QUANTIFYING WATER AND ENERGY LINKAGES IN IRRIGATION

EXPERIENCES FROM VIET NAM

ASIAN DEVELOPMENT BANK

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Abbreviations

ADB	Asian Development Bank
CBA	cost–benefit analysis
DARD	Department of Agriculture and Rural Development
HEIS	high-efficiency irrigation system
IFPRI	International Food Policy Research Institute
IWRP	Institute for Water Resources Planning
WEIDAP	Water Efficiency Improvement in Drought Affected Provinces in Viet Nam

Weights and Measures

D	Viet Nam dong
ha	hectare
kW	kilowatt
kWh	kilowatt-hour
m^3	cubic meter
m	million
mm	millimeter
MW	megawatt
MWh	megawatt-hour
yr	year

Executive Summary

Introduction

Global water demand is projected to grow by 55%, due to increasing requirements from manufacturing, thermal electricity generation, and domestic use but most freshwater resources will continue to be used for irrigation. Competing demands for finite water resources in Asia are increasingly putting the livelihoods of billions of people in Asia at risk. While Asia is the world's most dynamic region with the fastest economic growth in the world, 29 of the 48 countries assessed by the Asian Water Development Outlook 2016 are water insecure. If left unmanaged, and with the adverse impacts of climate change, this poses a real threat to continued growth and prosperity.

Water and energy are intrinsically linked. Almost all energy generation processes require significant amounts of water, ranging from hydropower to thermal electricity generation. At the same time, energy is typically needed to make water available for human use. Lifting water for irrigated agriculture is a particularly energy-intensive process. Yet, there is limited information to quantify the use of energy in irrigated agriculture.

With growing pressures on increasingly scarce and finite water resources, the region must move toward the reduction of water use per unit of crop produced. A key avenue is through the installation of High-Efficiency Irrigation Systems (HEIS) such as drip and sprinkler irrigation systems. While such technologies generally use more energy than traditional surface irrigation (which is still largely gravity-fed), the drive toward increasing crop production with less water has resulted in the encouragement to adopt HEIS more widely. There is, however, a need to better understand the feasibility of and incentives for farmers for adopting such technologies for various cropping systems and associated tradeoffs.

To better understand energy utilization in irrigated agriculture, ADB financed a study for Pilot and Demonstration Field-Based Research: Quantifying Water and Energy Links in Irrigation for Improved Resource Utilization in Viet Nam. The study was conducted by the International Food Policy Research Institute (IFPRI) with support from a Viet Nam-based consultant within a suitable area identified in the central highlands of Viet Nam.

The study is linked to an ADB-financed project preparation technical assistance for Water Efficiency Improvement in Drought Affected Provinces (WEIDAP). The project is under implementation in Viet Nam and aims to provide improved water saving practices and technologies for high value crop cultivation in the central highlands region.

The supporting activities undertaken by IFPRI complement the project by: (i) developing an energy use check list for irrigation systems, a first of its kind tool for irrigation developers;

(ii) identifying linkages between HEIS and improved water and energy productivity; and (iii) developing elements of a business model for introducing HEIS.

High-Efficiency Irrigation and Water and Energy Productivity

The Government of Viet Nam has recommended the adoption of HEIS on approximately 0.5 million hectares (ha), with a particular focus on the Central Highlands that are best suited to this technology. Key challenges in the agriculture sector include a need for increased diversification of the sector (away from rice) and the continued need for higher quality and increased productivity for major crops with comparative advantage. The government has also invested substantially in energy development and the national energy grid. As a result, all districts in the country have access to electricity and the country's rural access to electricity is one of the highest in the region.

To improve knowledge of energy and water use in irrigation activities in Viet Nam, two sites that form part of the WEIDAP project in Viet Nam were examined. These include the improvement of the Du Du–Tan Thanh Irrigation Canal in Binh Thuan where dragon fruit are grown through pumping from various small reservoirs and groundwater. The second location, in Dak Lak, is currently mostly used for coffee, irrigated with groundwater. The irrigation water–energy linkage assessment was informed by a review of planned irrigation improvements, stakeholder consultations, and farmer interviews.

The energy use assessment includes both direct energy use (electricity or diesel) and indirect energy use (fertilizers and pesticides) in the calculation since changes in the irrigation technologies could lead to concomitant changes in indirect energy use. The broader energy assessment shows that dragon fruit production inherently uses more energy than coffee production (by a factor of 5). For coffee cultivation, electricity use is only for pumping of water. For dragon fruit cultivation, the largest electricity cost component is for artificial light to support stimulation of flowering and accelerate the production process, which consumes eight times more electricity than pumping of water, on average. Across crops indirect energy use accounts for two-thirds or more of energy expenditures of conventional irrigators.

