Assessing technology and socioeconomic constraints and prospects of low-cost drip irrigation for vegetable farming in Southeast Asia

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ABSTRACT
Farmers' enthusiasm in using low-cost drip irrigation as seen at many on-farm research and demonstration sites across Southeast Asia clearly indicates a high potential of the technology to smallholding vegetable growers. Despite supports from several development agencies (NGOs and government agencies), a wide-scale farmer-to-farmer dissemination of this technology has not yet been occurred in the region. Farmers have not invested their own resources in low-cost drip irrigation kits that cost less than USD100 for irrigating a 200-300-m^2 cropland, with potential profits of more than USD200 within a crop season. Recently, questions have been raised on the effectiveness and sustainability of this technology. We have analyzed the constraints and prospects of the drip kits by reviewing and evaluating results from several on-farm research trials across the four countries in Southeast Asia (Cambodia, Indonesia, Philippines, and Vietnam). This was supplemented by information compiled from farmers' group level survey. Majority of the farmers surveyed reported saving on labor, water resources, and convenience in irrigating crops as main benefits under the drip systems. Nevertheless, farmers' adoption behavior towards the technology varies greatly across the study sites/countries. Some of the reasons for farmers' reluctant to invest on the technology are high initial investment costs, lack of local suppliers, inadequate input markets of the drip kits (inadequate local level business services to support the maintenances and services), farmers lack of understanding and basic know-how on using the drip kits, absence of rural credit systems, and poor targeting of clients/locations by the projects disseminating the technology. In fact, in many places, presence of a 'high subsidy-syndrome', that is, free kit distribution system adopted by many development projects, also has provided disincentives to farmers for investing on the technology using their sources of fund. Suggestions and recommendations are provided to encourage wider adoption of the drip technology for improving livelihoods of the smallholding farmers in Southeast Asia.

Keywords
Low-cost drip irrigation technology, vegetables, water productivity, rural livelihoods, technology adoption, impacts, farmers' perceptions, Southeast Asia.

INTRODUCTION
Flooding during the monsoon, and water shortage during the dry season are main characteristics of farming in monsoonal Asia. The majority of smallholding farmers in the Southeast Asia grow vegetables during the dry season, after harvesting rice. Therefore, agricultural water management issue in the region is closely linked with agricultural productivity, and in turn, with objectives of rural poverty alleviation. Some innovations have been made in providing water to smallholding farmers during the dry season to increase their productivity and farm income. "Simple and affordable micro-irrigation" scheme is one of them (Polak and Yoder, 2006). Other water management technologies developed for smallholding

farmers in tropical Asia include: treadle pumps, low cost water storage tank, drip kits, small electric-pump, hand pump, rain water harvesting pond, etc.

Recent effects of global warming and climate change have furthermore exacerbated the water scarcity problems in the Southeast Asia, and the way farmers grow crops (vegetables), manage the water resources, and reduce risk of crop losses. Flood related damage to farmlands and production in many parts of Southeast Asia in mid 2011 is just an example of a growing climate related risk and uncertainty in he region. Intensive vegetable production in tropical Asia takes place as peri-urban systems or cool highland systems in the hinterlands (Midmore and Jensen 2003). During the dry season, water scarcity is the major concerns for cultivation of vegetables in both the production systems. There is an urgent need for improved technology options for efficient water management to improve crop productivity, farm income, and the rural livelihoods.

With growing water scarcity, several rural development agencies have worked to develop irrigation technologies that are suitable for smallholding systems. For example, the International Development Enterprises (IDE), a non-governmental organization, has developed a low-pressure based low-cost drip irrigation technology, targeting requirements of small-plot size farmers in the tropics. This costs less than USD100 for irrigating 200-300 m^2 crop land. The focus of this paper is on the simple design and low-pressure based low-cost drip technology. Hence, hereafter the word “drip” is synonymous with a low-cost drip irrigation technology.

Wherever good access to water and market is available, farmers grow vegetables and other high value crops (Midmore and Jensen 2003; Mariyono and Bhattarai 2009). In the same way, whenever smallholding farmers adopt low-cost drip, by and large, they start growing vegetables, or other high value crops (for review, see Polak and Yoder 2006; Palanasami et al. 2011). Research and development agencies (and NGOs) are promoting this kind of low-cost drip irrigation technology also as a vehicle for growing vegetables, and to provide more income and employment to the smallholding farmers. Adoption of drip technology not only helps for diversification of crops and income sources but also makes the farming more resilient from the volatile agricultural markets, and the erratic climate change related stresses. In some clusters of Asia, adoption of the microirrigation technologies, and/or, low-cost microirrigation, has led to dramatic expansion of intensive vegetable production activities, and improved rural livelihoods (Namara et al. 2007; Bhattarai 2008; IDE 2009; Palada et al. 2010).

