Economic Analysis of Irrigation Policy Options for Methane and Nitrous Oxide Emission Reduction from Rice Cultivation in Nueva Ecija, Philippines

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Abstract

Rice production contributes a significant amount of greenhouse gases (GHG) from agriculture. The study analyzes policy options for water management in the national irrigation system for reducing GHG emissions from rice cultivation in Division 1 of the Upper Pampanga River Integrated Irrigation System (UPRIIS) in Nueva Ecija, Philippines. These options include policies associated with continuous flooding, single drainage, and multiple drainage of rice fields. The total economic values were calculated by estimating the cost avoided due to GHG reduction and water savings, and estimating the welfare effect.

The per season estimated economic values of the potential GHG emission reduction and value of water savings in the study area are: PhP 339 million (M) for shifting from continuous flooding to midseason (single) drainage and PhP 652M for shifting to alternate wetting and drying (AWD) or multiple drainage. Using choice experiment, farmer's willingness to pay for a policy change for single drainage is estimated at PhP 5,518/ha and PhP 6,774/ha for multiple drainage, or a total welfare effect of PhP 102M and PhP 125M, respectively. Aggregating these values results in a gross benefit of PhP 441M for midseason drainage and PhP 777M for AWD. The net present values (NVP) of net benefits from implementing the policies are both positive, although NPV is higher for the policy on multiple drainage.

Keywords: *irrigation policy, continuous flooding, single drainage, multiple drainage*

Introduction

Climate change due to global warming has been observed in the past decades. The change in climate over time was due to both natural variability and human activities. The greenhouse gas (GHG) contribution from agriculture comes mainly from methane (CH_4) due to enteric fermentation in livestock, irrigated rice farming and manure, as well as from nitrous oxide (N_2O) from nitrogen fertilizer application in crops. In the Philippines, more than 60% of total CH_4 emission comes from agriculture, with rice cultivation as the main source (62%) (UNFCC 2005).

Methane production in rice, however, is largely controlled by water management (Wassman et al. 2000, Sass 2008). The inaerobic methanogen bacteria responsible for methane production thrives in the water, while the aerobic bacteria that consumes methane do not. Irrigation cuts off supply of oxygen in the soil. Thus, the unconsumed methane is released into the atmosphere via the rice plant (Dessus et al. 2008). N_2O emissions, on the other hand, is largely controlled by the rate of N fertilizer application.

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Water is essential to the growth of rice plant. Farmers use double the required volume of water by applying irrigation water continuously from land preparation up to the hardening of grains (PhilRice 2007). This is especially true in the national irrigation systems (NIS).

To address these issues, this study analyzed alternative policy options for irrigation water management in NIS with the end in view of reducing GHG emission from rice cultivation in Nueva Ecija, Philippines. Specifically, it estimated the economic values of the potential GHG emission reduction associated with different alternative irrigation policy options for water management in Nueva Ecija, determined farmer's willingness to pay (WTP) for alternative irrigation policy options for water management for reduced GHG emissions, and analyzed the economic benefits of the various irrigation policy options.

Theoretical Framework

Total economic value (TEV) is the value associated with the consumption of goods and services that are both paid (purchased in the market) and not paid (no price or not traded). This implies that anything which gives utility or satisfaction to an individual is of value as long as the individual is willing to pay for it. TEV has two main categories: the use and non-use values (Figure 1). Use values are values associated with the consumption of a good while non-use values are the values of a good that are independent of their present consumption or are beyond the current use (Kjaer 2005).

