Greenhouse implications of water reuse in the Upper Pumpanga River Integrated Irrigation System, Philippines

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Abstract

With increasing demand being placed on water resources the efficient use of water is inevitable to increase rice productivity. The availability of water through a catchment can vary significantly with some water being used in upstream irrigation activities, for environmental flows, groundwater and infiltration movements, all resulting in challenges and costs for irrigators accessing water for their production systems. The use of tubewells, dams and groundwater extraction to access available water requires substantial capital investments. In addition, the production, transportation and application of pumps and pipes, and the associated fuels and oils needed to run them emit significant quantities of greenhouse gases (GHG). In this study, we analysed the GHG and water productivity implications of water reuse through pumping groundwater and creek water and compare this with canal irrigation systems under gravity-fed irrigation in the Upper Pumpanga River Integrated Irrigation System, in the Philippines. The results show that around 30% of total surface water applied was reused by internal check dams and pumping from shallow groundwater. The analysis indicates water reuse contributes significantly to water productivity; however, it does increase GHGs through pumping. The total amount of GHG emissions from pump irrigation system (with water reuse) is around 1.47 times higher than that of canal irrigation systems (without water reuse). Based on the finds, high priority on water reuse should be given only to the areas where water scarcity is a serious issue.

Key words: water productivity, greenhouse gas, canal irrigation systems, tubewell irrigation systems

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1. Introduction

Rice, grown under flooded or submerged conditions, is one of the largest users of the world’s developed freshwater resources (Tuong and Bouman, 2003). Bouman (2007a) estimated that 34-43% of the total world’s irrigation water is used for rice. Given these large water inputs, the water productivity of rice compared to other cereal crops is quite low (Tuong *et al.,* 2005). Additionally, increasing water scarcity and malfunctioning irrigation systems, now threatens the viability and sustainability of rice production (Rijsberman, 2006). The strong interdependence between water use in rice production and the operation of irrigation facilities for water services highlights the need for improving the performance of rice production systems (Bhuyan, 1996). Rijsberman (2006) advocates that water scarcity problems can be addressed through improved water productivity.

Irrigated rice receives at the field level 2-3 times more water than other cereals and is thus a major target for the development of water-saving irrigation technologies (Tuong *et al*., 2005). Rice water requirements varies from as little as 400 mm in heavy clay soils with shallow groundwater tables to more than 2000 mm in coarse textured soils with deep groundwater tables (Bouman and Tuong, 2001; Cabangon *et al.*, 2004). However, between 25 and 85% of all water inputs to rice fields is lost through percolation (Cabangon *et al.*, 2004; Dong *et al*., 2004; Singh *et al.*, 2002). Though percolation flows are losses at the field level, they can be re-captured and reused downstream and do not necessarily lead to true water depletion at the irrigation system level. The increased use of recycled water for the last few decades has considerably enhanced the availability of irrigation water at the farm gate in semi-arid countries, such as large parts of India and Pakistan’s Punjab. Therefore, it has been argued that the efficiency of water use and the water productivity of rice may be much higher at the irrigation system level than at the individual field level (Tuong *et al.*, 2005).

The effective recycling of drainage water and conjunctive use of groundwater poses a challenging question: should investment focus on the development and applicability of water saving irrigation practices such as alternate wetting and drying and aerobic rice or should investment be made in recycling outlets to increase water productivity (Tuong *et al.,* 2005).

