Economic Analysis of Rice Straw Management Alternatives and Understanding Farmers' Choices

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ECONOMIC ANALYSIS OF RICE STRAW MANAGEMENT ALTERNATIVES AND UNDERSTANDING FARMERS' CHOICES

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EXECUTIVE SUMMARY

The negative effects of open-field rice straw burning on the environment and human health are well documented in local and international literature. Farmers have thus been encouraged to refrain from burning rice straw and adopt more environment- and human-friendly rice straw management practices. This research project aimed at assessing the environmental consequences of rice straw burning and other straw management practices in terms of greenhouse gas (GHG) emissions, and evaluating the cost-effectiveness and adoption of selected rice straw management alternatives. The study evaluated emissions of methane (CH_4) and nitrous oxide (N_2O) gases only since carbon dioxide (CO_2) emissions from rice cultivation and associated practices are assumed to be reabsorbed during the next growing season.

Given the average yield and total rice area of the country by season and ecosystem, and the current use of rice straw based on our survey of farmers, rice stubble and straw contribution to CH_4 and N_2O emissions in paddy fields is around 16 M tons carbon dioxide equivalent[1] (CO_2-eq) in the base year. Incorporating stubble less than 30 days before crop establishment appears to be the largest contributor, accounting only for the current year. On a per hectare-basis and considering a time horizon of five years with associated assumptions on cost savings and secondary benefits, incorporating stubble more than 30 days before crop establishment, and incorporating composted rice straw in the field yielded the lowest cumulative CH_4 and N_2O emissions.

The most cost-effective option for farmers is to incorporate stubble and straw in the soil more than 30 days before crop establishment. Rapid straw composting and incorporation of rice straw compost entails much higher additional cost but it also significantly mitigates GHG emission, hence it is the next most cost-effective option. Incorporating rice stubble and straw less than a month before crop establishment, on the other hand, appears to result in a net increase in ton CO_2-eq given the assumed time horizon. Literature points to the potential of rice straw as raw material for power generation and bioethanol production and the corresponding reduction in GHG emissions, but this study has not evaluated the cost-effectiveness of these options, hence, this is recommended for further study. The estimated GHG emissions are generally indicative and the economic analysis must be interpreted in relative terms. Further study on water management and tillage options as mitigation options is recommended for a broader perspective useful for farmers, policy-makers and other rice stakeholders.

A mix of socio-economic, farm, and awareness and attitude variables determine why farmers choose to burn, incorporate, or remove rice straw. Training on rice production for farmers, increasing the demand for rice straw for other uses, developing options for reducing the cost of collection and transportation of rice straw, and intensifying information campaigns and drives regarding environmental regulations and policies are recommended.

[1] Carbon dioxide equivalent (CO_2-eq) is a measure used to compare the emissions from various greenhouse gases based upon their global warming potential. For example, the global warming potential for methane over 100 years is 21. This means that emissions of one million metric tons of methane is equivalent to emissions of 21 million metric tons of carbon dioxide (OECD, 2001)

1.0 INTRODUCTION

1.1 Research Problem

The practice of rice straw[2] open-field burning is a major source of air pollutants such as carbon dioxide (CO_2), carbon monoxide (CO), un-burnt carbon as well as traces of methane (CH_4), nitrogen oxide (N_2O) and comparatively less amount of sulphur dioxide (SO_2) (Gupta et al. 2004; Wassman and Dobbermann 2006; Tipayarom and Oanh 2007) .

Rice straw burning is also known to emit particulate matters and other elements such as dioxins and furans that impact human health (Torigoe et al. 2000; Gadde et al. 2009). Based on a study of the Department of Science and Technology (DOST), burning of rice straw and other agricultural waste contribute more dioxins and furans to air and land than vehicle emissions (DOST 2006). Studies also show that rice straw burning causes loss of major nutrients in the soil: almost complete nitrogen (N) loss, phosphorous (P) losses of about 25%, potassium (K) losses of 20%, and sulphur (S) losses of 5 to 60% (Dobbermann and Fairhurst 2002).

Given these negative effects of open-field rice straw burning on the environment and human health as documented in local and international literature, farmers have been encouraged to refrain from burning rice straw, and adopt more environment- and human-friendly rice straw management practices. In fact, both the existing solid waste management law in the Philippines (RA 9003) and the Philippine Clean Air Act of 1999 prohibit in principle open-field burning which includes burning of rice straw. Ordinances specific against rice straw burning have also been passed in some provinces and towns.

Scientists and researchers, on the other hand, have studied the potential impacts of various rice straw management technologies as alternatives to rice straw open-field burning. Crop residues properly returned to the soil can maintain or enhance soil quality and productivity through favorable effects on soil properties and life-support processes (Lal 1995). Continuous rice stubble and straw incorporation into the soil returns most of the nutrients and helps to conserve soil nutrient reserves in the long term (Dobermann and Fairhurst 2002). Eagle et al. (2000) concluded that the retention of straw in rice fields can result in increased soil N supply, suggesting that nitrogen fertilizer application rates can be reduced. Javier (2009) also reported that several studies have proven that continuous rice straw incorporation can build up potassium reserves which are essential for plant vigor.

However, it is also recognized in literature that the incorporation of straw and stubble into wet soil (during plowing) also results in temporary immobilization of N and a significant increase in methane (CH4) emission from rice paddies, a practice that contributes again to GHG emissions (Dobermann and Fairhurst 2002). The quantity of methane emission varies widely depending on the rice straw-based nutrient management practice used (Dobermann and Fairhurst 2002; Wassman and Vlek 2004; Vibol and Towprayoon 2010). Hence, rice straw management can significantly impact GHG emissions from rice fields, but also can provide a mitigation option. Using the proper rice straw-based nutrient management options may result in soil rejuvenation and environmental conservation (Javier 2009).

In practice, however, many farmers still burn their rice straw or if not, incorporate them into submerged soil during plowing. Local governments are also unable to implement the law especially with the large volume of rice straw produced each year in rice-producing regions. Rice straw burning thus continues to contribute to air pollution, compounding the already high methane emission levels inherent in irrigated rice-based farming systems. This raises the question of why farmers choose to burn their rice straw, and which straw management alternatives are cost-effective to farmers and to society as a whole.

This study hopes to contribute more concrete information on the external costs and benefits associated with selected rice straw management options in the Philippines. It aims to assess the status and potential environmental impacts of rice straw management alternatives. Such information will be useful to the Government of the Philippines' Department of Agriculture (DA), Department of Environment and

[2] The term "straw" often includes both the rice stubble left in the paddy field after harvesting and the rice straw by-product after threshing. In this report, we use stubble to refer to the lower part of the rice plant left in the field after harvesting, and rice straw to refer to loose straw output after threshing.

Natural Resources (DENR), and Local Government Units (LGUs) for advocacy. Concrete information on the potential incentives in quitting rice straw burning and shifting to other management options will be useful to farmers. By assessing the costs and benefits of rice straw management alternatives considering the environmental consequences, policy-makers and farmers can be guided not only on the potential and significance of rice straw management as mitigation options on the issue of GHG emissions and climate change, but also on how to achieve the goals of sustainable agriculture, higher productivity, and better income in rice-based farming systems.

1.2 Research Objectives

This research project aims to assess the environmental consequences of rice straw burning, and evaluate the adoption and cost-effectiveness of selected rice straw management alternatives.

Specifically, the objectives of the project are:

a) To quantify the contribution of rice straw burning to greenhouse gas (GHG) emissions in the Philippines using secondary information on emission factors;

b) To review and make an inventory of the status and environmental impacts of existing and potential rice straw management alternatives to open-field burning;

c) To compare selected rice straw management alternatives to open-field burning using cost-effectiveness analysis; and

d) To determine the factors and constraints involved in the adoption of rice straw management practices and farmers' perceptions of the environmental impacts of such practices.

1.3 Scope of the Study

While some evidence points to the negative health impacts of rice straw burning and the positive sustainability impacts of other rice straw management options, these benefits are difficult to value and incorporate in the economic analysis at this point. Thus, the economic analysis in this study is limited to considering the GHG emissions given the rice straw management alternatives. Also, while the study reports some literature on the potential use of rice straw for biofuel and power generation, it focuses more on evaluating farmers' applicable alternatives.

1.4 Research Questions

The study intends to provide answers to the following research questions:

a) What is the contribution of rice straw burning to GHG emissions in the Philippines?

b) What is the adoption status of other rice straw management alternatives such as the incorporation of rice straw into the soil and rice straw composting?

c) What are the environmental externalities associated with these other rice straw management alternatives?

d) What is the best rice straw management alternative to open-field burning in rice-based farming areas considering the environmental consequences?

e) Why do farmers choose to burn, incorporate, or compost their rice straw, and what is their perception of the environmental impacts of these practices?

2.0 LITERATURE REVIEW

2.1 Environmental Externalities from Rice Straw Management Options

To be able to quantify the value of environmental externalities from rice straw burning and compare it with the externalities in other rice straw management options, it is important to have greater accuracy in the estimated air pollutant emissions from rice straw open-field burning and other practices. Gadde et al. (2009) estimated air pollutant emissions from rice straw open-field burning in India, Thailand, and the Philippines. They estimated the quantity of rice straw subject to open-field burning in these countries, congregated pollutant- specific emission factors for rice straw burning, and quantified the resulting air pollutant emissions. Their results showed a substantial reduction in uncertainty compared to general methods in which emission factors for crop residues in general are used such as in Streets et al. (2003). The limitation of this study is that it did not account for the significant difference in rice straw management practices in the Philippines between wet and dry season rice crops, which will have a significant impact on the quantity of rice straw used for open-field burning.

Vibol and Towprayoon (2010) investigated the estimation of methane and nitrous oxide emissions from rice fields with rice straw management in Cambodia using IPCC guidelines and coefficients, and emission factors from experiments in Thailand and other countries. They distinguished methane emissions from different cultural practices related to rice straw management and found that fields with stubble-burning emitted the highest emission of methane, followed by stubble burning with manure.