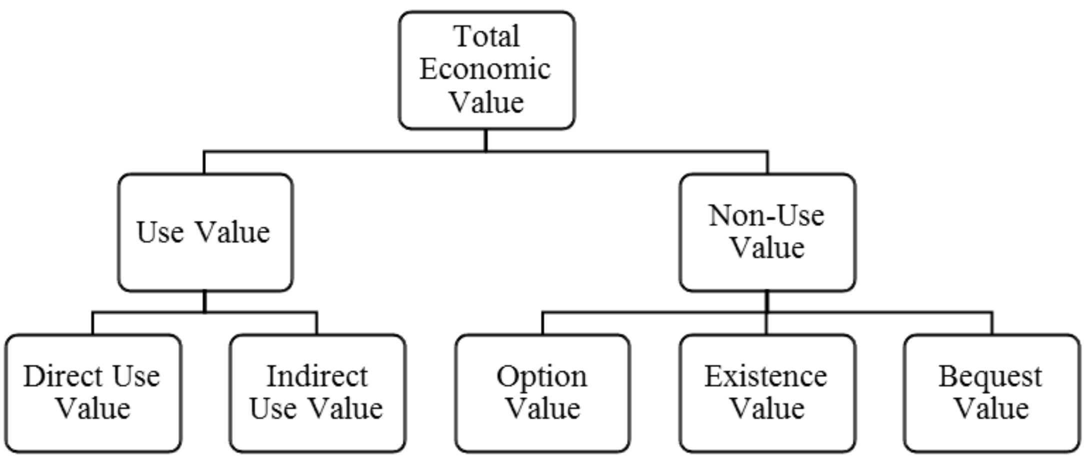

Figure 1. Total economic value of a good (adapted from Kjaer 2005)

There are three types of non-use values, namely, option value or the value that people place on something for its use in the future, bequest value or the value due to the satisfaction gained from preserving a good for the benefit of the future generation, and existence value or the preservation of the good or natural resource.

There are two main methods of eliciting willingness to pay (WTP) to reflect total economic values, namely, the revealed preference and stated preference methods. Revealed preference is generally used in market analysis and refers to the preferences revealed by real market behaviour, thus, there is a demand curve for the good. Stated preference, on the other hand, is used in valuing hypothetical goods and services. This method can incorporate the three types of non-use values.

Choice experiment (CE) is one type of stated preference technique that estimates the individual's willingness to pay by the use of price variables and the specific attributes of the good. The basic idea in CE is that consumers derive utility or satisfaction from the good through the attributes that the good provides. In CE, WTP is derived when respondents are asked to choose between different bundles of goods, where the goods are described in terms of their attributes or characteristics and the levels that these take (Hanley et al. 1998).

Methodology

The study was conducted in the rice producing province of Nueva Ecija in the Central Luzon Region in the Philippines. Ninety-two percent (92%) of the service area of the Upper Pampanga River Irrigation Systems (UPRIIS), one of the biggest NIS in the country, is located in Nueva Ecija. The specific study area is in Division 1, particularly along Lateral Canal G (Figure 2).

Three policy options were evaluated. These are policies that would promote the following water regimes during cultivation: (1) continuous flooding or the status quo; (2) midseason drainage or single aeration, or the draining of the field once during the middle of the planting season; and (3) multiple drainage or aeration, or draining of the fields once water reaches 15 cm below the soil surface, consistent with alternate wetting and drying (AWD).

Estimation of Economic Value

The economic values were calculated by (1) estimating the cost avoided due to GHG reduction as a result of the policies, (2) calculating the water savings, and (3) estimating the welfare effect using choice experiment.

In estimating the cost avoided due to GHG reduction, the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, in particular Volume 4: Agriculture, Forestry and Other Land Use, was used in computing for the GHG emissions from rice. The differences in the emissions from continuous flooding to single or multiple drainage were computed. This difference was multiplied with the social cost of carbon to estimate the cost avoided due to emission reduction.

In estimating CH_4 emission, tier 2 of the IPCC Guidelines was followed, particularly Equation 5.1 as follows:

$$CH_{4\,rice} = \sum_{n=1}^{n} \left(EF_{ijk} * t_{ijk} * A_{ijk} * \right) \qquad (1)$$

where: CH_{4rice} is the CH_4 emission from rice cultivation, EF_{ijk} is the daily emission factor for i,j,k conditions in kg CH_4/ha/day, t_{ijk} is the cultivation period of rice for i,j,k conditions, A_{ijk} is harvested area for i,j,k conditions in ha, and i,j,k represents the different ecosystems, water regimes, types and amounts of organic amendment, and other conditions in which CH_4 emission may vary.