The recapture and reuse of water involves additional investments and operation costs, such as pumping or the building of dams (Guerra *et al.,* 1998). Moreover, the production, transportation and application of pumps and pipes, and also fuels and oils to run them emit significant amounts of greenhouse gas (GHG) emissions (Maraseni *et al.,* 2007). For example, delivering the 10 million litres of water needed by 1 hectare of irrigated corn from surface water sources requires the expenditure of ~ 880 kWh of fossil fuel (Batty and Keller, 1980). In contrast, when groundwater is pumped from a depth of 100 m, the energy required increases to 28,500 kWh, or more than 32 times the cost of surface water (Gleick *et al.,* 2002). The choice obviously depends on the relative cost-effectiveness of the strategies. However, Dawe (2005) argued that while greater water productivity will almost certainly be necessary to reduce the negative impacts of future water scarcity, increasing water productivity in some instances does not necessarily result in increased benefits to society. For example, interventions may raise water productivity only at the expense of using more fossil fuels resources and increasing GHG, with the net effect being a reduction in economic efficiency.

With increasing concerns about climate change and the need to reduce carbon emissions, there is an urgent requirement to analyse GHG emission implications on water resources from increases in water productivity through to water reuse at the system level. This study builds upon the work of Hafeez *at al*. (2008), who estimated the water reuse and cost-benefit of pumping in a rice irrigation system. We analysed GHGs and water productivity implications of water reuse through pumping groundwater and creek water and compared these with canal gravity-fed irrigation systems of the Upper Pumpanga River Integrated Irrigation System (UPRIIS), Philippines

2. GHG emissions from farm inputs

Farm inputs include agrochemicals (fertilisers, herbicides, pesticides, insecticides and fungicides), fuels and oils, machinery, labour and farm yard manure. Energy consumption in agriculture is directly related to the development of technology and the level of production from a system (Hatirli *et al*., 2006; Ozkan *et al.*, 2004). However, reuse technologies increase the use of farm input; resulting in increases in GHG emissions.

Compared to the 1950s, the global use of fertilisers in 1999 has increased substantially with 23 times more nitrogen (N), almost eight times more phosphorus (P) and >4 times more potassium (K) since the 1950s (Smil, 1999). Nitrogen fertiliser is a significant concern as >50% of applied N is either lost through leaching or released to the atmosphere as N gases including nitrous oxide (N_2O) (Verge *et al.*, 2007), which has 296 times more global warming potential than CO_2. From 1990 to 2002, N_2O emissions from N fertilizer increased by 18.7% to 444 Mt CO_2e (Verge *et al.*, 2007). The worldwide use of agricultural pesticides has increased by an average of 3%/yr from an equivalent value of US$20.5 billion in 1993 to US$27.5 billion in 2003, resulting in substantially increased GHG emissions (Vlek *et al.*, 2003).

Water reuse has some benefits but it may also increase soil salinity. Salt-affected soils have relatively low fertility and the higher amount of fertiliser is needed (Stephens *et al.*, 1995). Therefore, there may be some discrepancies in the amount of agrochemicals used in canal (without water reuse) and pump (with water reuse) irrigations systems based on soil type. However, GHG emissions from agrochemicals at the farm level and due to water reuse technologies have been largely ignored.

Emission associated with farm machinery is another area of concern. Of the total energy used in world agriculture, about 51% goes into farm machinery manufacture and 45% into the production of chemical fertiliser (Helsel, 1992). Around 83.7 MJ of energy is required to produce 1 kg of farm machinery (Stout, 1990), yet the GHG emissions from the production of farm machinery has not been reflected in the literature. More importantly, water pumping and reuse may exacerbate the salinity problem. Sodic soils which are less permeable to water and air, require more energy for tillage (Guarnieri *et al*., 2005), and thus more tractor hrs/ha is needed to till the farm. Some differences in GHG emissions in pumping and canal irrigation systems may be presented, but they have not been researched.

Similarly, many land use activities such as the production, transportation and utilisation of different land use products need fuels and oils. The production, transportation and combustion of fuels emit significant amounts of GHGs, but the emissions associated with these activities are again not properly accounted for (Gower, 2003). This study considers all these factors and compares the GHG emissions from farm inputs for pump and canal irrigation systems in the Upper Pumpanga River Integrated Irrigation System, Philippines.