Several studies investigated the effects of straw and nutrient management practices on soil fertility and productivity. Dobermann and Fairhurst (2002) reported results from experimental farms which indicated that early dry shallow tillage at 5 to 10 cm depths (to incorporate crop residues and enhance soil aeration during fallow periods) has beneficial effects on soil fertility in intensive rice-rice systems. Gupta et al. (2004) discussed the causes and implications of residue burning in the rice-wheat cropping system. They reported that residue burning resulted in pollutant emission, loss of nutrients, diminished soil biota, and reduced total N and C in the topsoil layer. Xiurong et al. (2002), based on a long-term study of returning straw to soil, concluded that soil organic matter, soil porosity, available N, Zn, Fe, Mn, and enzymes are all remarkably positively related to the amount of straw applied. They further mentioned that the combined use of straw and fertilizer was better. Tuyen and Tan (2001) studied the effects of straw management and tillage practices on soil fertility and grain yield of rice. They concluded that N and P contents of the soil became higher when rice straw was returned to the soil any way by burning, leftovers, and incorporation or cultivation of mushrooms. Bird et al. (2001) studied the effects of straw management practices on the immobilization of fertilizer N in rice, taking the case of long-term experiments in California. Their findings suggested that rice systems there, utilizing repeated straw incorporation, benefitted through a greater active and available soil N fraction sustained through repeated straw additions. Consequently, a reduction in the rate of fertilizer N application could be warranted. All these studies covered the physical dimension estimates of the environmental impacts of rice straw management practices.

A China study investigated externalities beyond the physical dimension valuing environmental externalities from rice-wheat farming (Lv et al. 2010). It covered four environmental externalities including GHG emissions from agricultural land, non-point sources pollution, carbon sequestration, and flood control. For the valuation of GHG emissions, they used the average rate of 14.25 Euros/ton of CO_2. They concluded that crops and soil in their study region are important carbon sinks and that agriculture shows huge positive environmental externalities, although both GHG emissions from agricultural land and non-point source pollution have negative impacts on the environment.

This research will focus on determining the environmental consequences of various rice straw management alternatives and pinpointing the best solution to achieving lesser negative environmental externalities.

2.2 Cost-Effectiveness Analysis and Applications

Cost-Effectiveness Analysis (CEA) refers to a systematic method of finding the lowest-cost option among a set of different policy measures to reach a given target (Povellato et al. 2007). It is an economic analysis tool that can be used to compare interventions or technologies by considering the monetary costs

of different alternatives to achieve the same benefits. Unlike cost-benefit analysis (CBA), the benefits in CEA are not necessarily quantified in monetary units, but it is necessary to have the effects of all alternatives measured on a single scale. In the area of improving air quality, for example, Escobedo et al. (2008) used CEA to select the least-cost alternative for obtaining a defined policy goal to remove particulate matter less than 10μm (PM_{10}) in Santiago, Chile. They compared the cost-effectiveness of managing municipal urban forests and street trees to other control policies (e.g. alternative fuels) to abate PM_{10} and found them similar. Schleineger (1999), on the other hand, used the reduction of different pollutants aggregated to a damage index as a measure of the effectiveness of nitrogen reduction measures in Switzerland.

For the cost-effectiveness of GHG abatement options, it is defined as the costs of an option divided by its GHG abatement potential, and is expressed in a monetary unit per ton of C or CO_2-eq abated (Davidson and van Essen 2009). A survey of the existing literature assessing the cost-effectiveness and efficiency of GHG mitigation strategies or the effects of broader economic reforms in the agricultural and forestry sectors focusing mainly on European countries is found in Povellato et al. (2007). Their main findings are that agriculture can potentially provide emissions reduction at a competitive cost, mainly with methane abatement while carbon sequestration seems more cost-effective with appropriate forest management measures.

While many GHG mitigation options are identified in the area of agriculture, particularly in rice production, namely, reduction in cultivated rice area, reduction in the period of flooding, introduction of new plant varieties, and nutrient management (Halsnaes et al. 1998), this study will focus on rice straw management which cross-cuts the agriculture and waste management sectors. This study will attempt to compare GHG emissions from rice-based farming systems under various rice straw management alternatives and compare the incremental cost of CO_2 emission reduction, taking rice straw burning as the baseline scenario. As reported by Wassman and Dobberman (2006), crop residue management has a large impact on GHG emissions from rice fields, but also represents a significant mitigation option.

2.3 Understanding Farmers' Choice of Management Options

Apart from knowing the economics and air pollution impacts of rice straw management alternatives, it is also important to understand farmers' decision-making behavior regarding their current rice straw management practices. As Nowak (1992) reported, efforts to increase the rate of adoption of environment-friendly residue management systems must be based on understanding why farmers reject new production techniques. In a study of factors that affect household waste disposal decision-making in Northern Ethiopia using multinomial logit estimation, for example, Tadesse et al. (2008) found demographic features such as age, education, and household size as having insignificant impact on the choice of alternative waste disposal means. Instead, they found that the supply of waste facilities such as waste containers and the longer distance to these containers significantly affected waste disposal choices.

A study by Fuglie and Kascal (2001), on the other hand, concluded that the size of the farm owned by a household, the value of its livestock, off-farm income, family labor supply, and the educational attainment and gender of the household head, all had a significant positive effect on the likelihood of the adoption of integrated natural resources management techniques. Also, using discrete choice model, Deressa et al. (2009) concluded that the choice of method to adapt to climate change and the barriers to adaptation included level of education, gender age, and wealth of the head of household, access to extension and credit, information on climate, social capital, agroecological settings, and temperature; all influenced farmers' choices. Type of crop varieties and machines used in production also significantly impacted the choice of farmers to burn or not to burn agricultural residue (Gupta 2011).

In addition, policy-related variables also determine farmers' choices from among alternatives. Kara et al. (2008) found, for example, that many local and state environmental rules influence the management practices on US farms. In their study of corn farms, their results suggest that stringent environmental regulations could increase the likelihood of adoption of certain conservation practices, all else being constant. Similar to manufacturing plants in developing countries, environmental regulation and market pressure appear to exert more influence than community pressure on the adoption of environmentally sound technology (Luken and Rompaey 2008).

Farmers' perceptions, awareness, and attitudes are also potential determinants of environmentally sound management options. For example, farmers' awareness of their exposure level to an environmental problem, soil erosion, for example, combined with attitude toward soil conservation practice and other variables, determines their level of soil conservation (Vignola et al. 2010; Waters et al. 2010). Awareness of the negative effect of chemicals on health and the environment also increased the probability of a farmer adopting the low-external-input and sustainable agriculture (LEISA) technology (Filho et al. 1999). Related to this, a sound understanding of farmers' motivations and risk attitudes is required to tailor public investments to provide relevant improvements in the environmental performance of agriculture (Greiner et al. 2009).

Given the above-mentioned literature, this study specifically analyzes the determinants for the adoption of rice straw management alternatives, considering socio-economic, policy, and perception and attitude-related variables.

3.0 METHODOLOGY

3.1 Data and Information Sources

We used five-year (2006-2010) average data on area harvested, yield, and production from the Bureau of Agricultural Statistics. Farmers' management practices, on the other hand, were derived from the PhilRice Socioeconomics Division's Rice-Based Farm Household Survey (RBFHS) conducted in 33 provinces nation-wide covering the 2006 wet and 2007 dry crop seasons and this study's own household survey. This information was used to estimate the percentage of farmers who practice rice straw burning, rice straw incorporation, and rice straw composting. While the 2007 Dry Season (DS) results were clear, we assumed for the 2006 Wet Season (WS) that those who did not practice rice straw composting and soil incorporation practiced rice straw burning. We supplemented the information from the RBFHS with primary data and information from:

- *Focus Group Discussions (FGD).* Two FGDs were conducted in each of the four study provinces, covering farmers and farmer-leaders in irrigated and rainfed rice ecosystems. The purpose was to have thorough discussions on the perceived environmental impacts of rice straw burning, and the existing and potential policy and institutional options to reduce the negative impacts and promote the positive impacts. The existing rice straw management practices of farmers in the area were elicited and were used as basis in finalizing the household survey questionnaire. Appendix 1 presents the guide questions used for the FGDs.

- *Key informant surveys and technical expert consultations.* Interviews were also conducted with 142 key informants from local government units and 3 technical experts from PhilRice. Results of the interviews were used along with information from literature as input to the economic analyses.

- *Household survey*. Household surveys were conducted in four major rice-producing provinces, namely: (1) Nueva Ecija – top producer; (2) Leyte – to represent the Visayas and a province with an existing provincial ordinance banning rice straw burning; (3) North Cotabato – largest rice producer in Mindanao; and (4) Ilocos Norte – to represent province where there is an existing rice straw market. The questionnaire included WS and DS information on detailed rice stubble and straw management practices such as proportion and timing of rice straw burning, timing of incorporation of rice stubble, rice straw composting practices, and rice straw-based nutrient management (if any). In addition, perceptions of rice-based farming households on the environmental impacts of rice straw burning, and other rice straw management practices were elicited. Appendix 2 shows the household survey questionnaire used.

The multi-stage stratified area probability sample design was used in the household survey. The primary sampling unit (PSU) was the *barangay* (village) with the ecosystem (irrigated/rainfed) as a stratification variable. Random sample selection of farming households was carried out within the sample barangay. Ten *barangay*s were randomly sampled from the entire population of rice-producing *barangay*s in each province. The number of irrigated and rainfed *barangay*s was prorated depending on secondary data

of rice area harvested in the province. Ten farming households were randomly sampled in each sample barangay for a total of 100 household samples per province.

3.2 Data Analyses

3.2.1 GHG emission inventory and analysis

To estimate the GHG emissions from rice straw open burning and other straw management practices, we used methodologies and guidelines set by the Inter-governmental Panel on Climate Change (IPCC) Guidelines (2006). Thus, while CO_2 emission is affected by straw management practice, we did not include CO_2 emissions from biomass burning since the carbon released during the combustion process is assumed to be reabsorbed by the vegetation during the next growing season (IPCC 2006).