In South Asia (India, Nepal, Sri Lanka), the low-cost drip technology was first introduced by IDE in the mid 1990s. Several other local NGOs and governmental extension services there have also taken up the technology for out-scaling and up-scaling. In addition, recently, little more durable drip irrigation sets are provided by several private agencies in India; but with high governmental subsidy supports, which ranging from 50-90% of cost across the Indian states (Palanasami et al. 2011). Compared to South Asia, the extent of adoption and dissemination of the low-cost drip technology is at slower pace in Southeast Asia. Large part of distribution of the drip kits is done through project supports and project based distribution, with partly or complete subsidy on its cost.

Most of the studies on yield performance of simple and affordable drip irrigation kits are done largely on-station or on-farm trials, using small-size trial plots ranging from 50 to 200 m^2. The results from such on-farm research and trials have demonstrated large benefits of low-cost drip compared to the farmers’ conventional irrigation practices (Palada et al. 2010, IDE 2009; Roberts and Long 2006). However, limited numbers of socioeconomics assessments are done analyzing farmers’ constraints, their adoption behaviors and perceptions, and their investment decision-making process on the drip technologies.

Past studies have reported huge benefits of low cost drip irrigation system for smallholding farmers, and/or small-plot size farmers (Polak and Yoder 2006). However, farmer-to-farmer dissemination and wide-scale adoption of the technology have not yet been realized fully. For example, in Cambodia, most of the farmers using drip received the drip kits from project support; only very few of them have purchased, from their own source of fund[1]. The low-cost drip kits with cost less than USD100 can irrigate 200-300 m^2 cropland, which can give a potential profit of more than USD200 within a first crop season (in case of Cambodia). Nevertheless, recently, a little larger size of drip (for 1500 m^2 crop land) is getting popular among market-garden vegetables growers in northern Cambodia (Siem Reap areas). These large-size kits are distributed through input dealers in Cambodia, by an irrigation equipment supplier located in southern Vietnam.

Adoption behavior and impacts of the low-cost drip technologies have not yet been analyzed extensively, and as per the authors' knowledge, certainly not done comparing the results across wider countries (regions). Likewise, very limited information is available on farmers' experiences in its uses, and farmers evaluating the technology by themselves. In the context of South East Asia, we do not know yet what factors lead to more adoption, and/or, what factors lead to farmers' failure in sustainably maintaining and using the drip technologies. Recently, questions have been raised on the effectiveness and sustainability of this technology.

In the past, results on impacts of low-cost drip irrigation technology vary by study, by location, and crop season when the research was carried out. In one study in Sri Lanka, net income of farmers who used microirrigation systems (MIS) in the dry zone area increased substantially during 2000-2003, while there was hardly any such impact realized in the another zone (intermediate zone) of the country with moderate rainfall (Ekanayake et al. 2007). The same study reported a 19% technical efficiency improvement was recorded by high intensity MIS using farmers; land productivity measured by chili yield was highest with high intensity MIS users in the dry zone. Farmer satisfaction and land holding size were found to be important factors for better adoption of the microirrigation system (Ekanayake et al. 2007).

Outside of Asia, a recent review and synthesis study on performance and acceptability of microirrigation including drip irrigation kits has reported importance, profitability and farmers' preferences of low-cost drip for high value crops in the West Africa region (Abric et al, 2011). It also emphasizes on increasing productivity of smallholding farmers in the region by increasing their access to water through low-cost irrigation technologies. Likewise, a study in Kenya revealed that the majority of farmers who discontinued using micro-irrigation was largely due to lack of maintenance facilities nearby, irrelevant background of farming cultural where the technology was introduced, and unreliable supply of water (Kulecho and Weatherhead 2005).

Similarly, Stillhardt (2005) emphasized the importance of several factors to be considered while introducing microirrigation technologies in a place; some of them are: affordability of the drip kits, initial assistance to limited resource and subsistence farmers, training on farming knowledge, agronomic and technical support, and better access to infrastructure and markets. Local availability of system components and spare parts, and more local knowledge in customizing the kits according to farmers' needs, are also essential factors for wider adoption of the technology.

The rapid dissemination of the drip technology to smallholding farmers in eastern India was almost entirely done through subsidies provided by local NGOs, and in collaboration with IDE-India programme (DFID 2003). Whereas, the successful adoption of the affordable drip technology, particularly the customized drip kits in western India (Maharasthra and Gujarat states), was due to availability of better business support services and better output markets, and informed farmers. Market chains for fruits and vegetables in the states of Maharasthra and Gujarat,are better developed than other parts of India, thus low-cost drip kits were largely disseminated in those two states of through market-force, with least project subsidy. Relatively better education and agribusiness know-how of farmers in western India also supported this process (DFID 2003).

Both technical and economic factors are important to influence farmers' decision to adopt the low-cost microirrigation and other technologies. Namara et al. 2007 reported the following factors as important determinants for adoption of low-cost microirrigation in India: 1) level of

[1] In Cambodia, the IDE has distributed more than 1200 drip kits to farmers in the last 6-7 years. However, less than 5% of the farmers have purchased drip kits using their own funds.

education of the household head; 2) access to groundwater; 3) type of cropping pattern (cereals, vegetables and fruits, or other high value crops); 4) income source types; and 5) social and poverty status of households (communities).