EF in Eqn 5.1 of the IPCC guidelines is derived from Eqn. 5.2 of the same guidelines:

$$EF_i = EF_c * SF_w * SF_p * SF_o * SF_{sr}$$

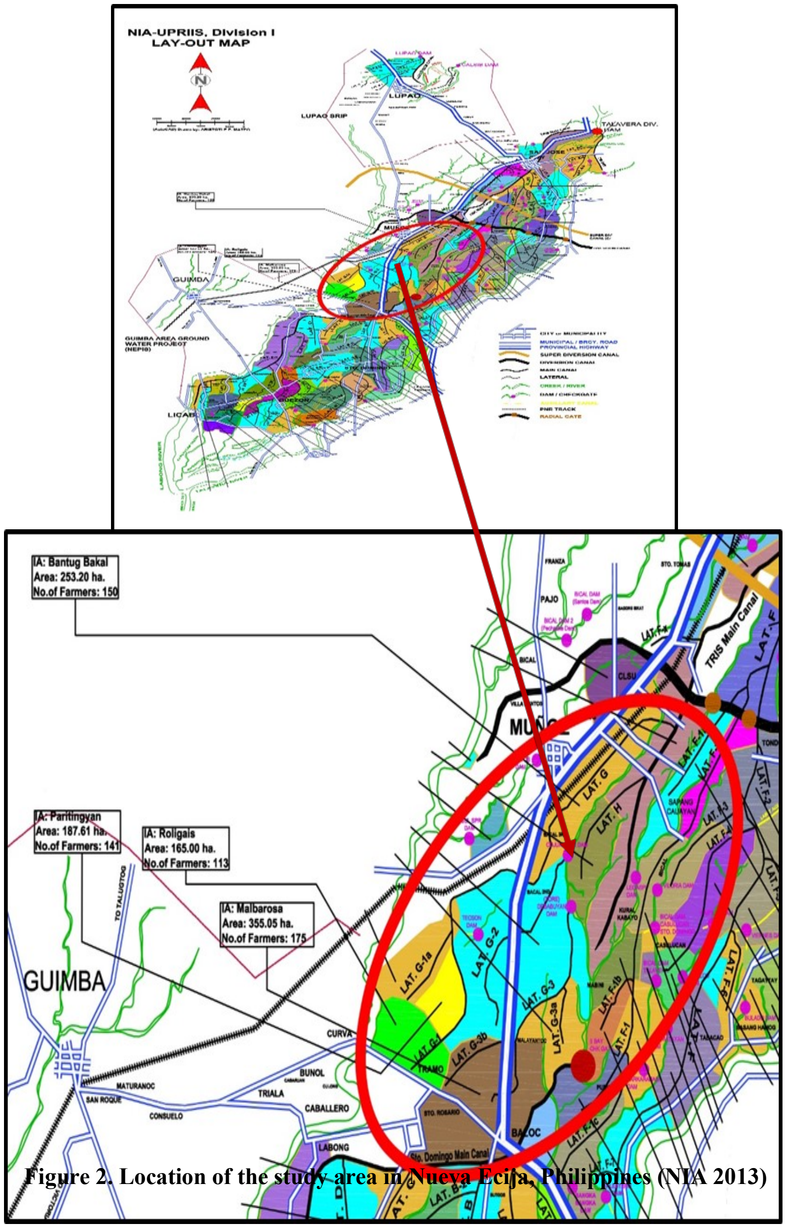

Figure 2. Location of the study area in Nueva Ecija, Philippines (NIA 2013)

where *EFc* is the baseline emission factor for continuously flooded fields without organic amendment, which is 1.3 based on Table 5.11 of the IPCC Guidelines; *SFw* is the scaling factor to account for the differences in water regime during cultivation period which is 1 for continuous flooding, 0.6 for single aeration and 0.52 for multiple aeration based on Table 5.12 of the Guidelines; *SFp* is the scaling factor to account for the differences in water regimes in pre-season before the cultivation period which, based on the Table 5.13 of the same Guidelines, is 1 since the water practice before cultivation in dry season rice in Canal G is considered "non-flooded for less than 180 days"; *SFo* is the type and amount of organic amendment; and SFsr is soil type and rice cultivar which was not included because of unavailability of data.

SFo in Eqn. 5.2 in the IPCC Guidelines was computed using Eqn 5.3 in the Guidelines as follows:

$$SF_o = (1 + \sum ROA * CFOA)^{.59} \quad (3)$$

where ROA is the application rate for organic amendment, dry weight for straws, in ton/ha; and $CFOA$ is the conversion factor. The average number of days of rice cultivation was 115. With the average palay grain yield of 5.14 t/ha for Nueva Ecija (N.E. Profile 2013), the dry straw weight was computed at 4.25 t/ha. This was the rate used for the ROA. The relevant size of the farm in terms of hectarage is 494 for Canal G and 18,515 for Division 1 of UPRIIS.