A cost–benefit analysis (CBA) comparing conventional and HEIS irrigation for coffee and dragon fruit finds a slight negative value for the adoption of drip by coffee farmers in Dak Lak. This is because the capital costs outweigh the net benefits from lower electricity, fertilizer, and labor costs. Meanwhile, the CBA finds a positive net return from investment in HEIS for dragon fruit in Binh Thuan, largely due to savings in fertilizers. If the water savings are converted into irrigated area expansions then the investment in drip irrigation is also favorable for drip in coffee production in the Dak Lak region.

Results are sensitive to the parameters used in the analysis. Key elements driving the conclusions are (i) initial investment costs for the system; (ii) actual fertilizer savings; and (iii) the period for reinvestment into the system. The main conclusion is that adoption of HEIS is unlikely to be driven by water savings. Overall changes in energy costs, and specifically savings in fertilizer and labor costs (but not changes in the electricity costs), may be more important incentives for adoption.

A Business Case for High-Efficiency Irrigation in Viet Nam

The adoption of HEIS has increased significantly over the last several years in Viet Nam and now covers approximately 100,000 hectares. The Ministry of Agriculture and Rural Development supports the adoption of HEIS as part of its agricultural transformation strategy while the Ministry of Natural Resources and the Environment promotes it as part of its water saving strategy. HEIS is concentrated in the Central Highlands and the southeastern provinces of the country; and is chiefly applied on perennials (coffee, tea, pepper, dragon fruit, and other fruit trees); vegetables; sugarcane; and to a lesser extent, groundnut and maize. These crops are likely increasing in area over time while rice area is expected to continue to decline (but not necessarily rice production). It is also likely that adoption of HEIS would increase as long as overall government support and markets continue to favor this development.

However, compared to overall irrigated area in the country, adoption rates remain low for a range of reasons:

- (i) The majority of farmers interviewed are satisfied with the performance of the conventional system and consider no need to switch to HEIS.
- (ii) High capital cost—about 22% of farmers consider the costs to be high. The capital investment ranges from $2,200 to $3,500 per hectare.
- (iii) Lack of knowledge of HEIS—up to 20% of farmers note that they have not seen such a system and there is a lack of capacity to operate it including to use it for reduced fertilizer applications through fertigation methods.

A business model for HEIS would have several characteristics:

- (i) Focus on areas of real water scarcity. A recent analysis pointed to areas in the eastern plateau of Dak Lak (no such analysis seems to be available for Binh Thuan).
- (ii) Provide access to credit (or a subsidy—but for sustained uptake a subsidy is suboptimal) to support uptake of HEIS.
- (iii) Increase access to technology suppliers. Continued support after installation of the HEIS system is an important indicator for the sustainability of the system.
- (iv) Review the role of the extension system for HEIS. Currently, the extension service is not considered a major entry point for the adoption of HEIS. This could change if a clear role for extension could be defined.
- (v) Focus on more holistic water management in the central highland and coastal areas by taking a watershed approach.
- (vi) Improve governance of groundwater management in the region.

Recommendations

Energy–irrigation checklist: This is the first energy checklist developed for irrigation projects in the region and elsewhere. It identifies all sources of energy associated with irrigated farming such as energy used to deliver water on field, used for irrigation technologies, as well as for pesticides, fertilizers, other machinery, and equipment. The checklist needs to be further piloted and applied, and then improved based on a broader sample of irrigation projects including different cropping patterns and water sources. Suggested options include projects in the Central and South Asia regions.

Business case for HEIS: Direct energy use (electricity and diesel) currently accounts for a small share of total energy consumption and total production costs in the study region. Fertilizer is the main component of total energy expenditures. HEIS cost, while significant, is generally not a significant factor affecting adoption as areas and incomes for perennial crops (like coffee, pepper, or dragon fruit) allow financing of HEIS systems. However, there is a limited understanding of the full benefits and full costs of HEIS. Farmers generally lack incentives for the adoption of HEIS. Key areas include:

(i) Limited lack of water shortages (shortage only for some farmers during small time windows in the dry season).
(ii) Electricity costs are not high enough to incentivize HEIS.
(iii) There are no water charges that might incentivize water savings and, in turn, HEIS.
(iv) Labor costs are not sufficiently high and shortages insubstantial to incentivize HEIS.

Adoption of HEIS could be profitable, largely from savings in the use of fertilizers—if HEIS uses fertigation. Key assumptions include the cost of the technology (costs are expected to further decline as more competition is introduced into the market); the actual energy savings (particularly fertilizer savings—and potential changes in fertilizer prices); the actual water savings; and the actual labor savings. A doubling of the electricity tariff would not make a significant difference and thus would not incentivize adoption. Adoption of HEIS would also need to (i) focus on new plantations as old trees do not respond well to drip irrigation, (ii) provide capacity building for farmers, and (iii) be linked to locations of water scarcity.