With this background, the objectives of this study are to: 1) review and assess the extent of use of low-cost microirrigation technologies for small-scale vegetable farming in selected countries in Southeast Asia; 2) evaluate constraints and opportunities faced by farmers in using the drip technology, and 3) assess its impacts on farmers' resource use-, their perceptions, and their adoption behavior.

METHODOLOGY

Project study sites and locations

The study summarizes information from previous studies and on-farm research carried out in four countries in Southeast Asia (Cambodia, Indonesia, Philippines and Vietnam). One to two farming communities in each of the countries were selected as project sites for studying farmers' field level performances of low-cost drip irrigation technology. The low-cost drip kits were introduced in these sites as a component of AVRDC's research and development projects in the last 5-6 years. The project sites (farm communities) were in Prey Veng and Svay Reing provinces in Cambodia, located about 150 km south of the capital ─Phnom Penh. These communities were the pilot sites for the AVRDC-IDE Cambodia joint project on water productivity funded from CGIAR Challenge Program on Water and Food (CG CPWF) in 2005-2006. IDE has on-going drip irrigation project activities in these provinces. In Indonesia, the low-cost drip irrigation technology was introduced to farmer collaborators under the two projects: Sustainable Agriculture and Natural Resource Management (SANREM) Collaborative Research Support Program (CRSP) Vegetable Agroforestry under U.S. Agency for International Development (USAID) in Bogor, West Java and Integrated Disease Management for Chili funded by Australian Centre for International Agricultural Research (ACIAR) in Rembang, East Java. The sites in the Philippines were located in Lantapan and Bukidnon provinces, the on-farm research were implemented under the SANREM CRSP. The project site in Vietnam was located in Binh Phouc Province, in Southern Vietnam under the SANREM CRSP Project.

Number of sites and vegetable crops

During 2005-2008, 59 on-farm trials (managed by farmers and project partners) were established to assess performances of low-cost drip irrigation technology in those four countries. The most number of trials were in Cambodia (49 sites), followed by Philippines (6 sites), Indonesia (2 sites) and Vietnam (2 sites). These on-farm trials were carried out under different research projects. The scopes and methodology of these studies, and crops selected for on-farm trails, varied across the sites countries[2].

The active involvement of IDE/Cambodia office on the research made it possible to encourage more farmers to join the on-farm trials; besides IDE/Cambodia was then also using the low-cost drip irrigation as its flagship technology for livelihood improvement activities in the nearby areas of the study sites. A large number of on-farm research trials were in Cambodia; thereby more issues related to Cambodia are discussed than that of other countries.

At these on-farm research sites, with the drip systems, a range of vegetables were grown, including: cucumber (*Cucumis sativus*), eggplant (*Solanum melongena*), sponge gourd (*Luffa acutangula*), bitter gourd (*Momordica charantia*), yard-long bean (*Vigna unguiculata* var. sesquipedalis), chili pepper (*Capsicum annuum*), amaranth (*Amarathus spp*.), kangkong (*Ipomoea aquatica*), green bean (*Phaseolus vulgaris*), katuk (*Sauropus spp*), sweet pepper

[2]). Ideally, for comparison of the performances of drip technology across the sites (countries), one needs to control effects of crops, crop growing seasons, and other farm practices. In practice, it is not feasible to control all of these factors in cross – countries comparisons with diverse set of agro-climatic conditions, and with different crop growing seasons. Comparison and interpretation of these results have been done taking into consideration of these limitations of the synthesis and review study at a regional scale.

(*Capsicum annuum*), cabbage (*Brassica campestris*), mustard (*Brassica juncea*) and pak-choi (*Brassica chinensis*).

Treatments and on-farm research

In each site, a simple research trial consisting of two treatments were laid out in plots of varying sizes (100 to 200 m^2). The two treatments were: low-cost drip irrigation (improved technology), and hand-watering (farmer's practice as control). In drip system, for water storage purpose, farmers used bucket kit for small plots (20-50 m^2), and drum kit for larger plots (100-200 m^2). Most of the trial plots were one-farmer-one replication type, where the two treatments are laid out side by side with no replication. Plant spacing, crop cultural practices including fertilizer application, weeding and pest management practices were all based on farmers' own methods, they were same for the two trial plots of a farmer, and varied with vegetable crops. For the trial plots, the project provided the low cost drip kits to farmers (farmer cooperators) at no cost. The farmers provided their land areas to grow vegetables, labor and material inputs for setting up the trial plots; and they kept the critical farm data of the trial plots, as instructed by the researchers (trial supervisors).

Table 1. Number of sites and vegetable crops grown by farmers under low-cost drip kits.