In estimating N_2O emission, the study considered only the direct N_2O emissions, following the 2006 IPCC Guidelines for National GHG Inventories, particularly Chapter 11:2.1 Direct N_2O Emissions. Under the Guidelines, the sources for N in estimating direct N_2O emissions to be considered are the following: (1) synthetic N fertilizers (*FSN*); (2) organic N applied as fertilizer (including compost) (*FON*); (3) urine and dung (*FPRP*); (3) N in crop residues, including from N-fixing crops and from forages during pasture renewal (*FCR*); (4) N mineralization associated with loss of soil organic matter resulting from change of land use or management of mineral soils (*FSOM*); and (5) drainage/management of organic soils (*FOS*).

Detailed emission factors and corresponding activity data in estimating the N_2O emissions from rice under various water regimes were available. Thus, this study used Tier 2 of the Guidelines, using Equation 11.2 Direct N_2O emissions from managed soils:

$$N_2O_{Direct} - N = \sum_i (F_{SN} + F_{ON})_i \cdot EF_{1i} + [F_{CR} + F_{SOM}] \cdot EF_1 + N_2O - N_{OS} + N_2O - N_{PRP} \quad (4)$$

where $N_2O_{Direct} - N$ is the direct N_2O emission produced from managed soils; EF_{1i} is the emission factor developed for N_2O emissions from synthetic fertilizer and organic N application under conditions i, $N_2O - N_{OS}$ is the direct N_2O - N emissions from N inputs to managed soils, and $N_2O - N_{PRP}$ is the annual direct emissions from urine and dung inputs to grazed soils.

The N_2O emissions were estimated specifically for rice. Thus, the equation used was only up to the first term of Eqn. 4.4, i.e.:

$$N_2O_{Direct-rice} - N = \sum_i (F_{SN} + F_{ON})_i \cdot EF_{1i} \quad (5)$$

where i represents the water regimes of continuous flooding, single aeration, and multiple aeration.

According to the Guidelines, the emission factor *EF* for flooded rice is 0.003 (default value). However, when the total quantity of N applied to flooded paddy rice is known, this N input may be multiplied by different emission factors (IPCC 2007). In this study, the emission factors from Zou et al. (2007) were used, where the emission factors of 0.02% for continuous flooding, 0.42% for single aeration, and 0.73% for multiple aeration were used.

The PhilRice-IRRI-Nueva Ecija Government recommendation for per hectare synthetic fertilizer input in the province was 225 kg N, equivalent to 163.75 kg Total N/ha. Organic fertilizer, on the other hand, was computed as 0.50% (Doberman and Fairhurst 2012) of the previously computed dry straw weight of 4.25t/ha which was 25.44.

In computing the total GHG and economic values of GHG avoided, the CH_4 and N_2O emissions were converted into their CO_2-eq before they were aggregated. The difference in the total GHG emissions from continuous flooding and single and multiple drainage was determined and then multiplied by the social cost of carbon of US$ 1/ton (US IWG 2013).

The second type of economic value considered was the potential water savings as a result of the policy change. In estimating these values, the following assumptions were used: (1) the water level use for policy of continuous flooding was 14,000 m^3/ha (David 2004); (2) the practice of single aeration consistent with midseason drainage reduced water use by 30% (Fowler 2011) which means that the volume of water use was 10,500 m^3/ha; and (3) the practice of multiple aeration consistent with AWD reduced water use by 50% or the equivalent volume of 7,000 m^3/ha (IRRI 2012, PhilRice 2009).

In addition, the following assumptions were used if the water saved will be used to irrigate more lowland palay areas in the dry season: (1) the additional areas to be irrigated will use continuous flooding levels of 14,000 m^3/ha; (2) average yield will be based on the dry season national average yield for lowland rice area of 3.9 t/ha; and (3) the price used was PhP 17/kg. These assumptions were used so that the estimated values may also be applied not only in UPRIIS but in other lowland rice areas as well.