3. Study area

The study area was District I, Upper Pampanga River Integrated Irrigation System (UPRIIS) in central Luzon, Philippines (Figure 1). District I has a total area of 28,205 ha including rice fields (dominant land use), upland crops, vegetables, roads, settlements, and water bodies. The District is bounded by the Talavera River on the east and the Ilog Baliwag River in the west, and consists of an upper part, called the Talavera River Irrigation System-Lower (TRISL), and a lower part, called the Santo Domingo Area (SDA). Water is supplied by Diversion Canal No. 1, which gets water from the Pantabangan Reservoir; and the TRIS main canal, which gets its water from the Talavera River through a run-off-the-river diversion dam. The major direction of water flow is from northeast to southwest. The TRIS main canal first supplies water to an irrigation system north of, and contiguous to, District I, called TRIS-Upper. The area is quite flat with elevations of around 20 m above sea level. Soils are Vertisols, Entisols, and Inceptisols, and have typically silty clay, silty clay loam, clay loam, and clay textures. The climate is characterized by two pronounced seasons, dry from November to April, and wet for the rest of the year. The average annual rainfall is about 1900 mm, of which 90% falls in the wet season (Tabbal *et al.*, 2002). Our study was conducted in the 2000-2001 dry season, which started with the first release of water into the main canals on November 19, 2000, and ended with the harvest of the last rice crop on May 18, 2001.

In the upper part (northeast) of District I, comprising 10,512 ha, canal water is used for irrigation. The more southwest we go the more people irrigate rice with reused water. In the lower (southwest) part of District I, where only 51% of rice area is grown using canal water, 49% area is irrigated using pump water. There are a total of 1,154 pumps in use. The survey data of both canal and pump irrigation and detailed information about the different farms inputs (machinery, agrochemicals, fuels and oils) are given in Appendix 1 and 2.

4. Water accounting and reuse estimation

4.1 Estimation of water reuse

Generally, irrigation water that percolates deeply and recharges an aquifer adds to the water supply available to groundwater` users. Water pumped from creeks and the shallow groundwater aquifers could, therefore, either be percolated from further upstream within the catchment, or be a net gain to the system if water comes from a larger regional aquifer. The volume of percolation was calculated by multiplying the catchment area with the average percolation rate within the rice fields. The volumes of extracted water were compared with estimates of water that percolated into the shallow aquifers. When the volume of pumped water was less than the amount of water percolated from upstream, the pumped water was classified as reused within the system. When the pumped water exceeded upstream percolation, it was classified as a net output in the system.

The UPRIIS was designed to reuse surface water by building check dams in creeks and drainage ways within the irrigated area. Farmers have contributed to water reuse by constructing small dams themselves that have been ‘sanctioned’ by the irrigation system management. There are a total of 15 formal check dams in District 1, which are operated and maintained by either National Irrigation Administration (NIA) or by groups of farmers. These check dams have structures for releasing water to supply additional water to the downstream canals for irrigation purposes. Water flows at inlets were calculated at nine of the 15 check dams to obtain flow volumes from the established rating curves (Hafeez, 2003).

A total of 50 farmers were selected that use different types of pumps and pumping regimes that were monitored during the growing season. The selection of farmers depended on the location, pump size and source of the water and the total pump usage by these farmers for all farming activities, starting from land preparation through to harvesting in the dry season during 2001 (Hafeez et al., 2007b). Each pump was calibrated 7-9 times with a V-notch weir to measure the actual discharge for different sizes of pumps. The pumped water volumes from groundwater, creeks and canals were obtained by multiplying calibrated flow rates by recorded durations of pumping for the dry season in 2001. The total water pumped was estimated by multiplying the average water being pumped for each pump size with the total number of pumps installed.

