Quantifying the Impacts of Water Environment and Conservation for Sustainability in Northern Philippines

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Abstract

Water scarcity and water pollution are some of the crucial issues in the world. One of the ways to reduce the impact of water scarcity and pollution is to expand water and wastewater reuse. This paper presents two case studies to quantify impacts on water environment and conservation for sustainability, such as (1) using a low-cost gravity-type drip irrigation system (LCDIS) for lettuce (Lactuca sativa) and tomato (Licopersicum esculentum) during two dry seasons; and (2) re-use of greywater (such as kitchen and laundry wastewater from households) for swamp cabbage (Ipomea aquatica).The case study 1 aimed to evaluate the performance of the low-cost gravity-type drip irrigation system under field conditions. Specifically, the study aimed to: a) determine the irrigation efficiency using gravity-type drip irrigation and furrow methods of irrigation; b) assess the growth and yield of lettuce and tomato as affected by different irrigation methods; and c) compare the economic feasibility of LCDIS with the farmer's practice on lettuce and tomato. Field plot experiments were laid out separately for each crop to compare LCDIS and furrow irrigation method (as farmer's practice). Agronomic parameters, irrigation performance indicators and crop yield components were gathered using standard methods. Results showed that using LCDIS revealed savings of 50% of water applied for lettuce and tomato with a yield increase up to 3 t ha-1 during the dry season as compared to the traditional furrow irrigation method used by farmers. Economic of scale suggest that LCDIS is feasible for large areas planted to high value crops. The case study 2 aimed to ascertain the effects of greywater such as kitchen waste water (KWW) and laundry waste water (LWW) from household on swamp cabbage in terms of the major chemical properties of KWW and LWW; effects of the level of concentration of KWW and LWW on the number of shoots, net growth and root length of swamp cabbage; and estimate the actual evapotranspiration of swamp cabbage. Swamp cabage plants were cultured in containers separately at different levels of KWW and LWW dillutions. The experiments were laid out in randomized complete block design under controlled environment. Water quality and agronomic parameters were gathered using standard procedures. Results of the study showed significant differences on some water quality and vine length, root length and net growth of swamp cabbage. After 6 weeks and thereafter, the plants reacted to the different dilutions where most plants wilted and severely injured as compared to plants cultured under lower dilution and tap water (as control). One hundred percent (100%) survival was observed under amended greywater (lower dilution) and tap water. The foregoing results showed that there is a need to amend greywater if reused for garden agriculture and industry in the near future. Effluent reuse for agriculture should be practiced with good integrated water management to reduce negative human health impacts that could be caused by uncontrolled use, so the effluent intended for reuse should be treated adequately and monitored to ensure that it is suitable for the intended use.

Keywords: Water environment, water quality, greywater, kitchen and laundry wastewater, sustainability

1. Introduction

Food production, safety and security coupled with water scarcity and water pollution are some of the crucial issues in the world. One of the ways to reduce the impact of water scarcity and pollution is to expand water and wastewater reuse. Access to water supply and improved sanitation is one of key factors in improving health and economic food productivity. In order to increase access to water supply the following three elements are especially important; 1) development of new water sources; 2) prevention of water resource degradation; and 3) improvement in efficiency of water consumption for food production and industries. Agricultural irrigation is crucial for improving the quality and quantity of food production. Worldwide, agriculture is the largest user of water; the sector has accounted for 67% of total freshwater withdrawal in the world. Therefore more efficient use of agricultural water through wastewater reuse is essential for sustainable water management. Sustainable development of our landscapes will require an economic system that supports environmental goals. There is growing demand for accountability of both taxes spent or the imposition of regulations by all government programs. Justifying spending on environmental programs or regulating land use will require demonstration of the benefits and performance of various policies and practices. This is never a simple task but is particularly challenging in the environmental world where natural weather and landscape variability can mask the best of intentions. As demand for conservation and environmental programs continues to grow, a question emerges from policy makers, agencies, interest groups, and the public: How do we measure success? How do we best communicate to the public our success? Environmentally sound technologies protect the environment, pollute less, use resources in a more sustainable manner, recycle more wastes and products, and handle residual wastes in a more acceptable manner than the technologies which they replace. Environmentally sound technologies in the context of pollution are technologies that generate low or no waste, and they may also cover end of the pipe technologies for treatment of pollution after it is generated. Environmentally sound technologies are not just individual technologies, but total systems which include know-how, procedures, goods and services, and equipment as well as organizational and managerial procedures. Some of this technologies include the drip irrigation system (Cuenca, 1989; Pascual and Dumaoal, 1999; and van Lier, 1999). for water conservation and re-use of greywater for household or garden irrigation which are often overlooked and has showed some potential uses but needs for baseline information for environmental concern (Guerrero and Guerrero, 2004). And since the cost of irrigation depends on water supply and energy resources, there is a need for an appropriate irrigation scheme for cash crops like lettuce (*Lactuca sativa L*) and tomato (*Licopersicum esculentum)*.