A choice experiment (CE) was conducted to determine the impact of the change in policy from continuous flooding to single or multiple drainage on the welfare of farmers. A total of 300 farmers from Canal G of UPRIIS were included in the CE. The complete methodology is described in Decena and Pabuayon (2015). The attributes and levels included in the CE are the following: (1) water availability (with levels continuous flooding, single drainage, and multiple drainage; (2) profitability (with levels same, 10% higher, and 10% lower); (3) GHG emission reduction (with levels none, 30% GHG emission reduction, and 60% emission reduction); and (4) price of water (with levels PhP 2,975, PhP 1,700, and PhP 850). The exchange rate used was PhP 43 per US dollar.

In analyzing the economic benefits from each of the alternative policy options, the main tool used was the incremental benefit-cost analysis (BCA). The unit of analysis was Division 1 of UPRIIS. The incremental benefits were computed from the total cost avoided as a result of emission reduction and the economic value of water savings, as well as the welfare impacts derived from the CE. These values were aggregated up to the Division 1 of UPRIIS

Cost of Policy Implementation

The costs considered were the cost to NIA in implementing the proposed policies. Since the policies involved a change in water regime, this meant that there will be no engineering infrastructure to be constructed. However, the change in the current water regime would require farmers to change their perception of water efficiency given the current practice. Thus, enforcing the policies would be difficult and would entail a lot of advocacy activities and incentives such as discounts to farmers to change their production practice.

The main economic indicator used was the net present value (NPV) for each alternative policy. This was computed using the formula:

$$NPV = \sum_{t=1}^{T} \frac{(Benefit_t - Cost_t)}{(1+r)^t} \quad (9)$$

where *benefits* is the stream of incremental benefits, *cost* is the stream of incremental costs, *t* is time period, and *r* is the discount rate (6% per annum).

Results and Discussion

Economic Values of GHG Emission Reduction due to Policy Change

The estimated CH_4 and N_2O emissions are shown in Figure 3. The figure shows the opposing effect of water level use on CH_4 and N_2O emissions: water level has a positive effect on CH_4 emissions and a negative effect on N_2O emissions.

Continuous flooding entailes the highest water level usage while the practice of multiple drainage has the lowest level. Under continuous flooding, total CO_2 equivalent (tCO_2-eq) was estimated as follows: CH_4 emission at the head/middle location is 2,515 tCO_2-eq and 2,405 tCO_2-eq at the tail, and 184,083 tCO_2-eq for Division 1. In general, the variation across locations is due to upscaling which depends mainly on the size of the area.

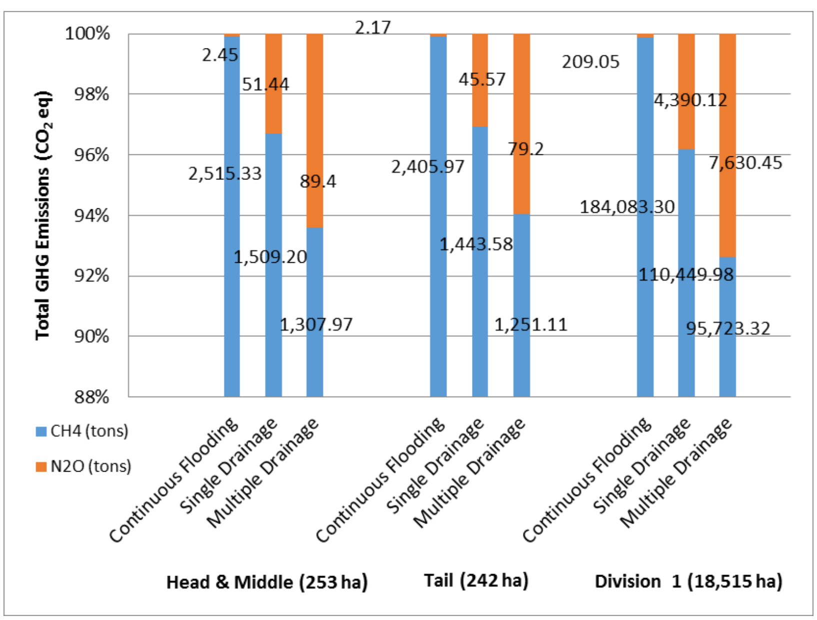

Figure 3. Total greenhouse gas emissions (tCO2-eq) from rice cultivation under different water regimes, Canal G and Division 1 UPRIIS, dry season 2012-13

With single drainage, water is drained once and methane production and emission is interrupted. CH_4 emission is 1,509 tCO_2-eq in the farms located at the head/middle canal, 1,443 tCO_2-eq in the farms at the tail, and 110,449 tCO_2-eq in the farms at UPRIIS Division 1. This means a 40% reduction of emission from continuous flooding.