4.2 Water accounting and balance

The water accounting focussed on surface water with net flows of water across the lower boundary (rootzone) being computed separately. All water flows were aggregated as seasonal totals from November 19, 2000 until May 18, 2001. The gross inflow was rainfall plus all surface irrigation water. The net inflows being the difference between gross inflows and the changes in water stored at the surface (mainly in the canals) and in the rootzone of the crops from beginning to end of the cropping season. Since canals were dry before the start of the season and after harvest of the last crop, the change in surface water storage was zero. The change in stored soil water in the rootzone was negligible since the dry season crop followed straight after a wet season crop. Consequently, we assumed that the amount of soil water available was the same after a harvested wet–season crop as after a harvested dry–season crop. Therefore, the net inflow was the same as the gross inflow. All surface outflows were considered "committed" when they flowed into a neighbouring spatial unit or further downstream in the irrigated area of District I. All water flowing out of District I was considered "uncommitted" since there was no immediate major water user downstream of District I. The only outflow considered "depletion" was evapotranspiration (ET) since no water percolated to irretrievably deep or saline groundwater. As the main purpose of UPRIIS is to irrigate rice, only rice ET was considered as "process depletion," and all non-rice ET as non-process depletion (following Loeve *et al*., 2004). The transpiration from non-rice crops is a beneficial water use, but no data on non-rice crops were available for this study, so water use for these crops could not be quantified. Further details on the water balance and associated measurements are given by Hafeez (2003).

4.3 Water performance indicators

Water productivity (WP) is the ratio of crop output to water either diverted or consumed, the ratio being expressed in either physical or monetary terms or some combination of the two. The WP indicators were calculated for gross inflow, available water and ET_{rice} with and without water reuse following the procedures presented by Molden (1997). Rice yield was obtained from the NIA who kept track of the yield of each farmer as reported to the Farmer Irrigation Associations (FIA) in the area from which total rice production was calculated.

5 GHG estimation

5.1 Estimation of GHG emissions from farm machinery[2]

Farm machinery is an essential farm input in modern agriculture. On average, approximately 12.8 kgCO_2e of GHG is emitted to produce 1 kg of farm machinery (Wells, 2001). Some GHGs would be emitted while transporting tractors from manufacturing sites to the rice farms, however it is negligible on a per ha basis and is thus not considered in this study. The life span of a tractor (12,500 hr), tractor accessories (2000 hr) and pumps (12,000 hr) were taken from Harris (2004) while the weight of tractor and tractor accessories[3] was obtained from the manufacturing company (Kubota, Philippines, 2008). The lifespan of farm machinery used for rice farming was derived from farmers' survey data (Appendix 1 & 2). From that information, the following equation by Maraseni *et al.* (2007) was used to estimate the GHG emissions attributed to tractor during rice production:

GHGs emission (kgCO_2e) = Weight of tractor (kg) x 12.8 kgCO_2e/kg x Proportion of lifespan of farm machinery used for rice production………………………………(1)

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[2] In rice cropping, farm machinery includes tractors and tractors' accessories, pumping machines and pipes.

[3] Various models of Kubota tractor were used; however, the most popular model was M6800DT with 50.7KW power and 2090kg weight. Therefore, this model was assumed for this study. Similarly, various tractor accessories (disc, cultivar, sprayer etc) of different weights were used for rice farming; however an average weight (550kg/accessory) of all accessories was used for this study. Moreover, most of the farmers used Kubota Model RK80 pumps with 5.22 KW power and 77kg weight; therefore, this was assumed for this study. Average pipe size used in the farm was 10cm diameter and 10m length (2.78kg/pipe). Since emissions from tractors and accessories and pumps and pipes were very small, these assumptions do not make a significant difference.

5.2 Estimation of GHG emissions from agrochemicals

Kim and Dale (2003) estimated the global warming impact (GWI) value (gm CO_2 equivalent/kg) of most agrochemicals (Table 1). The GWI value included all three GHGs (CO_2, CH_4 and N_2O) and their impact due to their production, packing, transportation and application. In addition**,** GWI also considered the emission of N_2O during the process of de-nitrification after applying nitrogen fertilisers (Kim and Dale, 2003) As it covers broad impact, we used these values for the estimation of GHG emissions by agrochemicals. However, GWI for insecticides, fungicides, herbicides and molluscides is not available in their estimation. These values for insecticides, fungicides and herbicides were taken from Barber (2004) and for molluscides, which was not available even in Barber's study, on average of all three was used.