For rice straw burning, we used the approach and emission factors congregated by Gadde (2009) modified for the season and rice ecosystem difference in the step of quantifying the amount and distribution of rice straw subject to open-field burning. The following equation was used to determine the quantity of rice straw subject to open burning:

$$Q_B = \sum\sum P_{ij}\, SGR_i Q_{PBij} \qquad \text{(Equation 1)}$$

where Q_B is the quantity of rice straw subject to open-field burning (Gg/yr)[3]; P_{ij} is the rough rice production (Gg/yr) in season *i* and rice ecosystem *j*; SGR_i is the straw to grain ratio in season *i*; and Q_{PBij} is the proportion of rice straw subject to open-field burning in season *i* and rice ecosystem *j* (Gg/yr).

Since in the Philippines the management of rice stubbles usually differs from rice straw, we differentiated the straw-grain ratio from the stubble-grain ratio. Based on total biomass and grain yield data from an average of four WS and five DS experimental data in the Philippines by Corton et al. (2000) and stubble to straw ratio derived from special sampling at PhilRice by one of the co-authors, we derived and used straw-grain ratio of 0.74 and 0.36, and stubble-grain ratio of 1.21 and 0.59 for WS and DS, respectively.

Equation 2 was then used to calculate GHG emissions from rice straw burning.

$$E_a = (Q_B)(f_{Co})(EF_a) \qquad \text{(Equation 2)}$$

where E_a = Emission of a in tons/yr; EF_a = emission factor of a in g/kg of dry straw; f_{Co} = combustion factor; and a = GHG species.

For incorporation in soil of rice straw and rice straw compost, we used the IPCC guidelines for rice cultivation and emission from managed agricultural soils where we adjusted the conversion factors considering organic amendments. We compared this with results using GHG emission changes from experiments conducted in the Philippines by Corton et al (2000) and considered the more conservative estimate. Table 1 shows the summary of emission factors, and other parameters used and corresponding references.

In the analysis of GHG emissions, the study focused on estimating the incremental change in the GHG emissions from paddy areas as a result of rice straw management alternatives, not the GHG emissions from paddy rice systems per se. For the annual current year estimate, the major rice straw management methods were focused on, namely: (1) burning; (2) incorporation of fresh stubble and straw in soil; (3) removal of straw and return to field as compost; and (4) removal from the field for use as animal feeds or substrate in mushroom production.

To answer researcher question 3, analysis focused on specific stubble and straw management practice options (see Table 2) doable by rice-based farm households. These various alternatives were analyzed on a per hectare basis considering the potential effects on GHG emission over a five-year period. The base case scenario is the current major practice where rice stubble is incorporated into the soil during

[3] Gg/year = 1,000 tons/year

the first land preparation activity in a flooded condition, and rice straw is burned at the threshing site. Based on the household survey, the average duration from the start of land preparation to crop establishment is 21 days so that the baseline case assumes that stubble is incorporated less than 30 days before cultivation.

While power generation and biofuel production are potential uses of removed rice straw from the field, a full-scale analysis is beyond the scope of this study. We include here only the potential impact on GHG emissions in the paddy sector if stubble and straw are removed from the field.

Table 1. GHG emission factors for different rice straw management practices

Rice straw/ stubble management practice	Name of pollutant	EF	Unit	Reference
Open burning	CH_4	1.2	$g/kg_{dryfuel}$	Based on EFs compiled by Gadde et al. 2009 IPCC Guidelines (2006)
	N_20	0.07	$g/kg_{dryfuel}$	
	Combustion factor	0.8		
Scattering and incorporation of rice stubble and straw in the soil (wet condition)	CH_4 (WS)	129.77	kg/ton yield	Corton et al. 2000 (Incremental CH_4 due to straw incorporation)
	CH_4 (DS)	36.99	kg/ton yield	
	Baseline EF for continuously flooded fields without organic amendments	1.3		IPCC Guidelines (2006)
	Conversion factor for rice straw amendment	1.0 for straw incorporated <30 days before cultivation; 0.29 for straw incorporated >30 days before cultivation		IPCC Guidelines (2006)
	Scaling factor to account for differences in water regime during cultivation period	0.78 for irrigated; 0.27 for rainfed		IPCC Guidelines (2006)
	Scaling factor to account for differences in water regime in the pre-season before cultivation period	1 for irrigated (<180 days); 1.22 for rainfed		IPCC Guidelines (2006)
Composting and incorporation	CH_4 (WS)	13.37	kg/ton yield	Corton et al. 2000 (Incremental CH_4 due to incorporated compost)
	CH_4 (DS)	2.1	kg/ton yield	
	Conversion factor for rice straw compost amendment	0.05		IPCC Guidelines (2006)
Rice straw used as animal feed	CH_4	10,000-20,000 gCH_4/ton dw		Singhal et al. 2005 as cited by Truc 2011
Rice straw for mushroom production	CH_4	72.7 gCH_4/ton dw		Truc 2011

Table 2. Rice straw management options evaluated for emission and economic analysis

	Rice Straw Management Options	Stubble	Straw	Timing of incorporation
M1	Late stubble incorporation and straw burning (BASELINE)	Incorporated	Burned	<30 days before cultivation
M2	Late stubble and straw incorporation	Incorporated	Scattered and incorporated	<30 days before cultivation
M3	Late stubble incorporation and straw removal for animal feed	Incorporated	Removed from field for animal feed	<30 days before cultivation
M4	Early stubble and straw incorporation	Incorporated	Scattered and incorporated	>30 days before cultivation
M5	Late stubble incorporation and straw compost incorporation	Incorporated	Rapidly composted and incorporated as compost	<30 days before cultivation
M6	Early stubble incorporation and straw compost incorporation	Incorporated	Rapidly composted and incorporated as compost	>30 days before cultivation
M7	Stubble and straw composting and straw compost incorporation	Removed from field, composted with the straw, and incorporated	Rapidly composted and incorporated as compost	>30 days before cultivation

3.2.2 Cost-effectiveness analysis (CEA)

To answer research objective 4, the CEA was employed to compare the selected rice straw management alternatives. The following steps were followed in the CEA:

1. Based on incremental GHG emission analysis, the net reduction in total CO_2-eq emission if farmers switch from the baseline scenario to each management option or the CO_2 eq abatement capacity for each alternative was determined. In order to have a single unit of effect, the estimated emissions of each kind of GHG from paddy rice systems under each rice straw management *j* were multiplied with their respective Global Warming Potential (GWP) to get the total GWP, that is,

$$\text{Total GWP}_j = \sum (\text{GHG}_{ij} \times \text{GWP}_{ij}),\ i = 1, 2, 3,... \qquad \text{(Equation 3)}$$

   where *i* is the kind of GHG such as CH_4 or N_20; and GWP is an internationally accepted scale of equivalence for other GHGs in units of tons of CO_2-eq (Lv et al., 2010). The GWP values used were: CO_2=1, CH_4 =23 and N_20=296 (IPCC, 2006) measured in metric ton CO_2-eq per year per hectare.

2. The cost of each rice straw management option expected to result in changes in GHG emission was estimated. It included the incremental operating and maintenance cost for the farmer implementing the management option as well as the secondary benefits due to changes in straw management practice. A five-year period was considered in the cost analysis of the options. The shadow wage rate used was 60% of the market wage rate as suggested by Philippine NEDA (2004).

3. The cost-effectiveness or abatement cost per ton of CO_2-eq was calculated and compared for each rice straw management alternative. The following generic formula for abatement cost calculation similar to that cited in Davidson and van Essen (2009) was used:

$$\text{Cost-effectiveness} = \frac{I^{an} + \Delta_{O\&M} \text{ - secondary benefits}}{\text{Annual reduction in } CO_2 \text{ equivalent emissions}} \qquad \text{(Equation 4)}$$

where I^{an} is the annuity of the investment cost (if applicable) and $\Delta_{O\&M}$ is the additional annual operating and maintenance cost. The formula also includes monetized secondary benefits (e.g. value of the composted rice straw) to be subtracted from the costs. The most cost-effective option is that with the lowest cost per reduction in tons CO_2-eq (Php/tons CO_2-eq). In this study, we calculated the costs for a five-year scenario to account for some effects expected at around five years. We used a 7.5% real discount rate based on the discount rate suggested by Philippine National Economic Development Authority (NEDA 2004) adjusted for inflation using the average from 2000 to 2010. The CEA was conducted from the farmers' perspective, without any assumed external social costs (or benefits).