Draining the fields multiple times also means methane production and emission is interrupted many times due to the aerobic-inaerobic process. CH_4 emission under this condition is 1,307 tCO_2-eq in farms located at the head/middle canal, 1,251 tCO_2-eq in farms located at the tail, and 95,723 tCO_2-eq at the Division 1 of UPRIIS. These values are only 48% of the CH_4 emission values under continuous flooding conditions.

In contrast, N_2O emission increases with reduced water use. This is because N_2O emission favors dry soils. Under continuous flooding, N_2O emissions at the head/ middle location is only 2.45 tCO_2-eq, 2.17 tCO2-eq in farms at the tail end, and the upscaled value of 209 tCO_2-eq at the Division 1 of UPRIIS. With single drainage, N_2O emission in the farms located at the head/middle canal increases to 45.57 tCO_2-eq, 97.91 tCO_2-eq in farms at the tail, and 4,390 tCO_2-eq at Division 1. This increase is more than 20 times that of emissions from continuously flooded fields.

With multiple drainage where the field is dried a number of times, N_2O is 34 times that of continuous flooded fields. Under this water condition, N_2O in tCO_2-eq is 89.40 in the farms at the head/middle, 79.2 in the farms at the tail, and 7,630 at Division 1.

The results show that CH_4 decreases with water level use but N_2O increases with water level use. Overall, since N_2O emissions represent only a small amount compared to CH_4 emissions, the overall decrease in emission in tCO_2-eq due to water level is high. The reduced CH_4 emission is offset by the increase in N_2O emission by only 0.1% under continuous flooding conditions, 3% under single drainage, and 7% under multiple drainage conditions. This trend shows that the benefits gained from the decrease in CH_4 emissions is offset by the increase in N_2O emissions in very small quantities.

Overall, the GHG emission in Division 1 of UPRIIS, an area of 18,515 ha under continuous flooding is 184,292 tCO_2-eq. Lower GHG emissions were estimated for fields under single and multiple drainage at 114,840 tCO_2-eq and 103,353 tCO_2-eq, respectively. This is almost a 36% reduction from single drainage and 45% reduction from multiple drainage fields. On a per hectare basis, the computed total GHG emissions are 9.5 tCO_2-eq in continuous flooding, 5.5 tCO_2-eq in multiple drainage, and 6.1 tCO_2-eq in single drainage conditions.

Based on these emission values, the economic values were computed by multiplying the total GHGs with the social cost of carbon. Using these economic values, the costs avoided due to a change in water regime were estimated (Table 1). These values represent the cost avoided by society because of the use of the controlled irrigation techniques. The cost avoided due to the shift from continuous flooding to multiple drainage was found to be higher than shifting to single drainage. Upscaling to the whole area of Division 1 of UPRIIS, the cost avoided amounts to PhP 32.8M for single drainage and PhP 38.2M for multiple drainage for the dry season in 2012-2013.

Table 1. Economic values of greenhouse gas avoided due to shift from continuous flooding to alternate irrigation systems, Canal G and Division 1, dry season 2012-2013

Location	**Area**	**Continuous Flooding Emission**	**Single Aeration**			**Multiple Aeration**		
			Emission	Avoided Emission	Cost Avoided	Emission	Avoided Emission	Cost Avoided
	(ha)	(t CO_2 eq.)	(t CO_2 eq.)	(t CO_2 eq.)	(PhP)	(t CO_2 eq.)	(CO_2 eq.)	(PhP)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Head & Middle	253.00	2,517.78	1,560.64	957.15	452,729	1,397.38	1,120.41	529,952.00
Tail	242.00	2,408.14	1,489.15	918.99	434,683	1,330.30	1,077.84	509,817.00
District 1	18,515.66	184,292.35	114,840.10	69,452.25	32,850,915	103,353.76	80,938.59	38,283,952.00
Per hectare		9.95	6.20	3.75	1,774	5.58	4.37	2,067.00

Notes:
(2), (3), (6) from Figure 3
(4) = (2) (3)
(5) = (4) × social cost of CO_2 (US$11/ton[US IWG, 2013] × PhP 43 = PhP 473/ton)
(7) = (2) – (6)
(8) = (7) × social cost of CO_2 (US$11/ton[US IWG, 2013] × PhP 43 = PhP473/ton)

This amount of cost avoided is approximately 2% of the total value of palay production in UPRIIS. Survey data show that the value of production during the dry season of 2012-2013 could reach PhP 1,792M given the average yield of 6.09 t/ha and average price of PhP 15.90 per kilo, or a per hectare value of PhP 97,400.