5.3 Estimation of GHG emissions from fuels and oils

Production, transportation and combustion of diesel and oil produce significant amount of GHG emissions. For this study 3.8 $kgCO_2e$ of GHG emissions per litre of diesel (Flessa *et al.*, 2002) and 2.68 $kgCO_2e/L$ oil (EIA, 2008) was used. The amount of fuels and oil consumed by pumps and tractors in different phases of rice production is derived from farm surveys (Appendix 1 and 2).

6. Results and discussions

Detailed site characteristics about District 1 in the UPRIIS are provided in Table 2. Rice is the dominant crop grown in District 1, with over 80% of the area is devoted to rice. Rice yields were highest in the upstream area (TRIS) and lowest in the downstream area (SDA), with an absolute difference of 1.36 t/ha.

6.1 Water accounting

Results for water balancing and water accounting for District 1 are shown Table 3. Due to limited rainfall during dry seasons, irrigation comprised 88% of all surface water inflows. Out of all surface water outflows, only 4.9 x10^7 m^3 was uncommitted as it flowed directly into the Talavera River. All other outflows were committed and flowed into the downstream irrigated area of District I. On a per unit area basis, the average rice ET was 665 mm for the whole season and 3.7 mm/d. The non-rice ET was 503 mm for the whole season and 2.8 mm/d.

6.2 Quantification of water reuse

The total volume of water derived from check dams, groundwater and creeks in District 1 is about 2.71 x 10^7 m^3, which is 38% of the percolation volume (7.0 X 10^7 m^3) (Table 4). As the percolation volume is greater than the pumping volume, groundwater pumping represents the reuse of percolated water. Hafeez *et al.* (2008) reported that the reuse of surface water through check dams was well distributed across the area and increased linearly with 4.6 x 10^6 m^3 per added 1,000 ha. At the District I level, the reuse of surface water was 22% of the applied surface water and 57% of the available water. Also, the water reuse by pumping was 7% of the applied surface water and 17% of the available water. The total amount of reused water from pumping (2.8 x 10^7 m^3) being equivalent to 30% of the water consumed through rice evapotranspiration (9.0 x 10^7 m^3) during the dry season in 2001 (Tables 3 and 4).

6.3 Water productivity indicators

Three performance indicators of water productivity i.e. gross inflow, available water and rice ET with and without water reuse are shown in Table 5. Water productivity with respect to gross inflow (WP_{gross}) without water reuse is 0.15 kg grain/m^3 water but it rose to 0.19 kg grain/m^3 with the reuse of water, indicating the critical role of water reuse in enhancing water productivity. Similarly, water productivity with respect to evapotranspiration of rice ($WPET_{rice}$) without water reuse was 0.67 kg grain/m^3 water. However, when we consider water reuse, the $WPET_{rice}$ was 0.86 kg grain/m^3, which was considerably higher than $WPET_{rice}$ without water reuse. Also, water productivity with respect to available water ($WP_{available}$) without water reuse was 0.38 kg grain/m^3 water while $WP_{available}$ with water reuse was 0.49 kg grain/m^3. This highlights that capturing of water reuse plays a very significant factor in improving water productivity at the system level.

6.4 GHG emissions from pump and canal irrigation systems

The analysis indicated that there are significant differences in GHG emissions in pump (with water reuse) and canal (without water reuse) irrigation systems due to the application of various farm inputs. The total amount of GHG emissions from pump irrigation is around 1.47 times that of the canal irrigation system. In total, for each hectare, 1242.7 $kgCO_2e$ will be emitted into the atmosphere from each season's rice crop from pump irrigation system, and 844.5 $kgCO_2e$ from canal irrigation systems (Table 6). There are two seasons of rice farming in the research area. So, if we assume similar emissions in the other season, the pump and canal irrigation systems would emit 2485 $kgCO_2e$/ha/yr and 1689 $kgCO_2e$/ha/yr, respectively.