3.2.3 Analysis of farmers' choices of rice straw management options

Finally, to answer research question 5, the factors significantly influencing farmers' choice of rice straw management practices was analyzed using data from the RBFH survey of PhilRice and the data from the supplementary household survey. The model for this study was a case of unordered-choice model which can be motivated by a random utility model (i.e. the observed choice between two choices reveals which one provides the greater utility, but not the unobservable utilities) (Greene 2003). In this case, it is assumed that the decision of a farmer of whether to burn rice straw, incorporate it into the soil, or practice rice straw composting, depends on the expected utility he perceives he can obtain from the rice straw management option. For the i^{th} respondent faced with j options, it is assumed that his utility of choice j is of the Equation 5 form.

$$U_{ij} = V_{ij} + e_{ij,} \qquad \text{(Equation 5)}$$

where V_{ij} is the deterministic or observable component of utility; and e_{ij} is the error component or the unobservable components influencing the choice. The choice option j of the respondent implies that the utility he gets from choosing option j (U_{ij}) is higher than the utility of other rice straw management options (U_{ik}). The probability that a respondent i will choose the option j from the set of J choices is Equation 6.

$$\text{Prob } (j) = \text{Prob } (V_j + e_j > V_k + e_k) \text{ for all other } k \text{ in j choice set; } k \neq j \qquad \text{(Equation 6)}$$

For this study, the observable component of utility (V_j) will be specified as a function of selected socio-economic factors, season and farm-related factors, policy-related and perception-related variables (Table 3). The general multinomial logit model was used in this study where the probability of choice j can be expressed as follows:

$$P(j) = \frac{\exp(\mu V_j)}{\sum_k \exp(\mu V_k)} \qquad \text{(Equation 7)}$$

Table 3. Hypothesized factors that determine farmers' choices of rice straw management options

Factors	Description
Policy-related	· Presence or absence of provincial ordinance banning rice straw burning · Presence or absence of provincial solid waste management program · Awareness of Solid Waste Management Act requiring proper disposal of all solid waste including agricultural biomass · Awareness of the Clean Air Act requiring the control of air pollution · Awareness of the Organic Farming Act, a measure seeking the development and promotion of organic farming
Perception-related	· Perception of global warming impact of open-field burning · Perception of air pollution impact of rice straw burning · Attitude towards environmental laws/regulations · Attitude towards potential incentive systems
Socio-economic and farm-related	· Age · Educational attainment · Number of family members working on the farm · Estimated income from rice farming and non-rice farming · Farming experience · Membership in organizations · Attendance in rice-related seminars or training · Rice ecosystem type · Season

4.0 GHG EMISSIONS INVENTORY ASSOCIATED WITH RICE STRAW MANAGEMENT PRACTICES IN THE PHILIPPINES

4.1 Rice Areas Harvested, Production, and Yields in the Philippines

Information on the rice area harvested and yield defines the extent of the source of GHG emissions associated with rice production and rice straw management, and the average volume of rice straw production in the country. On average from 2006 to 2010, the Philippines harvested around 16 M tons of rice each year from its 4.4 M ha total rice area harvested (Appendix Table 1). Most of the country's production (57%) came from the WS harvest (Appendix Table 2). Irrigated areas contributed 75% of the total production. The average yields in irrigated and rainfed rice ecosystems were 4.1 and 2.9 tons/ha, respectively.

Across major geographical divisions, Luzon provides the bulk of the country's rice production. In 2010, it accounted for about 57% of the total production equivalent (around 9 million tons). The shares of Visayas and Mindanao were 24% and 19% during the same period. The country's major rice-producing regions are Central Luzon, Western Visayas, Cagayan Valley, Ilocos, and Soccsksargen. On average from 2006 to 2010, these regions collectively contributed 60% to the total production.

4.2 Rice Straw Production by Season and Ecosystem

Most paddy rice in the Philippines are still harvested manually and farmers generally harvest or cut only the panicle portion of the rice crop leaving around two-thirds rice stubble on the ground. Using straw-grain ratio of 0.74 and 0.36 for wet and dry seasons, respectively, Table 4 shows that the total available rice straw (not including the rice stubble) is around 9 M tons per year based on the average rice production in the last five years. Most of the rice straw is produced in Central Luzon, Western Visayas, Cagayan Valley, and Ilocos regions where more than one million tons of straw are available each year from all rice ecosystems. In both ecosystems, rice straw is more available from the July to December harvest period.

Table 4. Average rice straw production (in '000 tons), by season, ecosystem, and region (2006-2010)

Region	All ecosystems			Irrigated			Rainfed		
	Jan-June	Jul-Dec	Total	Jan-June	Jul-Dec	Total	Jan-June	Jul-Dec	Total
CAR	66	186	252	64	136	200	2	50	52
Ilocos Region (I)	116	923	1,039	116	544	660	0	378	379
Cagayan Valley (II)	410	629	1,039	364	583	947	46	46	92
Central Luzon (III)	479	1,157	1,636	478	946	1,424	1	210	212
CALABARZON (IVA)	72	143	214	62	107	169	10	36	45
MIMAROPA (IVB)	119	403	522	87	238	325	32	165	197
Bicol Region (V)	177	380	557	137	265	402	41	114	155
Central Visayas (VI)	45	109	154	29	69	98	16	40	56
Western Visayas (VII)	238	1,010	1,247	155	551	706	83	458	541
Eastern Visayas (VIII)	187	320	507	116	190	306	71	130	201
Zamboanga Peninsula (IX)	72	258	330	57	155	213	15	103	118
Northern Mindanao (X)	86	223	309	83	198	280	3	25	28
Davao Region (XI)	76	164	240	68	149	217	7	15	22
SOCCSKSARGEN (XII)	170	540	710	149	427	576	21	113	134
Caraga (XIII)	85	144	229	55	111	166	30	33	63
ARMM	113	226	339	44	87	131	69	139	208
PHILIPPINES	**2,510**	**6,814**	**9,324**	**2,062**	**4,759**	**6,821**	**448**	**2,055**	**2,503**

4.3 Proportion of Rice Straw Subject to Open-Field Burning and Other Practices

Based on our FGDs and household surveys in four major rice-producing provinces in the country, more than 90% of rice stubble is incorporated into the soil during land preparation. The rest are burned along with rice straw piles in the threshing sites, left for grazing or cut for other purposes such as to give way to the planting of non-rice crops or to be used as mulch.

For the current uses of rice straw output from threshing, while burning seems to be the dominant rice straw disposal method at the national level (Table 5), it is not the major practice in some locations based on a 2007 PhilRice survey. Appendix Tables 3a and 3b present the uses by season, ecosystems, and region. In four regions, for example, less than 30% of the respondents reported burning their rice straw during the DS. For the WS, around 70% of respondents were neither practicing composting nor incorporating straw into the soil and are assumed to be burning or leaving the piles of rice straw in the threshing area. Since based on our FGDs, there is a short turnaround period between the end of the WS to the start of the DS, it is possible that most farmers burn their rice straw to get rid of the straw before the start of the land preparation stage.

Although covering only four provinces, our more recent FGDs and household survey covering 2010 wet and dry seasons confirmed that while around 65% of farmers in Nueva Ecija, the largest rice-producing province in the country, burn their rice straw, less than 25% practice straw burning in Ilocos Norte in Northern Luzon, North Cotabato in Mindanao, and Leyte in the Visayas region. Based on the average of the four survey provinces, around 30% burn their rice straw while many of the rest either scatter it in the fields and incorporate in the soil during land preparation, or just leave it in the threshing area for incorporation in the next cropping season. Other uses mentioned are for mulching non-rice crops and for use as animal feed. Since the RBFH survey sampling was deemed more representative, we used the proportion owing to rice straw management from that survey in the national GHG emission inventory.

Table 5. Percentage distribution of farmers by rice straw management practice (2006-07)

Rice straw management practice	Irrigated		Rainfed	
	Jan-June	Jul-Dec	Jan-June	Jul-Dec
Burning	57.5	71*	42.0	66*
Incorporation into soil	29.7	27**	40.2	32**
Composting	8.4	-	13.6	-
Animal feed	4.0	2	2.8	2
Mulching	0.2	-	1.0	-
Mushroom production	0.1	-	0.0	-
For sale/give-away	0.2	-	0.3	-

Source: PhilRice-SED Rice-based farm household survey (RBFHS) 2006-07
Note: * assumed if not practicing composting; **composting/incorporation in soil

4.4 Estimated Annual GHG Emissions in the Philippines based on Farmers' Straw Management Practices

Table 6 shows that the estimated total incremental GHG emissions due to rice straw and rice stubble management in paddy production areas are around 16 M tons CO_2-eq not considering CO_2 emissions. When compared to the 1994 national GHG inventory from agriculture based on the first initial national communication on climate change (Climate Change Commission 1999), this is more than 40%, which is not trivial. This is also approximately 8% of the 195 M tons projected total national equivalent CO_2 emissions for 2008 based on the same document.

Table 6. Estimated incremental GHG emissions in the Philippines due to rice straw and stubble management practices (tons CO_2-eq/year)

Rice straw management option	CH_4	N_2O	GWP (Ton CO_2 equivalent)	% Contribution
Burning of straw	5264	307	211,977	1.31
Soil incorporation				
Stubble	572,829	502	13,323,723	82.14
Straw	112,003	95	2,604,278	16.05
Removal of straw from field				
Returned to field as compost	221	4	6,280	0.04
For animal feed/mulch	3261	0.1	75,000	0.46
Total emissions	**693,578**	**909**	**16,221,259**	**100.0**

Note: Appendix Tables 4 to 7 show details of emission by season and ecosystem.

The incorporation of rice stubble and straw appears to be the straw management practice contributing the most to GHG emissions, followed by open-field burning. The common practice of farmers is to incorporate stubble and sometimes straw during the first plowing and this is normally done in wet conditions. From the perspective of minimizing GHG emissions from rice farming, this is the worst option in terms of CH_4 emissions especially where the soil is flooded continuously for the months following the incorporation (Bijay-Singh et al. 2008). It is important to note, however, that open-field burning not only emits GHG but also carbon monoxide and other air pollutants such as particulate matters, hydrocarbons, dioxins, and furans that are known to impact health and can adversely affect growing populations (Gadde et al. 2009; Moss et al. 1993).

5.0 COST-EFFECTIVENESS ANALYSIS OF SELECTED RICE STRAW MANAGEMENT OPTIONS

5.1 GHG Emissions Abatement Capacity of Selected Rice Straw Management Options

Table 7 shows the estimated potential GHG emissions and global warming potential (tons CO_2-eq) by rice straw management option for farmers calculated per hectare for a five-year period based on IPCC 2006 Guidelines, compiled factors from literature and various assumptions. For the baseline scenario, the total estimated emissions considering only CH_4 and N_2O emissions totalled around 51 tons CO2e per hectare over a five-year period.