Water Savings Due to Policy Change

Based on the assumptions in the methodology, the potential water savings were estimated to be 7,000 m^3/ha if the policy is for multiple drainage consistent with AWD and 3,500 m^3/ha if the policy is for midseason drainage (Table 2). Upscaling these values to Division 1 of UPRIIS which has an effective area of 18,515 ha in the dry season means that the volume of potential water savings could be as high as 129M m^3 due to AWD and 64.8M m^3 due to midseason drainage.

Table 2. Economic values of potential water savings due to policy change from continuous flooding to alternative irrigation

Item	Alternate Wetting and Drying	Midseason Drainage
Water savings (m^3/ha)[a/]	7,000	3,500
Total water savings from UPRIIS (m^3)[b/]	129,605,000	64,802,500
Option for water savings utilization		
Irrigation water in other lowland rice areas		
Hectares to be irrigated (ha)[c/]	9,257	4,628
Production (mt)[d/]	36,178	18,049
Economic value (PhP)[e/]	613,772,250	306,886,125

[a/]Policy for continuous flooding water level use = 14,000 m^3 (David 2004, Rivera et al. 2001); AWD results to 50% (IRRI 2012, PhilRice 2009) and midseason drainage leads to 30% water savings (Fowler 2011)
[b/]UPRIIS area = 18,515 ha
[c/]Areas to be irrigated will use 14,000 m^3/ha
[d/]Using dry season national yield for lowland rice of 3.9t/ha
[e/]Price of palay = PhP 17/kg

Given these, the additional potential areas that can be irrigated would be 9,257 ha and 4,628 ha due to a policy shift for AWD and midseason drainage, respectively. This is tantamount to an additional volume of palay production of 18,049 mt and 36,098 mt equivalent to 4% and 2% additional palay national inventory during the dry season valued at PhP 613M and PhP 306M, respectively.

Economic Values from Cost Avoidance and Water Savings due to Shift in Policy

The economic values due to the shift in policy were estimated to be PhP 652M due to AWD and PhP 339M due to midseason drainage (Table 3). The values of the co-benefit are 16 times higher than the value of the cost avoided estimated from the emission reduction. These values of the co-benefits are more tangible than the cost avoided.

Farmers' Willingness to Pay for Alternative Irrigation Policy

Three hundred (300) respondents from Lateral Canal G were included in the choice experiment. Details of the results of the estimation can be found in Decena and Pabuayon (2015)

Table 3. Summary of economic values of benefits from policy for reduced greenhouse gas emissions in Division 1 UPRIIS (PhP)

Benefit	Alternate Wetting and Drying	Midseason Drainage
Direct benefits		
Cost avoided	38,283,952	32,850,915
Co-benefit: water savings		
Value of potential palay production in lowland irrigated rice	613,772,250	306,886,125
Total economic benefits	652,056,202	339,737,040

On the whole, farmers' WTP for a policy for high and medium impact scenarios could reach as high as PhP 125,431,218 and PhP 102,187,717, respectively, for the whole of Division 1 in UPRIIS. These amounts are double the potential total irrigation service fee (ISF) collections in Division 1 for one season if all farmers pay. With the Division 1 area of 18,515.66 ha and ISF of PhP 2,975/ha, the potential ISF is PhP 55,082,125.

Aggregate Benefits from Policy Change

In summary, the benefits from policy implementation for AWD and single drainage are enumerated in Table 4. The table shows that the benefits can be quite substantial at PhP 77M and PhP 441M, respectively.