The following are the recommendations of this report:

(i) Raise awareness on water (and fertilizer) requirements for optimal yields (including groundwater governance mechanisms).
(ii) Collect data on HEIS adoption levels (to be carried out by provincial government agencies).
(iii) Assess the potential impact of a water service charge on HEIS adoption.
(iv) Conduct additional studies of HEIS impacts on all energy components.
(v) Highlight key energy savings, e.g., those from reduced fertilizer application (which also reduces water pollution levels, labor cost, etc.) in promoting adoption of HEIS.
(vi) Assess the potential of enhanced groundwater governance system to reduce over-watering and induce water savings.

1

Introduction

Water and energy are intrinsically linked. Almost all energy generation processes require significant amounts of water. The most straightforward water-related process is hydroelectricity generation, providing 16% of electricity globally, 14% in East Asia and the Pacific and 13% in South Asia (World Bank 2014, 2013 estimates). Biofuels and coal are also well-known water guzzlers; and fracking has joined the list more recently. Water requirements per unit of fossil-fuel based electricity generation are particularly high at 75 cubic meters per megawatt hour (m^3/MWh) to 450 m^3/MWh. Similarly, most water supply activities require large amounts of energy with ranges from 0.4 kilowatt-hour per cubic meter (kWh/$m^{3)}$ to about 8.3 kWh/m^3 to provide safe water for humans from rivers, lakes, or seawater, for example. This includes water treatment up to a standard so that it can be used for drinking or other purposes as well as treating sewage water and effluents before releasing such waters back into water bodies.

Another important use is the pumping of large amounts of water for irrigation—worldwide approximately 40% of irrigated areas depend on groundwater, for example. South Asia alone accounts for half of all groundwater used globally. Agriculture uses the bulk of withdrawn freshwater consumed globally, about 85%, and more in developing countries and the Asia region, such as South Asia, which consumed 91% in 2013 (World Bank 2014).

With growing pressures on water resources, there is a push to reduce water use per unit of crop produced. While there are many ways to increase water use efficiency or productivity, a key avenue is through the installation of High-Efficiency Irrigation Systems (HEIS). Globally, one-fifth of all irrigated area are now under some form of HEIS (Table 1). HEIS shares are largest in Europe and the Americas. Shares are much lower in Asia, but are increasing in the region. However, HEIS generally uses more energy than traditional surface irrigation as a large share of surface systems are still gravity-fed.

As economies develop, increasing demands will be placed on water for food and water for energy. In Asia, primary energy production is expected to double and power generation to more than triple by 2050. The increased demand for energy will put additional pressure on already constrained water resources. Estimates for Asia predict a 65% increase in industrial water use, 30% increase in domestic use, and a 5% increase in agriculture use by 2030 (World Bank 2013). This illustrates the growing and acute competition among principal water users. In the irrigation subsector, energy use is primarily for ground or surface water pumping and use of petroleum for on-farm irrigation technologies and other farm machinery. Energy is also used in the production of agricultural chemicals. Continued expansion of groundwater use, its impact on water tables, the growing demand for energy and the cost to the power sector are highly relevant for Asia where energy prices often do not reflect the true cost of supply.

Table 1: Net Irrigated Area and Share of High-Efficiency Irrigation Systems

	Irrigated Area (mha)	Area with Sprinkler and Microirrigation (mha)	HEIS Share of Irrigated area (%)
Africa	8.73	2.13	24
Americas	38.88	19.79	51
Asia and Oceania	157.77	17.34	11
Europe	20.26	12.62	62
Total	**225.64**	**51.89**	**23**

HEIS = high-efficiency irrigation system, mha = million hectares.

Source: International Commission on Irrigation and Drainage. 2015. *Annual Report 2015–2016*. http://www.icid.org/ar_2014.pdf

The Asian Development Bank (ADB) has supported the Pilot and Demonstration Field-Based Research: Quantifying Water and Energy Links in Irrigation for Improved Resource Utilization in Viet Nam to identify linkages between irrigation and energy use. The study is associated with the ongoing project preparatory technical assistance for the Water Efficiency Improvement in Drought Affected Provinces (WEIDAP) in Viet Nam. The overall goal of this pilot and demonstration activity (PDA) is to improve the understanding of water and energy productivity in the operational context and increase water and energy efficiency in irrigated agriculture. The main objectives of the PDA are:

(i) Development of an Energy Use Checklist to assess energy use in irrigation systems.