Table 7. Estimated incremental GHG emissions (ton CO_2-eq ha^{-1}) from rice fields for different rice straw management options

No.	Rice straw management option	Greenhouse gas emission (tons ha^{-1} yr^{-1})						5-year total (tons CO_2-eq)	% change from baseline
		Years 1 to 4			Year 5				
		CH4	N2O	Total GWP	CH4	N2O	Total GWP		
M1	Late stubble incorporation and straw burning (BASELINE)	7.60	0.16	7.77	7.60	12.32	19.92	50.99	
M2	Late stubble and straw incorporation	12.55	0.08	12.63	12.55	-12.07	0.48	51.01	-0.05
M3	Late stubble incorporation and straw removal for animal feed	9.02	0.07	9.10	9.02	12.23	21.25	57.63	-13.03
M4	Early stubble and straw incorporation	4.45	0.08	4.53	4.45	-12.07	-7.62	10.51	79.38
M5	Late stubble incorporation and straw compost incorporation	7.61	0.48	8.09	7.61	-11.67	-4.06	28.28	44.53
M6	Early stubble incorporation and straw compost incorporation	2.83	0.48	3.31	2.83	-11.67	-8.84	4.39	91.39
M7	Stubble and straw composting and compost incorporation	0.34	1.10	1.44	0.34	-11.01	-10.67	-4.91	109.64

Note: Details of calculation are presented in Appendix 3.

Results indicate that shifting from rice straw burning to rice straw incorporation will not necessarily reduce global warming potential if straw is incorporated less than 30 days before cultivation especially in a flooded condition after incorporation (M1 to M2). This is due to the higher CH_4 emission calculated. In the longer term, however, increase in CH_4 emission due to straw incorporation can also be offset by the reduction in N_2O emission from potential reduction in the use of chemical fertilizers (Bird et al., 2002). At the same time, while there is less CH_4 emission in straw burning, the loss of nutrients from the straw might eventually lead to increased use of chemical fertilizers that can significantly increase N_2O emission. Although not considered in the GHG accounting here, Wang et al. (2011) also reported significant interactive effects of straw with nitrogen on N_2O emissions, i.e. straw amendment significantly reduced, on average, N_2O emissions from rice fields when they received nitrogen fertilizer.

Merely shifting from burning rice straw (M1) or changing the timing of the stubble and straw incorporation from less to more than 30 days before cultivation (M2 to M4) can reduce the incremental GHG emissions due to straw management by around 80% largely because of its effect on CH_4 emission, assuming other factors are constant. A significant reduction of more than 90% in total incremental GHG emissions is

also expected if the rice stubble is incorporated more than 30 days after cultivation and the rice straw is removed from the soil and returned as rice straw compost. This is even more significant when the rice stubble is completely removed and returned as rice straw compost. Corton et al. (2000) reported from their experiments in the Philippines that addition of rice straw compost increased CH_4 by only 23-30% as compared with the 162-250% increase in emissions with the use of fresh rice straw.

When both stubble and straw are completely removed from the field and used for non-farm uses such as power generation or bioethanol production, GHG emissions from paddy rice systems can also be potentially reduced. While the study cannot afford to conduct a life cycle assessment of GHG emissions from using rice straw for power generation and bioethanol production, we present here reviewed literature on the issue. Delivand et al. (2011) taking the case of Thailand indicate that the life cycle GHG emissions of the straw combustion process chain is 30 kg CO_2-eq per ton dry straw or 0.043 kg CO2-eq/kWh, i.e. 0.613 kWh net electricity per kg straw. This considers both the logistics and grate boiler combustion. Using this as a factor and considering a scenario where the stubble is incorporated into the soil more than 30 days before cultivation, the approximate net GHG emission is estimated at 1,263 tons per year per hectare.

They also found that substituting the natural gas or coal fuels with rice straw fuels for power generation would result in a considerable fossil fuel savings and a lower GHG emission. For example, for the case of substituting natural gas with rice straw-fuel, it is estimated that 0.368 ton CO_2-eq will be avoided, while for imported coal, 0.683 ton CO_2-eq can be avoided (Delivand et al. 2011). Using rice straw as raw material for power generation will thus avoid emissions of GHG and other air pollutant particulates when compared with open straw burning and methane emissions when compared with incorporation.

Regarding the use of rice straw for bioethanol production, a review by Cheng and Timilsina (2011) reported that all advanced biofuel technologies have the advantage of producing fuels with almost zero or very little net carbon dioxide emissions to the atmosphere. The same authors stated that the advantage of lignocellulosic materials such as agricultural residues is that these are abundant in most land areas and their generation does not have to compete for arable land against food and feed production. Using 0.28 L kg^{-1} as ethanol yield (Kim and Dale 2004), the approximate ethanol production per hectare is calculated at around 1,250 liters per season. Assuming a 0.5 kg CO_2-eq reduction per liter ethanol[4], the estimated net emission reduction is 625 kg per hectare.

5.2 Cost Estimates for the Rice Stubble and Straw Management Options

The farmer-doable options included in the analysis entail changes in cost per season per hectare or annual production cost incurred for implementing rice straw management. Costs were based on the incremental differences between the baseline practice of incorporating stubbles during land preparation and burning straw, and other stubble-straw management options. Some of the relevant cost savings and secondary benefits are expected to be incurred or realized after around five years of continuous practice based on literature so for simplicity, we calculated the total cost per hectare for a five-year period as shown in Table 8.

For most of the options, the rice stubble and straw will be incorporated into the soil but will vary in form and timing; the costs analysis largely revolves around change in labor costs and some material costs in the case of composting. The expected changes in labor-use associated with the management option and prevailing wage rate at Php200 per man-day were based on results of the FGDs and household survey conducted. In the economic analysis, we used 60% of the market wage rate as the shadow wage rate.

Removal of stubble and straw from the field requires significant labor cost so that at current prices and based on existing practices, composting of both the straw and stubble entail the highest cost followed by the options where the straw will be composted and incorporated into the soil as compost (Table 8). Based on our household survey, manual cutting of rice stubble will take 20 to 21 man-days per hectare depending on the season. Collecting and gathering of the cut rice stubble were estimated to take another 7 to 10 man-days. For collecting and gathering piled rice straw and hauling it onto the roadside ("road-siding"), farmers estimate this to take about 12 man-days per hectare during DS and 14 man-days during WS. Considering these farmers' practices, we considered in this study, rapid composting where rice straw is composted in a

[4] http://www.autoevolution.com/news/emissions-gasoline-vs-diesel-vs-bioethanol-3657.html

designated area on farmers' fields using inoculants such as manure, effective organism activated solution (EMAS) or *Trichoderma spp*. An alternative common to developed countries and some Southeast Asian countries is the use of combine-harvester and baling machines, but these are capital-intensive and their use is still relatively unpopular.

Table 8. Estimated costs for each rice straw management option (Php ha^{-1} $year^{-1}$)

	Rice straw management option	Years 1 to 4			Year 5		
		WS	DS	Total	WS	DS	Total
M1	Late stubble incorporation and straw burning (BASELINE)	156	156	312	1,615	1,615	3,230
M2	Late stubble and straw incorporation	552	552	1,104	552	552	1,104
M3	Late stubble incorporation and straw removal for use as animal feed	876	756	1,632	2,335	2,215	4,550
M4	Early stubble and straw incorporation	552	552	1,104	552	552	1,104
M5	Late stubble incorporation and straw compost incorporation	3,134	1,729	4,863	3,134	1,729	4,863
M6	Early stubble incorporation and straw compost incorporation	3,134	1,729	4,863	3,134	1,729	4,863
M7	Stubble and straw composting and straw compost incorporation	10,654	7,188	17,842	10,654	7,188	17,842

Note: Details of calculation are presented in Appendix 4.

5.3 Cost-Effectiveness Analysis of Selected Rice Straw Management Options

Based on the estimates of GHG emission and potential abatement of GHG emission on farmers' fields from Table 7 and the estimated cost for each management option in Table 8, Table 9 presents abatement costs per ton CO_2-eq. From among the options that result in net reduction in incremental CO_2-eq, shifting from the current farmers' practice of late stubble incorporation or incorporating less than 30 days before cultivation and straw burning (M1) to early incorporation of both stubble and straw incorporation in soil more than 30 days before cultivation (M4) appears to be the most cost-effective with a negative abatement cost (net benefit) at Php21 or around US$0.50 per ton of CO_2-eq reduction. Results also suggest that incorporating the stubble more than one month before cultivation, and rapidly composting the straw and applying it back to the field (M6) is also a cost-effective option for farmers at around Php300/ton CO_2-eq. It significantly mitigates GHG emissions while improving the soil condition thus even with the additional labor cost of piling and composting, it is the next most cost-effective abatement option.

Incorporating both the stubble and straw less than 30 days before cultivation (M2), on the other hand, results in a slight net increase in emission and the increase in cost for the option is higher than the secondary benefit of savings from fertilizer given the time horizon. The amount of potential savings if a ton of CO_2-eq is not emitted is very significant. Incorporating stubble and removing straw for use as animal feed (M3) will also result in a net increase in emissions but the straw value as animal feed is very significant assuming rice straw can be sold at Php5/bundle of 5 kg. Stubble and straw removal and application as compost significantly reduce emissions, but the abatement cost is more than Php1000 per ton of CO_2-eq.

It was beyond the scope of this study to conduct a full-scale economic feasibility of using rice straw for power generation and biofuel production which are potential uses of rice straw. However, based on reviewed literature, second generation lingo-cellulosic technologies have considerably more potential for avoiding many of the GHG emission and other environmental shortfalls and perform better in terms of energy efficiency (CGIAR Science Council 2008). The same report, however, stated that cost-effective second generation biofuels are still at least 10 years down the road and bio-refineries and bio-based economies are even further afield. Gadde et al. (2009) studied the overall potential and limitations of energy contribution and greenhouse gas mitigation for rice straw as a renewable energy source in India, Thailand and the

Philippines. They found that the energy potential from rice straw in theory was different from the realizable energy due to the fact that residue collection efficiency or capacity and its transportation were challenging. Delivand et al.'s (2011) study on the feasibility of using rice straw residues for power generation in Thailand concluded that straw-based combustion facilities are financially feasible and profitable if the capacity of the power plant is 8 MWe or greater. In order to ensure secure fuel supply, they report that smaller scale power plants, i.e., 8 and 10 MWe, are more practicable.