Thus, the Case study 1 generally aimed to evaluate the performance of the low-cost gravity-type drip irrigation system under field conditions. Specifically, the study aimed to: a) determine the irrigation efficiency using gravity-type drip irrigation and furrow methods of irrigation; b) assess the growth and yield of lettuce and tomato as affected by different irrigation methods; and c) compare the economic feasibility of gravity–type drip irrigation system with the farmer's practice on lettuce and tomato. The Case study 2 aimed to ascertain the effects of greywater such as kitchen waste water (KWW) and laundry waste water (LWW) from household on swamp cabbage. Specific objectives were to: (a) estimate the major chemical properties of KWW and LWW from a household; (b) evaluate the effects of the level of concentration of detergent in KWW and LWW on the number of shoots, net growth and root length of swamp cabbage (*Ipomea aquatica*); and (c) estimate the actual evapotranspiration of swamp cabbage as affected by the level of concentration of KWW and LWW.

2. Materials and methods

2.1. Case study 1

The Case study 1 was conducted at the vegetable production area of the Mariano Marcos State University Batac, Ilocos Norte, Philippines. The experiment covered total area of 200 m^2 each and planted to lettuce and tomato, separately. The low-cost gravity-type drip irrigation system (US$0.48/$m^2$) was operated at constant water head of 3 meters with 20 meters length of dripperlines to simulate the steady flow rate of the emitters, which irrigated half of the area. The other half of the area was irrigated using furrow method. Each study area of 200 m^2 was divided into two plots to represent two treatments, the drip irrigation system and furrow irrigation. The irrigation performance indicators for drip include: the coefficient of manufacutring variation (Cv) was used as a measure of the anticipated variations in discharge for emitters (Van Lier, et.al., 1999); uniformity coefficient (EU) (Van Lier, et.al., 1999) and application efficiency (AE). Methods used in the studies were presented by Ganda (2005) and Balenzon (2006). The height of the plants was taken from ten sample plants in each treatment with the use of a meter stick set at the base of each plant. The diameter of the head was based on the polar and equatorial diameter of the samples from each treatment using a vernier caliper. The yield per hectare was computed based from the yield obtained from the harvest area. For alternative project cost analysis, three discounted measures commonly applied to agricultural projects were used namely, benefit-cost ratio (BCR), net present value (NPV) and internal rate of return (IRR) as described by Cuaresma (2001). The emitter discharges of the drip irrigation system were analyzed using randomized complete block design (RCBD) with four replications. The crop yield was analyzed also using RCBD with three replications. The treatment means were compared using the least significant difference test at 5% level of significance. T-test for uncorrelated means was used to analyze irrigation parameters and agronomic parameters of lettuce and tomato and separate experiments.

2.2 Case study 2

The Case study 2 was conducted at the Agricultural Engineering Model Farm, College of Agriculture and Forestry, Mariano Marcos State University, Batac, Ilocos Norte, Philippines. Four different levels of concentration of greywater such as kitchen waste water (KWW) and laundry waster water (LWW) were the treatments used is two separate controlled experiments. Four different levels of concentration of KWW and LWW were the treatments used. Three replications were laid out using completely randomized design (CRD). The KWW and LWW set-ups were placed in a 1 liter (1,000 ml) plastic bottle where the swamp cabbage was contained with soil anchorage. The following data were gathered: pH level using pH indicator paper; nitrate–nitrogen (NO_3–N) was determined using cadmium reduction method; evapotranspiration (ET) using a calibrated water level indicator was installed where the specimen was contained. Agronomic parameters gathered include vine length, number of shoots, root length, total N using the Kjeldahl method. Details of measurements are presented by Castro (2006) and Caraang (2006).

3. Results and discussion

3.1 Case Study 1

The low-cost gravity-type drip irrigation system that was used by dela Cruz (2004) which was donated by Plastro Philippines Inc., was used in the evaluation. The system was operated at 3 meters high water head with 20 meters length of dripline to evaluate the performance of the system and compare with furrow (farmer's practice) method of irrigation. Two plots were made and planted to lettuce to evaluate the performance of both irrigation methods (Ganda, 2005). The other two plots were also planted to tomato (Balenzon, 2006). The specific hydraulic parameters of the gravity-type drip irrigation system such as emitter discharge (Q_{emiter}), coefficient manufacturing variation (Cv) and emission uniformity (EU) were determined (Table 1). Emitter discharge is very important to consider in the design, operation and maintenance of drip irrigation system. Emitters were designed to discharge a small uniform flow of water at a constant rate. There were no significant differences on the emitter discharge between the two set-up of gravity-type drip irrigation system.