Canal irrigation does not need pumps, pipes, fuels and oils, but pump irrigation needs these farm machineries to run water pumps. Therefore, pump irrigation involves additional GHG emissions (338.7 $kgCO_2e$/ha/season) through the use of these machineries. Both canal and pump irrigation systems used tractors requiring fuels and oils to run them, with ~472 $kgCO_2e$/ha/season of GHG emissions associated with pump irrigation systems, and ~454

$kgCO_2e$/ha/season from canal irrigation systems. The slightly higher GHG emissions from pump irrigation systems is probably due to salinity problems emerging from water reuse in the pump irrigation systems. Since sodic soils become less permeable to water and air, they require more energy for tillage (Guarnieri *et al.*, 2005), more tractor time is required (107.5 hr/ha in pump irrigation and 103.4 hr/ha in canal irrigation) and thus emit more GHGs.

The total amount of GHG emissions from agrochemical usage under pump irrigation is 432.2 $kgCO_2e$/ha/season and canal irrigation is 390.4 $kgCO_2e$/ha/season (Table 6). The higher amount of emissions associated with agrochemicals in pump irrigation is due to higher use of all three fertilisers (N = 112kg/ha vs 100kg/ha; P = 22.9kg/ha vs 20kg/ha; and K = 15.8kg/ha vs 15.3 kg/ha) than that from canal irrigation. This is because salt-affected soils have limited nutrients in the soils and higher amounts of fertiliser are needed to compensate them (Stephens *et al.*, 1995).

5. Conclusions

Increasing water productivity is often recommended as a path to address water scarcity problems. However, increasing water productivity through the use of energy intensive technology and heavy use of energy inputs could increase dependency on fossil energy, which not only threaten the environmental sustainability of the practice, but could increase competition for energy uses among different sectors. The rice-based surface irrigation system was analysed to explore the water productivity and GHG emissions implications of water reuse in the Upper Pumpanga River Integrated Irrigation System (UPRIIS) in Central Luzon, Philippines.

In the study area, 22% of applied surface water was reused by internal check dams and 7% through pumping from shallow groundwater. Similarly, the total amount of reused water from pumping is equivalent to 30% of the water lost through rice evapotranspiration during the dry season 2001. Water performance indicators with and without water reuse can point to possibilities to further increase the general efficiency of water use. We indicate that the quantification of the amount of water reuse is crucial for understanding and finding water use efficiency at the irrigation system level.

Results indicate that water reuse contributes significantly to water productivity. However, it does increase GHGs due to pumping. Achieving high water productivity would require additional use of fossil energies, which in turn could increase the energy use competition and can result in a decrease in economic results. Given the increasing concerns on climate change and sustainable energy use, an optimal combination of water and energy use is essential.