On the part of Filipino rice farmers, if the demand for rice straw is created through its use as raw material for power or bioethanol production plants, they may be able to supply the straw with a direct cost of around Php 5,200/ha for two seasons or Php 1.20/kg of straw considering the labor cost of gathering and moving to a storage area. Removing even the stubble, on the other hand, will cost an additional Php 8,000/ha so that the rice straw cost will more than double at approximately Php 3/kg loose straw.

Table 9. Estimated abatement costs (Php/ton CO_2-eq) by rice straw management option

No.	Rice straw management option	Total Emission (tons CO_2-eq)	Abatement relative to baseline (tons CO_2-eq /ha)	Incremental abatement cost (Php/ha)	Secondary benefit (Php/ha)	Abatement cost* (Php/ton CO_2-eq)	Abatement cost** (US$/ton CO_2-eq)
M1	Late stubble incorporation and straw burning (BASELINE)	50.99					
M2	Late stubble and straw incorporation	51.01	-0.02	1,172	2,033		
M3	Late stubble incorporation and straw removal for use as animal feed	57.63	-6.64	5,341	18,122		
M4	Early stubble and straw incorporation	10.51	40.48	1,172	2,033	-21	-0.50
M5	Late stubble incorporation and straw compost incorporation	28.28	22.71	16,380	2,033	632	14.87
M6	Early stubble incorporation and straw compost incorporation	4.39	46.60	16,380	2,033	308	7.25
M7	Stubble and straw composting and straw compost incorporation	-4.91	55.90	68,892	2,033	1,196	28.14

Note: Details of calculation are presented in Appendix Tables 8 to 12.
* Values for M2 and M3 were not included since there is no net abatement.
**1US$ = 42.50Php - average for 2011 (Source: www.nscb.gov.ph)

6.0 FACTORS EXPLAINING FARMERS' CHOICES OF RICE STRAW MANAGEMENT OPTIONS

The previous analysis attempted to explore the potential of selected rice stubble and straw management practices that can be practiced by rice farmers in order to reduce the incremental non-CO_2 GHG emissions and estimated the costs associated with it. This section uses farm survey data in four major rice-producing provinces to ascertain factors explaining actual farmers' choices of straw management options. Since there are some options with no adopters, we generalized the choices to straw burning, incorporation and removal options.

6.1 Respondent and Household Characteristics

Overall, the mean age of respondents is 51 with average farming experience of 24 years. The average household size is 4.8 with 3.5 adult members and on average, two earning household members. Most are elementary school graduates although some 48% are high school graduates and above. Some 50% are members of farming organizations and almost 47% have attended a rice production-related training in the last five years. Average annual rice income is around Php 150,000/household while the average income from non-rice farming is around Php 13,000. On farm asset ownership, around 70% of the respondents are farmland owners, a quarter own cows or carabaos, and a quarter own two-wheel tractors. The average number of cows owned by a household is two.

Table 10 describes some socio-economic characteristics of farmer-respondents, by management practice. Age, average household size and educational attainment did not appear to differ among the three groups of respondents by management practice. The percentage of farmer-respondents who own cows is 26-45% among those incorporating rice straw in or removing rice straw from the field while only 10% of those who burn rice straw on the field own cows. In a similar manner, the frequency of farmers with non-farm income among those who incorporate and remove straw from the field is higher compared with those who burn.

6.2 Farm Profile and Characteristics

Most of the respondents have rice farm sizes ranging from one to three hectares and the average total area cultivated is 1.6 ha. Overall, 63% are practicing double rice cropping while some 8% are fallow during the dry season and 1% are fallow during the wet season. While rice-rice is the dominant cropping pattern in all four provinces surveyed, majority of the rice farmers in Ilocos Norte engage in rice-based farming systems such as rice-vegetables or rice-rice-vegetable with rice-onion practiced by around 20%.

Average area cultivated by those practicing removal of rice straw in both wet and dry seasons is relatively smaller compared with those who practice rice straw burning. More farmers also practice the removal of rice straw in rain-fed conditions compared with irrigated rice ecosystems. Table 11 describes other selected farm characteristics of respondents categorized by rice straw management practice.

Table 10. Selected socio-economic characteristics of farmer-respondents by rice straw management practice and season in four provinces (2010-2011 crop year)

Particulars	WET SEASON						DRY SEASON					
	Burn		Incorporate		Remove		Burn		Incorporate		Remove	
	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev
N	94		216		74		86		186		47	
Age	50.3	14.5	51.9	12.3	49.9	13.0	49.7	13.7	52.4	12.3	50.7	11.3
Average number of years in farming	23.6	15.6	24.4	13.4	24.8	13.4	22.6	14.4	24.9	13.4	25.1	14.3
Average household size	4.6	1.9	4.9	2.1	4.7	1.8	4.6	2.0	5.0	2.1	4.9	1.9
Average no. of HH members aged >13 years	3.1	1.4	3.6	1.8	3.7	1.6	3.1	1.7	3.6	1.7	3.9	1.8
Average no. of earning HH members	1.5	1.1	1.7	1.0	1.7	1.1	1.5	1.0	1.7	1.1	1.8	1.2
Total farmland owned	1.2	2.0	1.2	2.2	0.5	0.7	1.2	1.9	1.2	1.9	0.5	0.7
% owning cows	10.0	10.6	45.0	20.8	26.0	35.1	8.0	9.3	30.0	16.1	24.0	51.1
No. of cows	3.0	1.7	1.9	1.4	2.2	2.3	3.8	2.1	1.6	0.8	3.0	2.4
Mean annual household income ('000 Php)	259	248	224	217	201	176	280	285	225	219	235	156
Mean per capita annual income ('000 Php)	67	72	54	62	50	50	74	83	54	61	57	52
% Non-farming Income	17.4	23.4	23.5	24.3	28.1	29.3	18.5	23.5	22.3	24.4	24.0	23.0
	No.	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**
Gender												
Male	72	76.6	158	73.1	67	90.5	63	73.3	132	71.0	41	87.2
Female	22	23.4	58	26.9	7	9.5	23	26.7	54	29.0	6	12.8
Educational Attainment												
Elementary undergraduate	17	18.1	25	11.6	8	10.8	14	16.3	26	14.0	3	6.4
Elementary graduate	26	27.7	57	26.4	12	16.2	21	24.4	52	28.0	11	23.4
High School Undergraduate	9	9.6	29	13.4	17	23.0	6	7.0	24	12.9	11	23.4
High School Graduate	16	17.0	39	18.1	22	29.7	15	17.4	33	17.7	12	25.5
College Undergraduate	13	13.8	32	14.8	7	9.5	13	15.1	25	13.4	5	10.6
College Graduate	11	11.7	33	15.3	8	10.8	15	17.4	25	13.4	5	10.6
No Response	2	2.1	1	0.5			2	2.3	1	0.5		
Have relatives abroad providing regular support												
Yes	16	17.0	34	15.7	22	29.7	14	16.3	27	14.5	9	19.1
No	78	83.0	182	84.3	52	70.3	72	83.7	159	85.5	38	80.9
Membership in organizations												
Yes	35	37.2	126	58.3	33	44.6	37	43.0	111	59.7	21	44.7
No	59	62.8	90	41.7	41	55.4	49	57.0	75	40.3	26	55.3
Attendance in trainings on rice production in the last 5 years												
Yes	35	37.2	126	58.3	24	32.4	33	38.4	114	61.3	20	42.6
No	59	62.8	90	41.7	50	67.6	53	61.6	72	38.7	27	57.4

Table 11. Selected farm profile characteristics of farmer-respondents by rice straw management practice and season in four provinces (2010-2011 crop year)

Particulars	WET SEASON						DRY SEASON					
	Burn		Incorporate		Remove		Burn		Incorporate		Remove	
	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev
N	94		216		74		86		186		47	
Mean total area cultivated	1.90	1.97	1.69	2.14	0.97	0.72	1.88	2.06	1.71	1.84	1.21	0.75
Mean number of parcels	1.73	1.41	1.70	1.32	3.07	2.98	1.97	1.94	1.74	1.36	2.40	3.11
Mean rice farm area	1.25	1.08	1.19	1.00	0.75	0.57	1.35	1.11	1.15	1.02	0.64	0.68
Yield	4.13	1.59	3.84	1.67	4.72	1.96	5.04	2.70	3.70	2.10	4.65	2.45
Average distance of farm to nearest road (km)	0.25	0.47	0.25	0.51	0.28	0.57	0.28	0.48	0.24	0.49	0.18	0.49
Average distance of farm to house (km)	1.36	1.98	0.98	1.51	0.85	1.03	1.20	1.78	0.91	1.36	0.70	0.76
Average distance of farm to nearest market (km)	6.25	6.79	4.25	3.93	7.00	3.68	6.19	7.32	3.94	3.25	5.43	3.59
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Farm Type												
Irrigated	77	81.91	164	75.93	50	67.57	77	89.53	146	78.49	38	80.85
Rainfed	17	18.09	52	24.07	24	32.43	9	10.47	40	21.51	9	19.15
Tenurial status of farm parcels												
Non-Owner	42	44.68	101	46.76	28	37.84	37	43.02	86	46.24	24	51.06
Owner	52	55.32	115	53.24	46	62.16	49	56.98	100	53.76	23	48.94
Cropping patterns												
Rice-Fallow	4	4.26	9	4.17	16	21.62	0	0.00	2	1.08	1	2.13
Rice-Rice	87	92.55	199	92.13	24	32.43	83	96.51	178	95.70	44	93.62
Rice-Vegetable	3	3.19	8	3.70	34	45.95	3	3.49	6	3.23	2	4.26
Soil texture												
Clayey	41	43.62	85	39.35	33	44.59	49	56.98	63	33.87	20	42.55
Loamy	11	11.70	23	10.65	11	14.86	6	6.98	22	11.83	9	19.15
Sandy	27	28.72	59	27.31	18	24.32	19	22.09	53	28.49	11	23.40
Silty	5	5.32	8	3.70	2	2.70	2	2.33	11	5.91	0	0.00
Others	10	10.64	41	18.98	10	13.51	10	11.63	37	19.89	7	14.89
Source/s of irrigation												
NIA/CIS	67	71.28	143	66.20	31	41.89	66	76.74	129	69.35	32	68.09
Private	17	18.09	29	13.43	23	31.08	11	12.79	24	12.90	13	27.66
Rain/Others	10	10.64	44	20.37	20	27.03	9	10.47	33	17.74	2	4.26

