tillage, direct seeded, Inbred
Treatments: 5. Conventional tillage, transplanted, Inbred
Treatments: 6. Conventional tillage, transplanted, hybrid
Treatments: 7. Conventional tillage, direct seeded, hybrid
Treatments: 8. Conventional tillage, direct seeded, Inbred

Findings:

- Results showed that during the dry season 2016, the highest yielding plot was those transplanted inbred variety and using reduced tillage (4,165kg/ha). It was followed by plot 8 with Inbred variety in direct seeded conventional tillage (3,814kg/ha). The yield component was harvested in three 2x2 square meter areas in each plot while the actual yield was monitored during actual harvesting of the whole plots. Plot 3 and 7 did not have harvest because direct seeded hybrid did not continue to grow due to climate and rodent problems. The inbred varieties got the highest yields among treatments.

Table 10. The yield component and actual yield of experimental plots.

	Yield, kg/ha.		Average yield
	YC	Actual	(adjusted to 14% MC
Plot 1 (ITR)	3,885	4,444	**4,165**
Plot 2 (HTR)	3,758	3,750	**3,754**
Plot 3 (HDR)	0	0	**0**
Plot 4 (IDR)	3,830	3,657	**3,743**
Plot 5 (ITC)	3,451	3,241	**3,346**
Plot 6(HTC)	3,454	3,667	**3,561**
Plot 7 (HDC)	0	0	
Plot 8 (IDC)	3,740	3,889	**3814**

Note: I inbred D-Direct seeded
H-hybrid C-conventional tillage
T-transplanted R-Reduced tillage

- The highest energy inputs were observed from reduced tillage plots 1 and 2 for both transplanted inbred and hybrid rice followed by the transplanted plots using conventional tillage. This was due to additional energy input used during transplanting as compared to direct seeding operation. The inbred varieties in plot 1 and 8, produced more energy output compared to others. Plot 8 and 4 had the highest output/input ratio of 5.15 and 5.30, respectively. This showed that the efficiency of rice production did not solely depend on yield but also to the amount of energy input applied.

Table 11. Energy input-output of rice production.

	Energy input	Energy output	O/I ratio
Plot 1 (ITR)	10,505	51,477	4.90
Plot 2 (HTR)	10,478	46,399	4.43
Plot 3 (HDR)	9,034	0	0
Plot 4 (IDR)	8,994	46,275	5.15
Plot 5 (ITC)	10,070	41,352	4.11
Plot 6(HTC)	10,045	44,003	4.38
Plot 7 (HDC)	8,930	0	0
Plot 8 (IDC)	8,902	47,144	5.30

- The plot 1 and 2 of reduced tillage transplanted had the highest GHG emission among plots. It is true to both inbred and hybrid rice under mechanical transplanting method. This was due to more fuel used during machine operations which included mechanical transplanting. Lowest GHG emissions were found in plots 7 and 8 under direct seeding method.

Table 12. GHG emission of rice production.

	GHG emission, kg CO2 eq. /ha
Plot 1 (ITR)	2,052
Plot 2 (HTR)	2,051
Plot 3 (HDR)	1,682
Plot 4 (IDR)	1,671
Plot 5 (ITC)	1,905
Plot 6(HTC)	1,901
Plot 7 (HDC)	1,664
Plot 8 (IDC)	1,657

- Comparing reduced tillage and conventional system, the average energy input and output as well as output-input ratio were higher in reduced tillage. However, the GHG emission was higher with reduced tillage. Transplanted rice has higher energy input compared to direct seeding, however direct seeding had higher energy output which apparently affect the output-input ratio and becomes higher.