Country	No. of trial sites	Vegetable crops grown
Cambodia	49	Cucumber, eggplant, yard-long bean, sponge gourd, bitter gourd
Indonesia	2	Chili pepper, amaranth, kangkong, yard-long bean, green bean, katuk (*Sauropus*)
Philippines	6	Sweet pepper, tomato, cabbage, Chinese cabbage
Vietnam	2	Amaranth, kangkong, mustard
Total	59	

Note: These trials were conducted at different periods (and different seasons) during 2005-2008.

Observations and data collection

The drip kits were evaluated based on: 1) technical performances in terms of differences on yield level, labor uses and water uses across the treatments (drip and locally followed practices); 2) suitability of the drip technology at local context of farming; and 3) marketability and profitability of the drip technology (farmers perceive additional benefits across the two treatments; drip versus local irrigation practices).

In each site, data on water use, time and labor use in irrigating crop on on-farm trials plots, and harvested yield (vegetable quantity) were collected and recorded by the farmer cooperators, with assistance of the research team (research assistants/field supervisors). To assess the sustainability of the technology, follow-up evaluation were conducted at selected sites one to two years after completion of the trials. At selected sites, farm group surveys were conducted by the project team focusing on farmers' perceptions on the technical and socioeconomic performances of the drip kits, including discussions on its limitations, further modifications and refinements needed. The results are summarized by comparing and contrasting the drip irrigation technologies related findings across the sites (and countries). Results from large numbers of on-farm trial are included from the project work in Cambodia, for convenience in comparison; the information is compared across the four countries. Our discussion, conclusions and implications are provided at the end.

RESULTS AND DISCUSSION

Data collected were at high quality and reliability, despite involvement of large numbers of farmers and huge variation on on-farm trial setting across the locations (countries). The nature and scope of the trials varied by countries, depending upon nature of project-funding available for the drip irrigation trials in each country. The results on performances of drip uses are summarized by countries.

Results from on-farm trials

Cambodia

Evaluation of the results of the on-farm trials in Cambodia in 2006 showed that, compared to traditional farmers practice (hand watering), the increased on crop yield as well as labor productivity (return per hour) and water productivity (yield per unit of water applied) all were higher in drip system (Table 2). The increase in yield (15%) coupled with the decrease in water and labor usage led to an improvement in labor productivity. The return on labor use on farming under drip irrigation was about $3.75 per eight-hour of work day, which is three times the average farm labor wage ($1.25 per day) in Cambodia in 2005-2006 (Palada et al. 2008 and 2010; Roberts and Long 2006).

Table 2. Effect of drip irrigation on selected farm performances in Cambodia (Adapted from Roberts and Long 2006; and Palada et al. 2008).

Parameters	Farmer Practice	Drip	Difference
Total crop yield (kg/m²)	0.52	0.60	+15%
Total labor use (hr/m2)	0.27	0.17	- 37%
Irrigation per unit labor use (hr/m^2)	0.15	0.04	-0.73%
Net income per unit labor use (US$/hr)	0.28	0.47	+68%
Total water usage (mm/m2)	189	108	-43%

Note: Derived from average of 49 on-farm trial data.

The most important advantages of the drip system reported by the framers were labor time saving, less drudgery of irrigating the crops, and water saving (Table 3). Other benefits of the drip, as reported by farmers, include better soil moisture, better soil aeration around plant roots, less need for weeding (labor saving), easier to irrigate, and less incidence of diseases and pests on crops (Table 3). Large-share of the additional vegetables produced were consumed within the household, majority of the drip users were subsistence farmers, and they were learning to grow vegetables and other high value crops.

Table 3. Advantages of drip irrigation as identified by drip users (farmers) in Cambodia (2006), under different project regimes (Source: Roberts and Long 2006).

Advantage/Feature of drip	CIDA-CPWF funded project (n=19)	CARE- funded project (n=30)	Sample Avg.
Labor saving (%)	82	71	75
Water saving (%)	64	76	72
Soil with good moisture (%)	36	62	53
Less weeds (%)	18	62	47
Easy to irrigate (%)	36	48	44
Healthy crops (%)	18	38	31

CIDA – Canadian International Development Agency
CPWF – Challenge Program for Water and Food
CARE- Cooperative for Assistance and Relief Everywhere

Notes: Table values indicate the percentage of respondents that selected the specified advantage. Column totals sum to more than 100% because farmers were able to identify more than one advantage.

Indonesia

In Indonesia, except for green bean, the use of drip irrigation in Bogor, West Java, did not increase vegetables yield significantly compared to similar vegetables under rainfed[3] conditions (Table 4). The relatively ineffectiveness of drip irrigation there was attributed to high rainfall since the trial was conducted during the wet season. The yields of amaranth and kangkong under rainfed conditions were slightly higher than that of the crops under drip irrigation. But in the other parts of Indonesia with less rainfall, and/or, area with inadequate access to water such as in Rembang, East Java, the benefit of drip irrigation on chili production was substantially high than that of crops in farmers' practices (Palada et al. 2011).