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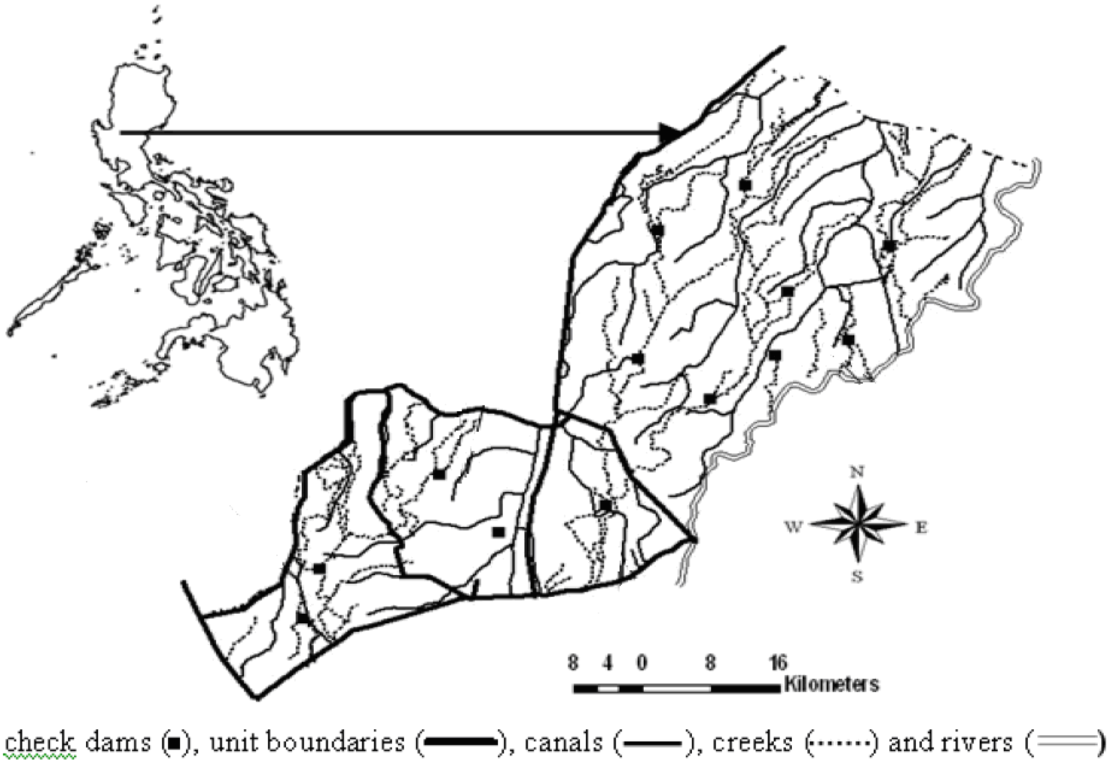

Figure 1 Location of the District 1 of the UPRISS, Philippines

Table 1 Global warming impact (GWI) (kgCO$_2$e/kg) of agrochemicals

Chemicals	GWI[1]	Chemicals	GWI[2]	Chemicals[2]	GWI
Nitrogen	3.270	Insecticides	21.7	Molluscides	22.16
Phosphorus	1.340	Herbicides	30.10		
Potassium	0.642	Fungicides	14.7		

Source: [1]Kim and Dale (2003) and [2] Barber (2004)

Table 2 Main characteristics of District I, UPRIIS

Descriptions	**District I**
Total area (ha)	18,003
Rice area (ha)	13,571
Upland crop (ha)	1,629
Rest (ha)	2,803
Canal Rice area (ha)	10512
Pump Rice area (ha)	3059
Rice Yield (t ha^{-1})	5.31
FIA’s (number)	66
Farmers (number)	9,910
Pumps (number)	1,154
Pump users (number)	1586
Check Dams (number)	15

Table 3 Water accounting components in District I, UPRIIS

Water flows across boundaries (all in 10^6 m^3)	
Gross Inflow	408.4
Irrigation	358.4
Rainfall	50.0
Storage Change	0.0
Net Inflow	408.4
Total Surface Outflow	368.8
Committed outflow	249.7
Uncommitted Outflow	49.1
Total Depletion	112.6
Process - ET_{rice}	90.2
Non Process $ET_{non\text{-}rice}$	22.4
Available Water	158.7
Balance*	-3.0

* Calculated as net inflow – total surface outflow (committed and uncommitted) – total depletion (Rice ET and non-rice ET)

Table 4 Volume of percolation, and water reuse from groundwater, creek and check dams for District I