Table 1. Hydraulic parameters of two set-ups of gravity-type drip irrigation system.

SET-UP	$Q_{emitter}$(lph)	Cv (lph)	EU (%)
	ns	ns	ns
1	0.195	0.088	66.38
2	0.190	0.145	59.85
Mean	0.1925	0.117	63.12

ns – not significant

The coefficient of manufacturing variation was also determined and used to measure the anticipated variations in the discharge of emitters. The Cv value for Set-up 1 and Set-up 2 were 0.088 lph and 0.145 lph, respectively. Such Cv values were within the permissible level of emitter design. The emission uniformity (EU) was determined and used to describe the water distribution uniformity of the drip irrigation system. Field measurements revealed that the EU of Set-up 1 and Set-up 2 were 66.38% and 59.85%, respectively. Low EUs could be attributed to the clogging of emitters during flow measurements. However, studies of dela Cruz (2004) showed high EU of 89 to 90%. The plant parameters such as plant height, head size (polar and equatorial) and yield were considered to evaluate the performance difference between two irrigation methods. Table 2 shows that the average plant heights, head size and yield of lettuce and tomato were not significantly affected by the two methods of irrigation.

Table 2. Plant height, head size (polar and equatorial) and yield of lettuce and tomato as affected by different methods of irrigation.

TREATMENT	PLANT HEIGHT (cm)	HEAD SIZE (cm)		YIELD ($t\ ha^{-1}$)
		Polar	Equatorial	
Lettuce				
	ns	ns	ns	ns
Drip irrigation	13.20	11.93	14.79	16.09
Flush flooding	11.64	11.55	14.14	15.49
Tomato				
	ns	ns	ns	ns
Drip irrigation	80.17	4.41	3.98	36.57
Flush flooding	78.97	4.35	3.92	33.95

ns-not significant

However, the plants irrigated by the drip irrigation were numerically taller than those irrigated by flush flooding method. Furthermore, Table 2 shows that the yield of lettuce and tomato produced in plots irrigated by drip irrigation are higher than by furrow method of about 1.5 to 3 tons but did not differ significantly. The application efficiency of an irrigation system is an important indicator to know how efficient the water was applied to the field in order to minimize water waste. Table 3 shows that the application efficiency obtained on drip irrigation system did not differ significantly from the flush flooding method. The drip irrigation system gave numerically higher application efficiency because water was directly applied to the plants from time to time with a total saving on water by 50% as compared to the farmer's practice. Water might have applied directly to the rootzone; hence, losses due to evaporation and runoff were minimized.

Table 3. Application efficiency on lettuce and tomato as affected by the gravity-type drip irrigation system and furrow method of irrigation.

TREATMENT	DEPTH OF WATER (cm)		APPLICATION EFFICIENCY (%)
	Applied	Required	
Lettuce			
			ns
Drip irrigation system	2.658	2.087	78.51
Furrow irrigation	4.301	3.334	77.58
Tomato			
			**
Drip irrigation system	4.77	3.78	79.20
Furrow irrigation	4.69	3.25	69.29

** - Significant at 1% level; ns-not significant

Discounted measure using BCR, NPV and IRR showd that both irrigation systems are economically feasible (Table 4).

Table 4. Economic analysis per hectare of lettuce and tomato for agricultural production using drip irrigation system and furrow methods of irrigation.

TREATMENT	DISCOUNTED ECONOMIC MEASURE		
	BCR	NPV (US$)	IRR (%)
Lettuce			
Drip Irrigation System	1.99	50,158	49.07
Furrow irrigation	1.76	41,809	43.67
Tomato			
Drip Irrigation System	1.64	33,096	38.11
Furrow irrigation	1.39	22245	36.43

However, drip irrigation having the higher BCR is more attractive to invest in than the flush flooding method. The projected NPV_s indicate the net present value of money as well as the stream of cash flows on the entire life of investment. However, drip irrigation is more profitable than the flush flooding practice; thus, it is advisable to invest on drip irrigation system. Both IRR estimates are greater than the opportunity rate of investment of 13% which reflects that both investment options are attractive and feasible. The foregoing economic analysis showed that drip irrigation is more attractive and feasible to invest in than the furrow irrigation method. The economics of scale suggest that a drip irrigation system should be invested in a large production area planted with high value crops.

3.2 Case study 2

Table 5 shows that the pH, NO_3-N, ET, vine length, root length, net growth and total N of KWW showed significant differences among treatments of varying evels of concentration. As of this time the pH level is within the recommended values for irrigation (Van Lier, 1999).