Table 4. Yield of vegetables (t/ha) under drip irrigation, Bogor, Indonesia, 2008 (Source: Susila et al. 2009)

Treatment	Ama	Kan	LoB	GrB	Kat
Drip	4.21	3.73	5.37	6.42	7.30
Rainfed	4.23	4.00	5.18	6.36	7.12
T-test	NS	NS	NS	*	NS

NS = not significant; *=P≤0.05

Ama-Amaranth; Kan-Kangkong; LoB-Long Bean; GrB-Green Bean; Kat-Katuk

In a focus group discussion in Rembang, Central Java, in December 2008, farmers using the low-cost drip for chili mentioned that they were even ready to pay up to USD150 per set of the drip kit, if the kits were available at the local market. Chili farmers in Rembang pointed out several benefits of using drip such as convenience (less drudgery) of irrigation, saving in electricity cost on pumping water, saving of labor time, and increased crop yield. The low-cost drip kits used on trial in Rembang in 2008 were imported from India, with cost of about 50 USD per kits (price in India). IDE has no project activities in Indonesia and as per the authors' knowledge; no other NGOs or private agency is supplying such low-cost drip technologies in Indonesia. Ready availability of the low-cost drip kits is a major also observed in several other countries in Asia. .

Philippines

Selected results from on-farm trials with low-cost drip irrigation are summarized in Table 5. Yield of Chinese cabbage was increased by over 47% under drip irrigation compared to locally followed rainfed farming. Yield of common cabbage, tomato and pepper under low-cost drip irrigation system increased by 32%, 23% and 38%, respectively, despite of frequent rainfall during the crop growing season in that particular year (2007). Frequent rains narrowed down the yield difference between drip and rainfed plots. A benefit-cost analysis cross these alternate means of irrigation also showed that drip irrigation was more profitable for these crops than alternate practices (Palada et al. 2011).

Table 5. Yield of common and Chinese cabbage under drip irrigation, Lantapan, Bukidon, Philippines. Dry season, 2008 (Source: Ella et al. 2008).

Crop	Drip (t/ha)	Rainfed (t/ha)	T-test (5%)	Yield increase on drip (%)
Common cabbage	45	34	NS	32
Chinese cabbage	50	34	*	47
Tomato	48	39	NS	23
Pepper	11	8	NS	38
Mean	39	29		34

*Significant; NS= Not significant

On the other hand, in a research managed vegetable agroforestry system trial in the Philippines, drip irrigation on bell pepper did not provide advantage over the control treatment (rainfed) (Table 6). Installing root barrier between pepper and tree hedgerows improved growth parameters and pepper yield; they were almost similar with that of drip-irrigated plots without

[3] Unlike other places, the tropical Indonesia receives frequent rainfall; hence, rainfed vegetable is cultivated profitably at several places in Indonesia.

root barrier (Table 6). The difference in fruit yield and total biomass between the control and drip-irrigated plots was about 1.0 $t.ha^{-1}$ (Table 6). This insignificant effect of drip irrigation treatment was due to the even distribution of rainfall during the field experiment period; the rainfed crop did not have any moisture stress during the crop growth period. Compared to farmers practice (rainfed), the installation of root barrier slightly increased yield of bell pepper, but the difference was statistically not significant at 5 % level.

Table 6. Effect of drip irrigation on growth parameters and yield of bell pepper, Bukidnon, Philippines, Dry season, 2008 (Source: Mercado et al. 2008).

Treatment	Biomass[1] (t/ha)	Fruit yield DW[2] (t/ha)
Rainfed	3.77	2.12
Drip	4.80	3.23
Root bar.	5.58	3.00
Mean	4.72	2.78
SED	0.40ns	0.33ns

[1] Determined at harvest. [2]Dry weight. ns=not significant.

Vietnam

Of the three leafy vegetable crops included in trials in Vietnam study sites, yields of amaranth and mustard green were significantly higher in drip irrigated plots than in plots under furrow surface irrigation, or plot with hand watering (Table 7). Drip irrigation did not increase yield of kangkong, instead was slightly lower than that of the crop under farmer's practice (hand watering). There was also no major economic advantage (cost saving) from vegetables cultivation in under the low-cost drip irrigation kits developed by IDE with compared to farmer's irrigation practices.

Table 7. Yield of selected vegetables under drip irrigation and alternate technologies, Vietnam, 2008 (Source: Phouc et al. 2011).

Treatment	Amaranth (t/ha)	Mustard (t/ha)	Kangkong (t/ha)
Drip	10.3	9.5	11.6
Hand watering	9.3	8.8	11.4
T-test	*	**	ns

* = P<0.05; ** = P<0.01; ns = Not significant

Farmers' evaluation and experience

This section presents farmers' responses compiled from interviews with farmers' group using the drip irrigation, and farmer cooperators involved in on-farm research. The information is summarized in terms of technical performance, suitability, and marketability of the drip technology. The specific results and farmers' responses varied by the sites, nevertheless, in all these sites, the most common benefits of low-cost drip irrigation reported by the farmers are savings in labor time and quantity of water use under drip system compared to farmers' practice of irrigation (control).