Source: Household Survey in Nueva Ecija, North Cotabato, Leyte, and Ilocos Norte (2011)

6.3 Rice Stubble and Straw Management Practices

On average, the number of days from the harvesting of the last crop and the start of rotavating or first plowing is 77 days before wet seasons (June to November) and 58 days before dry (December to May) seasons. Around 90% of land preparation activity is done in wet or flooded conditions, after the onset of rain or after the first irrigation activity. The number of days from the start of rotavating or first plowing when rice stubble is incorporated to transplanting is 21 days, but can be as short as seven days. In favorable rainfed areas that allow two crops per year, as they are dependent on the availability of rainwater, WS rice stubble is incorporated while still fresh, and transplanting is sometimes done even while rice stubble is not fully decomposed. Rice stubble in rainfed areas with only one crop a year are just left in the field throughout the fallow period and the dry stubble is usually incorporated during land preparation for the subsequent cropping. Around 36% to 43% of respondents in the household survey claim that stubbles are already dry when they incorporate in soil. Some 30% claim that the stubbles are already almost decomposed. Only 2% of respondents claim to use any catalysts or inoculants to hasten stubble decomposition.

For rice straw management, considering the practices in the four surveyed provinces covering the 2009-2010 crop year, around 30% practice open-field burning, 40% scatter and incorporate the straw into soil during land preparation, and the rest either leave the straw in the threshing area to decompose or for feeding animals, or gather and stack it in one place for other purposes such as mulching for vegetable crops. Burning is generally conducted as soon as the rice straw is combustible (around from five days to two weeks from harvest during WS and two days to a week after harvest during DS since most harvest when the grain is ripe, hence the straw is semi-dry and combustible). It is usually done in late morning or early afternoon during WS and early or late afternoon during DS. Farmers usually do not scatter but instead burn the rice straw piles. The number of piles per hectare depends on the paddy size, production and location. Farmers in irrigated areas in Nueva Ecija, for example, have eight to ten piles of rice straw per hectare measuring an average diameter of five meters per pile. On the other hand, usually in Leyte and North Cotabato, there is only one pile per hectare with a wider diameter or area covered with rice straw. In rainfed areas in Nueva Ecija, on the other hand, the number of piles is generally less at two to five partly because of lower yield and in some areas, for easier hauling. Overall, the number of piles on average is six per hectare. These practices have implications on the assembly and transportation costs of rice straw when considering alternative uses.

Farmers who practiced straw incorporation claimed that they scattered the straw 15 to 18 days after harvesting, and incorporated the straw 23 to 27 days before transplanting. Most of the farmers reported that the rice straw was already dry when incorporated into the soil although during WS, some 35% of the respondents reported incorporating fresh or semi-dry rice straw. Only around half of respondents said they made sure that the rice straw was fully decomposed before transplanting.

Farmers who collected and stacked straw reported that the average length of stacking was six months although it could be stacked for as long as 11 months before decomposing. In Ilocos Norte and Nueva Ecija, where rice straw is used as mulch for onions, for example, around 10 tons of rice straw is required for a hectare of onion farm.

6.4 Perceptions, Awareness, and Attitudes towards Rice Straw Management and Environmental Consequences

Around 90% of the respondents believed in the expected benefits of incorporating rice straw in the soil such as its effect on soil conditions and fertility, and yield in general. On the other hand, only around 20% believed in some of the perceived negative consequences of incorporating rice straw into the soil. In terms of awareness of environmental issues related to rice farming, while more than 80% of the respondents were aware of the impact of open-field burning on air pollution and ozone layer destruction, only around 30% of them were aware of the methane gas emissions in rice farming and as a result of the incorporation of rice straw. On awareness of environmental regulations, majority agreed that they were aware of the Solid Waste Management and Clean Air Acts of the Philippines although less than 30% strongly agreed. Majority were also aware of the provincial or municipal ordinances against open-field burning of solid waste.

Table 12 presents the perceptions of farmers categorized by rice straw management practice. The mean Likert scale for the perception statements related to positive effects of incorporation appear to be higher for the groups of respondents who incorporate straw in soil or remove straw from the field during the

WS. It also appears that the group who incorporates straw in soil are more aware of the environmental issues in rice farming, environmental regulations and ordinances, and even the responsibility for environmental problems, as suggested by their relatively higher mean scale or higher scale of agreement in most of the statements.

Table 12. Perceptions, awareness, and attitudes of farmers regarding rice straw management and environmental issues and policies

STATEMENTS	WET SEASON			DRY SEASON		
	Burn	Incorporate	Remove	Burn	Incorporate	Remove
Expected changes owing to incorporation of rice straw in soil	**3.4**	**3.6**	**3.5**	**3.5**	**3.5**	**3.4**
1. Incorporating rice straw in the soil results in less use of chemical fertilizers.	3.9	4.3	4.3	4.2	4.3	3.9
2. Incorporating rice straw in the soil results in better soil condition in rice farm.	4.1	4.4	4.5	4.3	4.5	4.1
3. Incorporating rice straw into the soil results in more pest/disease attacks.	2.4	2.4	2.2	2.3	2.2	2.4
4. Incorporating rice straw in the soil results in more acidic soil condition.	2.6	2.5	2.3	2.5	2.3	2.6
5. Incorporating rice straw into the soil results in higher yields.	4.1	4.4	4.1	4.0	4.2	4.1
Positive Effects of Incorporation (1,2,5)	4.0	4.4	4.3	4.2	4.3	4.1
Negative Effects Of Incorporation (3,4)	2.5	2.4	2.3	2.4	2.3	2.5
Awareness of environmental issues in rice farming	**3.4**	**3.8**	**3.2**	**3.3**	**3.3**	**3.4**
1. Open-field burning of rice straw and other solid waste contributes to ozone layer destruction.	3.8	4.3	3.5	3.7	3.9	3.7
2. Open-field burning of rice straw causes air pollution.	3.9	4.3	3.7	3.8	4.1	3.8
3. Rice farming emits methane gas that contributes to global warming.	2.8	3.1	2.5	2.7	2.5	2.8
4. Incorporation of non-decomposed rice straw into soil under wet conditions causes more methane gas emissions which contribute to global warming.	3.1	3.2	2.7	2.8	2.7	3.1
5. Intensive use of inorganic nitrogenous fertilizer and pesticides may cause groundwater contamination or soil and water pollution.	3.4	4.0	3.4	3.5	3.4	3.5
Awareness of environmental regulations	**3.6**	**4.0**	**3.6**	**3.6**	**3.9**	**3.6**
1. I am aware of the Solid Waste Management Act requiring proper disposal of all solid wastes.	3.9	4.1	4.0	3.9	4.1	3.9
2. I know about the Clean Air Act or law requiring the government to control air pollution and maintain air quality that protects human health.	4.0	4.1	3.8	3.7	4.0	4.0
3. I am aware of the Organic Farming Act of the Philippines, a measure seeking development and promotion of organic farming, or a chemical-free agricultural method.	3.3	3.9	3.1	3.3	3.3	3.3
4. I am aware of the provincial/municipal ordinances against open-field burning of solid wastes.	3.5	4.1	3.7	3.6	4.1	3.6
5. I am aware of provincial/municipal ordinances against open-field rice straw burning.	3.4	4.1	3.7	3.6	3.8	3.4

Table 12 continued

STATEMENTS	WET SEASON			DRY SEASON		
	Burn	Incorporate	Remove	Burn	Incorporate	Remove
Responsibility for environmental problems	**3.3**	**3.8**	**3.4**	**3.4**	**3.5**	**3.3**
1. Those who burn rice straw and other solid waste in open fields should be fined or punished by law.	2.6	4.0	3.1	3.2	3.4	2.7
2. It is everyone's duty to ensure that the air we breathe is clean.	4.3	4.3	4.4	4.3	4.4	4.3
3. The government should raise taxes to improve air quality.	2.2	2.3	1.8	2.0	2.1	2.2
4. It is the government's responsibility to prevent air pollution and ensure proper solid waste disposal.	3.9	4.1	4.0	4.0	4.0	3.9
5. Everyone should be responsible for environmental problems caused by farming activities because they benefit from agricultural products.	3.6	4.0	3.6	3.7	3.7	3.5
Priority for environmental issues	**3.8**	**3.8**	**4.0**	**3.8**	**3.8**	**3.8**
1. We should use our resources to achieve rice self-sufficiency before looking at environmental damage	3.4	3.3	3.5	3.6	3.3	3.4
2. The government should invest more in helping farmers rise above poverty before it spends on improving air quality.	3.8	3.7	4.0	3.9	3.8	3.8
3. There are more important environmental concerns than air pollution.	3.7	3.7	3.9	3.8	3.6	3.7
4. The Government should prioritize policies that protect and conserve the environment.	4.0	4.0	4.0	4.0	3.8	3.9
5. The Government should only promote technologies that are environment-friendly.	4.2	4.3	4.5	4.2	4.4	4.2
Obedience to environmental laws/ordinances	**3.7**	**3.1**	**3.3**	**3.3**	**3.3**	**3.6**
1. I will obey the law/ordinance if I see someone caught or fined or imprisoned for open-field burning or burning rice straw.	3.1	2.7	2.6	2.7	2.9	3.1
2. The government is not serious in implementing laws and regulations.	3.6	3.3	3.6	3.4	3.4	3.6
3. I will not burn my rice straw if the government gives me an incentive for not doing so, for e.g shouldering my expense in spreading rice straw in the field.	3.8	3.1	3.3	3.4	3.0	3.7
4. I will not burn my rice straw if somebody collects it and uses it for other purposes.	4.2	3.2	3.9	3.7	3.9	4.1
5. I will not burn my rice straw if there is market for it (somebody will buy it or I can sell it).	4.3	3.1	4.1	3.7	4.0	4.3

Note: The figures in the table represent a mean Likert scale where 1 = strongly disagree and 5 = strongly agree)
Source: Household survey in 4 provinces (2011)

6.5 Determinants of Farmers' Choices of Rice Straw Management Options

Table 13 shows the results obtained from the estimated multinomial logit model reported as relative risk ratios (Appendix 5 shows the estimated coefficients). The model is statistically significant based on the Likelihood Ratio Chi-square criteria, and overall correctly predicts 76% of respondents in terms of their choice of rice straw management practice.