Table 5**.** Chemical properties of greywater KWW and LWW and agronomic characteristics of swamp cabbage (*Ipomoea aquatica*) as affected by the level of concentration of treatments.

TREATMENT	pH	NO_3-N (ppm)	ET (mm d^{-1})	Vine Length (mm) at 4^{th} WAP	Root Length (mm) at 4^{th} WAP	Net Growth (mm)	Total N (%)
KWW							
	*	**	**	**	**	**	*
T_1- 0 (0%)	7.78 a	1.23 a	3.46 a	534.89 a	147.61 a	72.39 a	1.82 b
T_2-Low (25%)	7.75 a	0.21 c	2.60 b	374.94 d	24.00 c	-28.67 c	2.55 a

T_3-Medium (50%)	7.58 b	0.29 b	3.33 a	386.33 c	28.89 c	-2.67 c	2.28 a
T_4-High (100%)	7.48 c	0.33 b	2.76 b	426.00 b	50.22 c	-13.50 d	2.22 a
CV (%)	1.31	10.05	8.70	1.81	8.47	7.68	9.01
LWW							
	ns	ns	ns	ns	*	*	ns
T1- 0 (0%)	7.9	0.14	2.04	16.43	59.60 b	0.23 a	1.84
T2-Low (25%)	7.8	0.18	1.46	16.07	44.20 c	0.27 a	1.85
T3-Medium (50%)	7.9	0.17	2.44	22.33	66.67 a	-3.73 c	1.82
T4-High (100%)	7.8	0.22	2.03	14.28	59.57 b	-0.19 b	1.89
CV (%)	0.70	11.57	13.22	16.61	11.95	14.47	1.71

Note: * - significant at 5% level; ** - significant at 1% level; ns - not significant; CV - coefficient of variation. Comparison between the treatment mean of a control and each of the 3 level of concentration treatments, using the LSD.

For NO_3-N concentrations are below the maximum contamination level of 10 ppm set by the WHO. It is worthy to note that most plants obtain nitrogen as NH_4^+ and NO_3^- ions from the soil solution. Hence, irrigation with nitrogen rich effluents is beneficial to soils and plants. The foregoing results showed that the different level of concentration of KWW severely injured the swamp cabbage onward after 4th WAP. Survived was 100% at Treatment I with tap water as the medium. Based on the results of the study, high concentration of kitchen waste water severely injured swamp cabbage toward the 6th week after planting. Survival was observed for all sample plants of swamp cabbage when cultured with tap water. There is a need to treat KWW if used in irrigating aquatic plants like swamp cabbage. This time, KWW is not suitable for irrigation. Such finding corroborates with the study of Guererro and Guerrero (2004).

For the LWW, no significant differences on pH, NO_3-N, ET, vine length, total N, except on root length and net growth among four treatments (Table 5). It was observed however, that LWW is not detrimental on the growth and development of swamp cabbage up to 35 day after planting. Different levels of LWW severly injured swamp cabbage toward 42 days after planting. There is a need to treat LWW before it is used for irrigation. It is not advisable to use LWW to irrigate plants especially those that are fragile and sensitive to pollutants.

4. Conclusions

Economic indicators such as BCR, NPC and IRR revealed that both irrigation methods are economically feasible. However, the low-cost gravity-type drip irrigation system is more attractive to invest in than the furrow irrigation method. The economics of scale suggest that drip irrigation system should be chosen for larger production area of more than 1 ha be planted to high value crops. However, there is a need to consider some technical, economic and social attributes that distinguish low-cost drip irrigation systems from commercial, and other state-of-the-art of micro-irrigation systems, like drip. Likewise, fertigation using drip irrigation system should be explored. Since the fertilizer is one of the most basic needs of the plants, there is a need to know how the drip irrigation system distributes the fertilizer and how this practice can affect the growth and yield of plants. Moreover, the performance of the drip irrigation system should be evaluated on other high value crops in the locality. Based on the results of the case study 2 on greywater, high concentration of KWW and LWW severely injured swamp cabbage towards the 6^{th} week after planting. Survival was observed for all sample plants of swamp cabbage when cultured with tap water. There is a need to amend KWW and KWW if used in irrigating aquatic plants like swamp cabbage. As of this time, it is not advisable to irrigate plants especially those that are fragile and sensitive to pollutants.

Effluent reuse for agriculture should be practiced with good management to reduce negative human health impacts that could be caused by uncontrolled use, so the effluent intended for reuse should be treated adequately and monitored to ensure that it is suitable for the intended use. Effluent reuse for agriculture needs to be planned with attention to target crops and existing water delivery methods. Excess nitrogen may cause overgrowth, delayed maturity, and poor quality of crops.

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