Technical performance

This section presents variation on selected technical performance of the drip technology across the sites (countries). Farmers in Vietnam and Cambodia reported about 42-43% water savings[4] under the low cost drip irrigation versus alternate hand watering irrigation method (Table 8). Labor saving in drip systems ranged from 27% in Vietnam to 65% in Indonesia, and it was 38% in Cambodia (Table 8). Crop yield under drip irrigation increased by 10% in Vietnam to 64% for the Philippines (Table 8), however, the use of drip irrigation did not result in higher net

[4] No data on quantity of water uses by irrigation regimes were available (collected) from on-farm trials conducted in Indonesia and the Philippines.

income to the farmers in the very first year of cultivation. Farmers in Cambodia reported a net income increase by only of 3%, whereas farmers in Vietnam reported a 7% increase in net income (Table 8) in the first year of drip use. This is due to high initial cost of the drip kits, an added expense in farming in the first year. However, in the second and succeeding cropping season, the net income could increase as the drip kits will last for 3- 4 cropping season.

Table 8. Technical performance of low-cost drip irrigation technology based on farmers' response and experience across the study sites (Source: Palada et al. 2011)[1].

Criteria	Cambodia (%)	Indonesia (%)	Philippines (%)	Vietnam (%)
Water savings	43	NA	NA	42
Labor savings	38	65	NA	27
Yield increase	15	15	64	10
Net farm Income	3	NA	NA	7

NA = data not available
[1]The data are compiled from on-farm research trials as reported earlier; out of results from each country level studies, as also noted earlier.

Suitability

In this section we present results on: 1) problems or constraints farmers experienced in using the drip irrigation system; and 2) farmers' suggestions for improving the drip irrigation system. The major issues on use of the drip, as mentioned by the drip users (farmers), are grouped into two major categories: technical and socioeconomic constraints. The results are summarized in Table 9. The most important constraints on using the drip system, as faced by the farmers, was clogging of drip lines. In Cambodia, farmers mentioned difficulty in filling the water jar (water container) since it was raised up to 2 meters high and hauling water from water source took considerable amount of their time and also it was drudgeries task. In Indonesia, farmers reported that the main line (tube) was not working properly─with several leakages, and additional labor days required to set up the drip system. Uniformity in water distribution, especially on uneven slope of field, was the other major problem encountered by farmers in the Philippines and Vietnam. Farmers also faced leaking of water from the fittings (joints) that connect the main and sub-main lines to the main valve. The O-rings and gaskets of the low-cost drip were made of low-quality materials and so were broken easily. The farmers there also pointed out that frequent rainfall led drip irrigation to be less effective. This was particularly the problem in Indonesia and Philippines, with high tropical rainfall frequency.

In terms of gender aspect of technology adoption, farmers in Cambodia pointed out some extent of different roles of men and women in using the drip and in growing vegetable under drip systems. Men prepared the row/beds, carried or pumped water into the jar and managed the use of fertilizers and pesticides. In most cases, women planted the crop, involved in weeding and taking care of the crop, and were responsible for selling the crops.

In Cambodia, most farmers were able to solve locally the drip use related problems such as cleaning blocked micro tubes by blowing and shaking, placing a ladder near water jars that were too high, and pumping water to small jars and needed to be filled regularly. Farmers also suggested using high quality fittings, O-rings and gaskets to reduce water leaks. In the case of non-uniformity of water distribution, farmers also suggested to have a control valve on the drip system to improve irrigation uniformity for uneven types of land.

Table 9. Technical and socio-economic constraints experienced by farmers using the low-cost drip technology.

Country\ Constraints	Technical	Socioeconomics
Cambodia	Difficulty filling jar, water leakage from fittings, poor quality components, clogged lines, kits not assembled, kits do not include drums	More labor needed in filling water tank, if water lifted manually
Philippines	Reduced water distribution and uniformity, drip technology is not suitable in sloping land, or, area with frequent rainfalls	No local fabricators of drip kits, so thee kits are not available locally
Indonesia	Main line not working properly, frequent rainfall drip less effective	Extra labor to set up drip, no local supply of drip, no local fabricators, or spare parts
Vietnam	Drip is not suitable for broadcasted and direct seeded vegetables	Low-cost drip sets are not readily available at the local market.

Source: Information compiled from several group discussions at the project sites with farmers using the drip irrigation, conducted at different periods during 2006-09.

Marketability

Farmers' responses on marketability of the drip irrigation system is evaluated in this section based on perceived benefits, willingness to purchase the drip kit, technology design characteristics, and source of technical information. These factors largely also varied by the sites/countries. Almost all drip users reported saving in use of factor inputs such as labor, time, and water. Other benefits mentioned by farmers were uniform water distribution on the field (Indonesia), higher and better quality of crop yields (Philippines and Vietnam).