Abbreviations and acronymns

ABA – Abscicic acid
Ac – anther culture
AC – amylose content
AESA – Agro-ecosystems Analysis
AEW – agricultural extension workers
AG – anaerobic germination
AIS – Agricultural Information System
ANOVA – analysis of variance
AON – advance observation nursery
AT – agricultural technologist
AYT – advanced yield trial
BCA – biological control agent
BLB – bacterial leaf blight
BLS – bacterial leaf streak
BPH – brown planthopper
Bo - boron
BR – brown rice
BSWM – Bureau of Soils and Water Management
Ca - Calcium
CARP – Comprehensive Agrarian Reform Program
cav – cavan, usually 50 kg
CBFM – community-based forestry management
CLSU – Central Luzon State University
cm – centimeter
CMS – cystoplasmic male sterile
CP – protein content
CRH – carbonized rice hull
CTRHC – continuous-type rice hull carbonizer
CT – conventional tillage
Cu – copper
DA – Department of Agriculture
DA-RFU – Department of Agriculture-Regional Field Units
DAE – days after emergence
DAS – days after seeding
DAT – days after transplanting
DBMS – database management system
DDTK – disease diagnostic tool kit
DENR – Department of Environment and Natural Resources
DH L– double haploid lines
DRR – drought recovery rate
DS – dry season
DSA - diversity and stress adaptation
DSR – direct seeded rice
DUST – distinctness, uniformity and stability trial
DWSR – direct wet-seeded rice
EGS – early generation screening
EH – early heading
EMBI – effective microorganism-based inoculant
EPI – early panicle initiation
ET – early tillering
FAO – Food and Agriculture Organization
Fe – Iron
FFA – free fatty acid
FFP – farmer's fertilizer practice
FFS – farmers' field school
FGD – focus group discussion
FI – farmer innovator
FSSP – Food Staples Self-sufficiency Plan
g – gram
GAS – golden apple snail
GC – gel consistency
GIS – geographic information system
GHG – greenhouse gas
GLH – green leafhopper
GPS – global positioning system
GQ – grain quality
GUI – graphical user interface
GWS – genomwide selection
GYT – general yield trial
h – hour
ha – hectare
HIP - high inorganic phosphate
HPL – hybrid parental line
I - intermediate
ICIS – International Crop Information System
ICT – information and communication technology
IMO – indigenous microorganism
IF – inorganic fertilizer
INGER - International Network for Genetic Evaluation of Rice
IP – insect pest
IPDTK – insect pest diagnostic tool kit
IPM – Integrated Pest Management
IRRI – International Rice Research Institute
IVC – in vitro culture
IVM – in vitro mutagenesis
IWM – integrated weed management
JICA – Japan International Cooperation Agency
K – potassium
kg – kilogram
KP – knowledge product
KSL – knowledge sharing and learning
LCC – leaf color chart
LDIS – low-cost drip irrigation system
LeD – leaf drying
LeR – leaf rolling
lpa – low phytic acid
LGU – local government unit
LSTD – location specific technology development
m – meter
MAS – marker-assisted selection
MAT – Multi-Adaption Trial
MC – moisture content
MDDST – modified dry direct seeding technique
MET – multi-environment trial
MFE – male fertile environment
MLM – mixed-effects linear model
Mg – magnesium
Mn – Manganese
MDDST – Modified Dry Direct Seeding Technique
MOET – minus one element technique
MR – moderately resistant
MRT – Mobile Rice TeknoKlinik
MSE – male-sterile environment
MT – minimum tillage
mtha^{-1} - metric ton per hectare
MYT – multi-location yield trials
N – nitrogen
NAFC – National Agricultural and Fishery Council
NBS – narrow brown spot
NCT – National Cooperative Testing
NFA – National Food Authority
NGO – non-government organization
NE – natural enemies
NIL – near isogenic line
NM – Nutrient Manager
NOPT – Nutrient Omission Plot Technique
NR – new reagent
NSIC – National Seed Industry Council
NSQCS – National Seed Quality Control Services
OF – organic fertilizer
OFT – on-farm trial
OM – organic matter
ON – observational nursery
OPAg – Office of Provincial Agriculturist
OpAPA – Open Academy for Philippine Agriculture
P – phosphorus
PA – phytic acid
PCR – Polymerase chain reaction
PDW – plant dry weight
PF – participating farmer
PFS – PalayCheck field school
PhilRice – Philippine Rice Research Institute
PhilSCAT – Philippine-Sino Center for Agricultural Technology
PHilMech – Philippine Center for Postharvest Development and Mechanization
PCA – principal component analysis
PI – panicle initiation
PN – pedigree nursery
PRKB – Pinoy Rice Knowledge Bank
PTD – participatory technology development
PYT – preliminary yield trial
QTL – quantitative trait loci
R - resistant
RBB – rice black bug
RCBD – randomized complete block design
RDI – regulated deficit irrigation
RF – rainfed
RP – resource person
RPM – revolution per minute
RQCS – Rice Quality Classification Software
RS4D – Rice Science for Development
RSO – rice sufficiency officer
RFL – Rainfed lowland
RTV – rice tungro virus
RTWG – Rice Technical Working Group
S – sulfur
SACLOB – Sealed Storage Enclosure for Rice Seeds
SALT – Sloping Agricultural Land Technology
SB – sheath blight
SFR – small farm reservoir
SME – small-medium enterprise
SMS – short message service
SN – source nursery
SSNM – site-specific nutrient management
SSR – simple sequence repeat
STK – soil test kit
STR – sequence tandem repeat
SV – seedling vigor
t – ton
TCN – testcross nursery
TCP – technical cooperation project
TGMS – thermo-sensitive genetic male sterile
TN – testcross nursery
TOT – training of trainers
TPR – transplanted rice
TRV – traditional variety
TSS – total soluble solid
UEM – ultra-early maturing
UPLB – University of the Philippines Los Baños
VSU – Visayas State University
WBPH – white-backed planthopper
WEPP – water erosion prediction project
WHC – water holding capacity
WHO – World Health Organization
WS – wet season
WT – weed tolerance
YA – yield advantage
Zn – zinc
ZT – zero tillage