Table 4. Summary of benefits (PhP) from a change in irrigation water policy, Division 1, UPRIIS

Benefit	Alternate Wetting and Drying	Single Drainage
Choice experiment	125,431,281	102,187,717
Total WTP of farmers		
Market valuation		
Cost avoided due to emission reduction	38,283,952	32,850,915
Value of potential palay production due to water savings	613,772,250	306,886,125
Sub-total	652,056,202	339,737,040
Total economic value of benefits	777,487,483	441,924,757

Cost of Policy Implementation

The costs considered are those associated with the implementation of the policy that enforces the technology on controlled irrigation of AWD and single drainage in Division 1 of UPRIIS. The major components of policy formulation and enforcement include advocacy activities, training of NIA personnel as well as farmers, consultation with experts, information education and communication materials, demonstration farms, and coordination and evaluation costs. Implementing the policy for an initial of five years would cost an estimated PhP 29M for the policy on AWD and PhP 27M for single drainage. The difference is due to the observation tubes used in AWD.

The benefit-cost analysis showed that the policy involving AWD is superior to that of the policy involving midseason drainage (Figure 4). In fact, the annual net benefits from multiple drainage for the discounted ISF and 75% collection rate is still higher compared to the no discount scenario with 100% collection of the ISF.

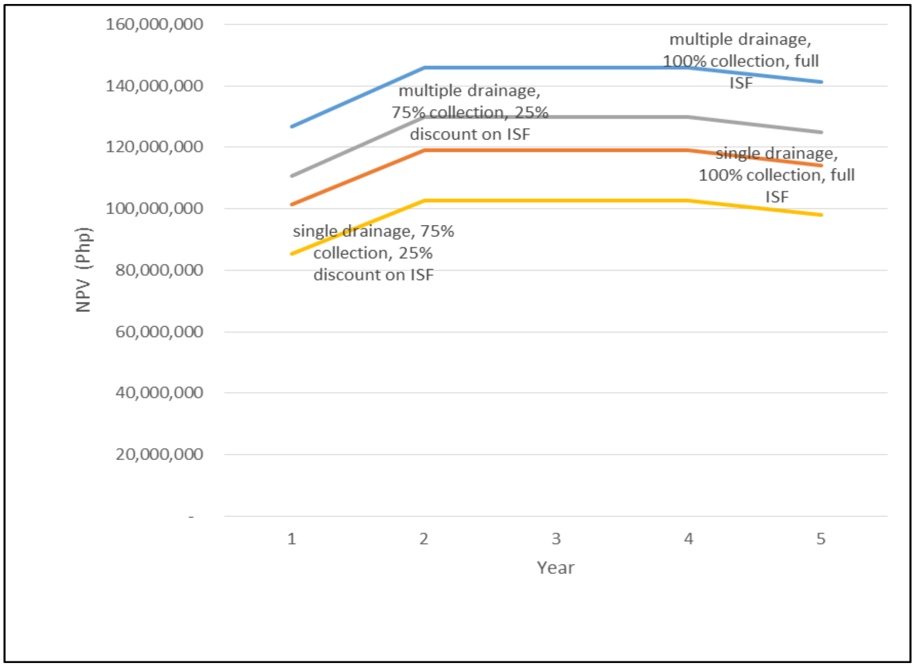

Figure 4. Comparison of net present value (NPV) of net benefits from implementing the policy to use multiple and multiple drainage in Division 1 of UPRIIS, 100% collection and no discount, and 75% collection and 25% discount

Conclusion and Recommendations

The study demonstrates the feasibility of estimating total economic value from a proposed policy change and using these values in ex-ante assessment of the said policy.

Findings reveal that the estimated economic values of the alternative irrigation policies aimed at reducing GHG emissions from rice cropping is higher for multiple drainage than in single drainage of water in the rice fields. This result is consistent with the higher per hectare WTP of farmers as well as the total welfare effect for a shift from continuous flooding to multiple drainage than in single drainage associated policies. Consequently, the NPV of the economic benefits from the implementation of a policy for multiple drainage is also higher.

Policy makers should take advantage of the farmers' willingness to pay for a policy change in irrigation. The shift in policy should take into consideration the characteristics found to be important. These are water availability, which defines the type of technology or practice on controlled irrigation to be used, GHG reduction potential of the technology or practice, and the irrigation water price. Based on these results, the policy involving multiple drainage may be chosen. The specific technology associated with this policy is the safe AWD. This policy entails the imposition of a water delivery schedule in accordance with the requirement in the farms based on the information from the tubes that indicates the level of water in the rice fields.

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