In the early stage of technology dissemination in Cambodia**,** 22-25% of the Cambodian farmers were willing to pay between US$5.00 and $20.00 per kit (Roberts and Long 2006). Farmers in the Indonesia, Philippines, and Vietnam were also willing to buy the drip kits if the kits were locally available, and the price is affordable, or at least the same price on which it is provided by the IDE. Unlike the case in Cambodia, the low-cost drip kits are not readily available at local markets in the Philippines and Indonesia, but need to be imported from outside. Since 2009, in Vietnam, a private sector started supplying drip kits for commercial uses for larger crop acreage, and with three times higher cost than that of the drip kit supplied by IDE. This same commercial size drip kit is retailed by private dealers in some parts of Cambodia (in Siem Reap market center), with technical support from IDE. Through the help of private retailing agencies, IDE/Cambodia is importing components of drip kits, from Southern Vietnam (Ho Chi-Minh City) and retailing the drip kits in southern provinces of Cambodia.

In the context of Indonesia and the Philippines, unavailability of local fabricators to make such simple drip kits and non-existence of regular business support systems─disseminating NGOs or business support agencies─ are the critical bottle necks. In the case of the Philippines, in 2009-2010, the local government of the study site, attempted to import the drip kits from India, and to disseminate it to farmers nearby. However, due to several administrative hurdles in processing the import-permit from the government in India, the local government had to cancel the import order. In the case of the Philippines, had there been a local fabricator, the low-cost drip kits would have been disseminated to a large number of farmers.

In relation to technology design and system configuration, 60% of the farmers surveyed in Cambodia mentioned that the drip kits should be sold as pre-assembled and it should also include a water container (bucket, tank or drum) for easy and convenience in its installation even by an inexperienced farmer. A pre-assembled kit should include tank, spigot, filter, and sub-main pipe so that the farmers themselves could assemble the rest of the system (IDE 2009; Palada et al. 2008). They also reported that smaller systems of 100 m^2 to 200 m^2 would be better for them, especially for those using the drip for the first time. Only some (less than 25%)

of the surveyed farmers─ those experienced in using the drip kits─ in Cambodia preferred for a larger plot-size drip kit such as for 1,000 m^2 to 2,000 m^2 .

In Indonesia, drip users, who were also commercial vegetable farmers, suggested that the main line of the drip should be of larger-size than what is being supplied by IDE. Farmers in the Philippines felt that the drip system should be modified to increase water distribution uniformity by installing control valves to regulate water pressure. In Vietnam, farmers mentioned that the low-cost drip irrigation is not suitable for vegetables broadcasted and/or direct seeded with no fixed width between rows.

Determinants to adoption of low-cost drip kits

Based on the survey, suggestions of farmers using the drip kits, and review of literature on the topic, the major factors affecting adoption of the drip kits by smallholding farmers can be divided into four major categories[5] , as mentioned below.

1. *Location-specific factors*: agroecology, local climate, wind, rainfall pattern, crop growing season, and local farming systems;
2. *Technology-specific characteristics*: simple or complex technology, support services to farmers, and type of crops cultivated (high valued or low-valued);
3. *Farmers' specific determinants*: level of entrepreneurship, vegetable growing experience, farm training, education level, risk taking ability, etc., and;
4. *Institutions and policy factors*: agricultural policies, markets, local government supports, access to credit, training and other support, technology subsidy (or import tax).

In areas with a distinct wet and dry season, drip irrigation is more effective in the dry season. However, drip irrigation is not an effective technology for increasing farm productivity in areas with high rainfall or with frequent rainfall even in the dry season, with no distinct wet and dry season. In those areas, farmers would be reluctant to invest on the drip or other water saving devices (technologies), as was the case in some of our surveyed sites in Indonesia (Bogor) and the Philippines (Lantapan and Bukidon provinces).

Farmers' adoption decision of the drip technology is also influenced by its design (simplicity of complexity) of the drip-technology, configuration system, and how it is convenient to use. In addition, the material quality of drip kit components, its durability as perceived by the farmers, is equally important factors. Poor quality of the drip components can result in reduced efficiency and shorter life span. Farmers in Indonesia found ways to replace some of the components with other locally available materials (water supply pipe), when they encountered problems of water leaks, uneven irrigation due to low-pressure. In concurring with the facts reported by drip farmers in Cambodia, we also think that smallholding vegetable farmers will most likely adopt drip irrigation kits, even purchase in the local markets, if the system (kit) comes in a complete package, which includes tank (water container) and pre-assembled components of major parts rather than separate components. In some parts of South Asia, the low-cost drip kits are also sold in a preset package for smaller size plot area such as for home garden uses.

Under farmers' specific determinant: socioeconomic factors associated with individual farmers' characteristics, including his entrepreneurship, risk bearing ability, farming experiences, and gender dimensions of individual farmers are impact factors determining level of adoption of the drip technology. Other factors include relative cost of drip kits, availability of disposable income to the farm households, nature of crops grown by farmers. These factors greatly vary across the farmers in a community, and among farmers groups across the communities, thus, affecting level of adoption of the drip in the site.