List of Tables

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Department of Agriculture
Philippine Rice Research Institute

PhilRice Central Experiment Station; Maligaya, Science City of Muñoz, 3119 Nueva Ecija
Tel: (44) 456-0277 • Direct line/Telefax: (44) 456-0112 • Email: prri.mail@philrice.gov.ph
PhilRice Text Center: 0920-911-1398 • Websites: www.philrice.gov.ph; www.pinoyrice.com

BRANCH STATIONS:

PhilRice Agusan, Basilisa, RTRomualdez, 8611 Agusan del Norte;
Telefax: (85) 343-0768; Tel: 343-0534; 343-0778; Email: agusan.station@philrice.gov.ph
PhilRice Batac, MMSU Campus, Batac City, 2906 Ilocos Norte;
Telefax: (77) 772- 0654; 670-1867; Tel: 667-1508; Email: batac.station@philrice.gov.ph
PhilRice Bicol, Batang, Ligao City, 4504 Albay; Tel: (52) 284-4860; Mobile: 0918-946-7439 ;
Email: bicol.station@philrice.gov.ph
PhilRice Isabela, Malasin, San Mateo, 3318 Isabela; Mobile: 0908-895-7796; 0915-765-2105;
Email: isabela.station@philrice.gov.ph
PhilRice Los Baños, UPLB Campus, Los Baños, 4030 Laguna; Tel: (49) 536-8620; 501-1917;
Mobile: 0920-911-1420; Email: losbanos@philrice.gov.ph
PhilRice Midsayap, Bual Norte, Midsayap, 9410 North Cotabato;
Tel: (64) 229-8178; 229-7241 to 43; Email: midsayap.station@philrice.gov.ph
PhilRice Negros, Cansilayan, Murcia, 6129 Negros Occidental;
Mobile: 0932-850-1531; 0915-349-0142; Email: negros.station@philrice.gov.ph
PhilRice Field Office, CMU Campus, Maramag, 8714 Bukidnon;
Mobile: 0916-367-6086; 0909-822-9813
Liaison Office, 3rd Floor, ATI Bldg, Elliptical Road, Diliman, Quezon City; Tel: (02) 920-5129

SATELLITE STATIONS:

Mindoro Satellite Station, Alacaak, Sta. Cruz, 5105 Occidental Mindoro; Mobile: 0908-104-0855
Samar Satellite Station, UEP Campus, Catarman, 6400 Northern Samar; Mobile: 0948-800-5284