Descriptions	District I
Rice irrigated area by pumps (ha)	3,059
Groundwater pumping (10^6 m^3)	25.93
Pumping from creek (10^6 m^3)	1.15
Total pumping (10^6 m^3)	27.07
Water reuse from check dams (10^6m^3)	89.69
Percolation (10^6 m^3)	70.06

Table 5. Water productivity indicators with and without water reuse for District I

Descriptions	Water Productivity (kg grain m^{-3} water) -	
	Without Water Reuse	With Water Reuse
Rice area (ha)	10512	13571
WP_{gross}	0.15	0.19
WP_{riceET}	0.67	0.86
$WP_{Available}$	0.38	0.49

Table 6 GHG emissions (KgCO_2e/ha/season) from different farm inputs in rice farming from pump and canal irrigation systems

Sources	Pump irrigation (with water reuse)	Canal irrigation (without water reuse)
Pumps, pipes, fuels and oils	338.7	NA
Tractors, accessories, fuels & oils	471.8	454.1
Agrochemicals	432.2	390.4
Total	1242.7	844.5

Annex 1 GHG emissions under pump irrigation (water reuse) in District I

Descriptions	District I	GHG emissions (kgCO_2e/kg or L)	Tot GHG emissions(kgCO_2e)
No. of pumps (Kubota Model RK80)	1,154		
Pump weight	77kg/pump		26512
Total pipes wt (4”x10m PVC=2.78kg/pipe)	3208kg		1027
Pumping hour	336,241		
Diesel (L)	263,246	3.8	1000335
Oil for pumps (L)	3,116	2.68	8351
Tractor use (hr)	32,425		
Tractor wt (Kubota M. M6800DT)	2090kg		69395
Accessories wt (vary, average taken)	550kg		114136
Diesel for tractor (50.7 KW)	328789	3.8	1249398
Oil for tractor (L)	3891	2.68	10428
Fertilizer use (kg)			
N	342,608	3.27	1120328
P	70,051	1.34	93868
K	48,332	0.64	30932
Pesticides use (L)			
Insecticides	612	21.7	13280
Herbicides	1,835	30.1	55234
Molluscicides	367	22.16	8133
Total GHG emissions 3,059 ha rice (kgCO_2e/season)			3801357
GHG emissions (kgCO_2e/ha/season)			1242.7

GHG emissions associated with pumps: 77kg x 12.8kgCO_2e/kg x 336241hr/12500hr=26512kg;
GHG associated with pipes = 3208kg x 12.8kgCO_2e/kg x 6mon/240mon= 1027kg;
GHG emissions associated with tractors: 2090kg x 12.8kgCO_2e/kg x 32425hr/12500hr=69395kg;
GHG associated with tractor’s accessories = 550kg x 12.8kgCO_2e/kg x 32425hr/2000hr= 114136kg

Annex 2 GHG emissions under canal irrigation (without water reuse) in District I

Descriptions	District I	GHG emissions ($kgCO_2e$/kg or L)	Tot GHG emissions ($KgCO_2e$)
Tractor use (hr)	107,222		
Tractor wt (Kubota M. M6800DT)	2090kg		229472
Accessories wt (vary, average taken)	550kg		377421
Diesel for tractor (50.7 KW)	1087231	3.8	4131478
Oil for tractor (L)	12869	2.68	34489
Fertilizer use (kg)			
N	1,051,200	3.27	3437424
P	210,240	1.34	281722
K	160,834	0.64	102934
Pesticides (L)			
Insecticides	3,048	21.7	66142
Herbicides	6,307	30.1	189841
Molluscicides	1,156	22.16	25617
Total GHG emissions10,512 ha rice ($kgCO_2e$/season)			8877781
GHG emissions ($kgCO_2e$/ha/season)			844.5

GHG emissions associated with tractor: 2090kg x 12.8$kgCO_2e$/kg x 107222hr/12500hr=229472kg;
GHG associated with tractor accessories = 550kg x 12.8$kgCO_2e$/kg x 107222hr/2000hr= 377421kg