Under institutions and policy factors: availability and access to market for the crops produced, farmers access to credit market for purchasing the drips and other farm inputs,

[5] Detailed discussions on factors affecting adoption of an agricultural technology can be found in (CIMMYT 1993; Doss 2006):

technical supports from the local extension agencies (or NGOs), access to infrastructure and road, as well as level of training and capacity building elements attached to the dissemination activities. Namara et al. (2007) have also pointed out importance of these issues in determining adoption of low-cost drip in India.

Farmers are willing to pay for the cost of the drip kits where farmers are growing high value vegetables and for market-sale (e.g. chili in Indonesia). Dissemination of this technology in areas with functional market and good infrastructure, and to farmers already familiar in growing market garden type of vegetable farming will lead to higher adoption. In areas where commercial vegetables farming is a new technology, training the farmers on how to use the drip technology, as well as how to grow vegetables for the markets would likely to increase its acceptability and adoption level. Aside from relatively high initial investment cost in setting up the drip system, the establishment of an effective distribution chain for drip irrigation kits has still a difficult task. In many places in Southeast Asia, the network of drip-kit suppliers is not well developed, and the technology largely depends on project funds that provide partial or full subsidy to acquire the kits (Abric et al. 2011).

CONCLUSIONS AND IMPLICATIONS

In our review and survey assessments, vegetables grown under the drip irrigation system generally resulted in higher crop yield and labor saving compared to the case in farmers local practices (hand watering or rainfed systems). Farmers also got more marketed yield and net farm income from drip irrigated vegetables than the alternate production system. Hence, the low-cost drip kits are effective tools for improving their access to water, and in turn, for improving productivity of smallholding farmers, especially for small plot-size farmers.

In water scarce environments, access to drip (or irrigation) alone is necessary but not sufficient for enhancing crop yield and farming productivity. Farmers' feedback on use of the drip, and its impacts on farm performances, varied by the study sites (countries) selected. This is consistent with diverse sets of study sites (countries) included in the survey. The most important benefits of using the drip, as reported by large numbers of the farmers surveyed, are savings on labor use (time) for irrigation and in other farm operation, in convenience in irrigating crops, and saving of water quantity. Yield increase under drip irrigation was not reported by large-number of farmers (sites), which also varied by crop types and by sites. The drip technology can not be effective in areas with high rainfall, and/or, areas with frequent rainfall in the dry season. Crop failures due to pest infestation, flooding and rain damage can also easily negate the benefits of drip irrigation technology, as reported by many of the farmers (sites) that we surveyed. The crop production issues also need to address along with dissemination of the low-cost drip kits.

In our study sites, clogging of drip emitters and pipe-lines was some of the common technical constraints experienced by farmers in using the drip; then, water leaking in fittings and reduced uniformity of water distribution were also reported by many farmers. At many of these surveyed sites, lack of local supply of drip kits was another critical obstacle for effective dissemination of this technology. As noted earlier, farmer level of adoption of drip irrigation technology is determined by: location specific agro-climate (growing season, rainfall pattern); technology specific factor (design and configuration, its cost); farmers specific factors (level of risk taking ability, entrepreneurship, farming experience, education, etc); and socioeconomic and policy factors (including local supply chain of drip kits, building up knowledge base, farm sector training). Thus, for successful adoption and dissemination of the low-cost drip technology, one needs to address several of these factors together.

Although benefits of increased labor and water use efficiency (productivity) were demonstrated with the use of low-cost drip irrigation, there exist several areas of further improvement to achieve its full potential. Many of the farmers surveyed (drip users) lacked farming knowledge on when and how much water to apply for their crops. Many farmers had the tendency to over irrigate the crops, which resulted in to reduce water use efficiency even in the drip irrigation systems. Along with the use of drip, training farmers in growing vegetables and other high-value crops is also critical step for sustaining adoption of the new technologies.

The crop production training should include use of new production technologies, mulching, agronomy package, IPM to decrease crop failure risk, and to improve crop yield.

Finally, improved local supply chains of the low-cost drip kits within a country (region) would facilitate effective technology dissemination, and in turn, its easy availability and affordability to farmers. In many places that we surveyed, the absence of local supply of drip kit, and local fabricators, was a major obstacle in adoption and dissemination of the technology. This is a simple technology, once farmers know how to use it, they would demand it, but at many places, private input suppliers (manufacturers) are not directly involved on its fabrication. This needs to be studied and explored in subsequent studies on the topic.

To encourage farmers to adopt the low-cost drip kits and continuation of its use in the future, external intervention on several fronts are required, as noted earlier. It is not only just distribution of the drip kits by an external agency (development NGO, or R&D agency), but continuous farm technical support from extension services locally (government, NGOs or private sectors), business development services, repair and maintenance services, and providing better access to farmers to the local markets for sale of increased produces and enhanced profitability. Assurance on sale of increased produces (vegetables) is also a good incentive to the smallholding farmers for prospectus of better farm income and profitability, which would then encourage for adoption of the improved technology such as the low-cost drip or even the large-size drip.

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