Table 13. Results of multinomial logit model (Baseline category: straw burning)

Variable	Straw incorporation			Straw removal		
	RRR	SE (RRR)		RRR	SE (RRR)	
Season	1.35	0.33		1.02	0.32	
Farm Type	0.51	0.18	*	0.23	0.10	***
North Cotabato	2.20	0.94	*	0.03	0.02	***
Leyte	16.51	7.50	***	0.46	0.33	
Ilocos Norte	5.11	2.29	***	5.44	2.84	***
Attendance in Training	1.60	0.42	*	0.90	0.32	
Age	1.01	0.01		1.00	0.01	
Educational Attainment	0.95	0.04		1.04	0.06	
No. of household members with age >13	1.25	0.10	***	1.38	0.14	***
Income in non-rice farming	1.00	0.00		1.00	0.00	***
Total area cultivated	0.97	0.07		0.67	0.10	***
Cow ownership	2.50	0.91	***	4.41	1.78	***
Tenure status	1.51	0.40		1.77	0.61	*
Distance from farm to house	0.87	0.07	*	0.79	0.11	*
Yield	1.00	0.07		1.07	0.09	
Perceptions						
Negative impacts of open-field burning	1.48	0.24	**	0.70	0.13	**
Positive effects of rice straw incorporation	1.78	0.41	***	1.08	0.31	
Negative effects of rice straw incorporation	0.72	0.11	**	0.86	0.17	
Awareness of environmental regulations	2.23	0.51	***	2.33	0.64	***
Attitudes toward incentives/market	0.36	0.05	***	0.37	0.07	***
Burning ordinance in province	1.17	0.32		0.47	0.18	**
Solid waste management program in province	1.23	0.34		3.23	1.58	**
No. of observations=687 Log-likelihood: -390.81 Pseudo-R^2: 0.41	*** p<0.01; **p< 0.05; *p<0.10					

While season did not appear to be a significant factor affecting choice of straw management in the surveyed provinces, farm type was a significant factor with a 0.51 relative risk ratio. This means that if a rainfed farmer becomes an irrigated farmer, the ratio of the probability for him to choose to incorporate straw in soil relative to the probability to practice burning is expected to decrease by a factor of 0.51 given the variables in the model are held constant. Irrigated farmers are also less likely to remove rice straw from the field as shown by the highly significant negative coefficient. A possible explanation is that intensive rice-rice cropping is largely practiced in irrigated farms in the country so that the turnaround or interval period between rice crops is shorter and farmers have to dispose rice straw and stubbles more quickly. Flinn and Marciano (1984) in studying straw management practices in an irrigated and rainfed environments concluded that stacking of rice straw for livestock consumption is higher in rainfed compared with irrigated areas. In relation to this, the model also shows that cow ownership is a significant variable related to choosing straw incorporation and straw removal over burning.

Relative to the largest rice-producing province of Nueva Ecija, farmers in North Cotabato, Leyte, and Ilocos Norte are more likely to incorporate straw than burn when all other factors are held constant. For Leyte, for example, the risk for farmers incorporating relative to burning is higher by a factor of 17 given that other factors in the model are constant. For Ilocos Norte, the relative risk of farmers removing straw from the field relative to burning is higher by a factor of 5.

Considering economic factors, an increasing number of adult household members who can be proxy for available family labor are positively related to choice of straw incorporation or straw removal

relative to straw burning. This is consistent with our descriptive results that straw incorporation and removal are much more labor-intensive than straw burning. Related to this, total area cultivated is also significantly related with the choice of straw removal over straw burning possibly because the larger the total area cultivated, the more labor required in removing straw from the field. This result is consistent with the result of a binary analysis done using a separate data (see Appendix 6). Income from non-rice farming which can also be a proxy for household engagement in vegetable or other crop farming is a highly significant variable related to rice straw removal relative to burning. Rice straw has value as mulch to households engaged in non-rice farming especially onion and garlic production.

The increased distance from house to farm was found to be negatively related with the log-odds of choosing straw incorporation and straw removal relative to burning. A possible explanation is the higher cost of collection and transportation when the farm is located farther from the house where they usually stack the rice straw for livestock feed or other purposes.

In terms of perception-related variables, the more farmers agreed with the statements on the negative effects of open-field burning on global warming and air pollution, the higher the relative risk ratio of choosing to incorporate straw relative to burning straw. An inconsistent result is that agreement with the statements on the negative effects of open- field burning is negatively related to the choice of straw removal over burning. A possible explanation is that even while they agree with the negative impacts on air quality and climate, the additional cost of straw removal is much higher than their willingness to mitigate these perceived negative impacts. Also, a higher awareness of environmental regulations and policies is significantly and positively related to the choice of straw incorporation or straw removal relative to burning.

On the other hand, for the attitudinal statements on possible behavior given incentives or increased demand of rice straw, farmers who require incentives are less inclined to practice straw incorporation or straw removal relative to burning unless such incentives are given. Finally, the presence or absence of a provincial ordinance against rice straw burning appears to be insignificantly related to the choice of farmers to practice straw incorporation; respondents in provinces with an ordinance banning rice straw burning are less likely to remove their rice straw. This result is probably because in Leyte province where there is a specific ordinance against rice straw burning, the more common practice is straw incorporation. The implementation of a provincial solid waste management program is significantly and positively related to the practice of straw removal relative to straw burning.

7.0 CONCLUSIONS AND RECOMMENDATIONS

This research project was generally aimed at assessing the environmental consequences of rice straw burning and other straw management practices and evaluating the cost-effectiveness and adoption of selected rice straw management alternatives. Based on the emissions inventory considering the incremental GHG emissions from rice straw management practices, the estimated contribution of rice residues is around 16 M tons of CO_2-eq considering only CH_4 and N_2O emissions. This is approximately 8% of the total projected CO_2-eqemissions for 2008 based on the Philippines' first initial national communication on climate change. The current practice of incorporating rice straw stubble into soil during land preparation in wet or flooded conditions less than a month before transplanting is the largest contributory rice residue management practice on a per year basis not considering potential long-term impacts.

On a per hectare basis calculated for a five-year period based on IPCC 2006 Guidelines, compiled factors from literature and various assumptions, the total estimated emission level, considering only CH_4 and N_2O gases, is around 51 tons CO_2-eq for the baseline scenario. This is not very different if the practice changes from straw burning to straw incorporation less than 30 days before crop establishment. Aside from GHG, rice straw burning, however, emits particulates that are known to be harmful to human health. Changing the timing of straw incorporation from less than 30 days to more than 30 days before crop establishment will significantly reduce the incremental GHG emissions in paddy fields due to straw management by around 80%.

Economic analysis from the point of view of rice farmers indicated that merely shifting from incorporating stubble before transplanting and straw burning to incorporating both stubble and straw in the soil over 30 days before crop establishment appears to be the most cost-effective option with a negative

abatement cost (benefit) of Php 21 (US$ 0.50) per ton CO_2-eq reduction. Incorporating both rice stubble and straw less than a month before cultivation, on the other hand, appears to result in a slight net increase in emissions. Rapid composting and incorporating the rice straw compost in the field entail significantly higher additional costs, but significantly mitigates GHG emissions, hence it is the next most cost-effective option. While a full-scale cost-effectiveness analysis of using rice straw for power generation and bioethanol production was not included in this study due to data limitations, creating higher rice straw demand given the same supply will result in higher economic value for rice straw which is favorable for rice-based farmers. Further study on the technical and economic feasibility of using rice straw for power generation and bioethanol production and the consequent GHG emissions from these options in the case of the Philippines is recommended.

Also, there is evident uncertainty about the rate of growth of emissions, their general effects, and their local effects (GEF 1992). The results of this study, particularly on GHG emissions, are only indicative and the cost-effectiveness analysis must be interpreted in relative terms. For rice-based farmers, there are other mitigation options such as water management and tillage options. Since affordability of technologies is a prime issue in the mitigation of GHG emissions, further study of the economics of these other mitigation options relative and complementary to rice straw management practices would provide broader information useful for farmers, policy-makers, and other rice stakeholders.

On the determinants of rice straw management practice or why farmers choose to burn, incorporate, or remove rice straw, a mix of socio-economic, farm, and awareness and attitude variables are prominent. Continually providing training on rice production to farmers is a particular policy direction that significantly relates to choice of straw incorporation over straw burning, as shown by the significantly positive coefficient of the training variable and perceptions of the benefits of straw incorporation. Increasing the demand for rice straw for other uses such as mulch is also another significant factor, as shown by the significance of non-rice farm income used as proxy for households engaged in vegetable and other non-rice farming. While awareness of the environmental impacts of rice straw burning appears to be a significant positive factor for choosing straw incorporation over straw burning, farmers' choice of straw removal relative to burning may not be affected in the same manner owing to the significantly larger cost of straw removal. Options for reducing the cost of collection and transportation of rice straw such as mechanization of harvesting and baling activities may reduce costs in the long run and increase the probability of the adoption of straw removal options including composting. Awareness of environmental laws and regulations appear to be a consistent positive factor that can increase the relative risk of choosing straw incorporation and removal over burning, so that increasing information campaigns and drives regarding these laws as well as strict implementation of sanctions are also recommended.

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