(ii) Application of the checklist in two planned irrigation investments to identify linkages between HEIS and improved water and energy productivity: (a) the Du Du irrigation scheme, served by the Tan Thanh Irrigation Canal in Ham Thuan Nam district, Bin Thuan Province; and (b) the proposed pumped irrigation from the Krong Buk Ha reservoir in Dak Lak Province.

(iii) Identification of elements of a business model for HEIS (cost-sharing measures adopted, role of private sector, uptake today).

2

Energy Checklist for Irrigation Projects

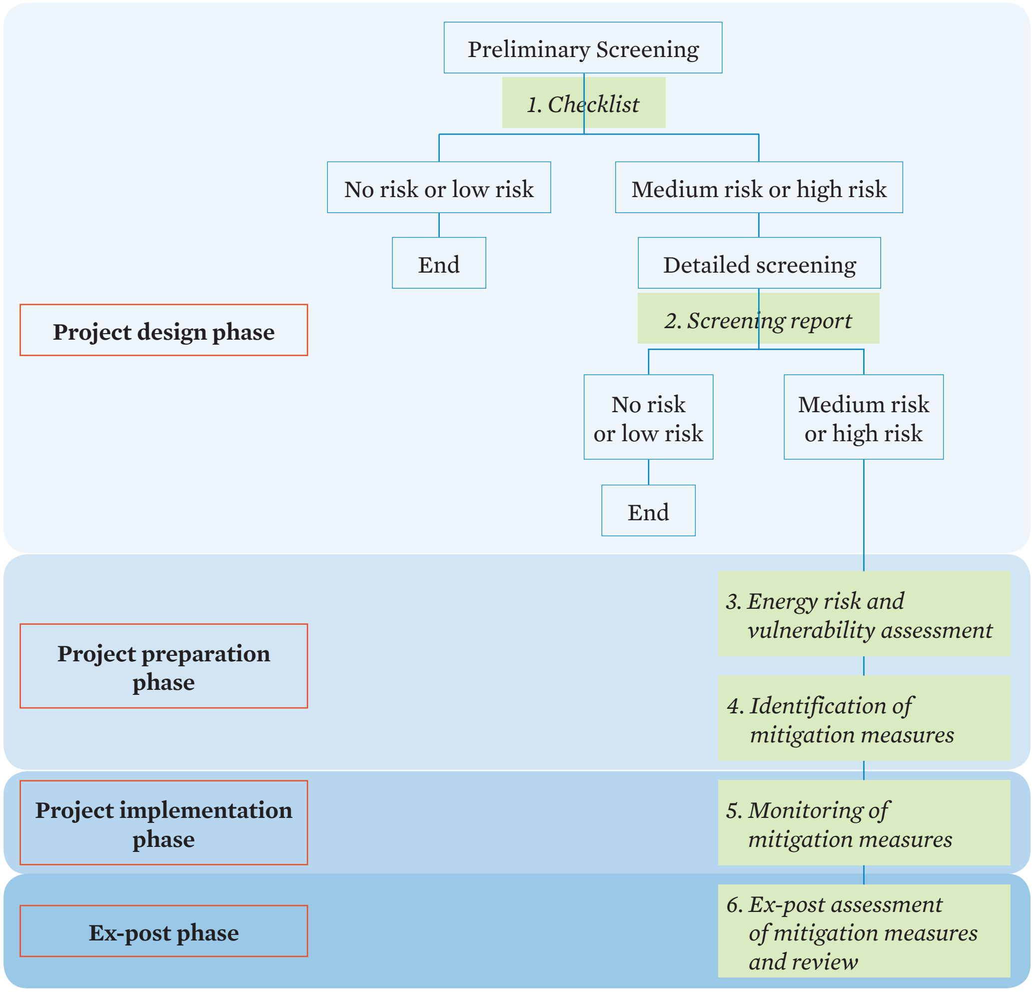
The energy checklist was developed to guide ADB project officers and other stakeholders who work on irrigation design, development, or modernization on how to assess the energy use in irrigation systems. The checklist includes three major components: (i) energy access of the site in question; (ii) information on energy linkages to the specific irrigation project; and (iii) environmental impacts like greenhouse gas emissions (Appendix, Table 1). To get feedback on the checklist, it was presented at a Water–Energy–Food Nexus workshop that was held at the International Food Policy Research Institute (IFPRI) headquarters in Washington, DC. in July 2016. The draft checklist was also shared with the Irrigation Listserve for feedback as well as with selected experts at ADB.

The following comments were received from the Irrigation Listserve and then incorporated into an updated list:

(i) Differentiate between river basin and irrigation system issues.
(ii) Distinguish between hydropower upstream, from the same source reservoir, and within the system (turbining canal water, for example).
(iii) Identify issues related to not just water sharing/supply but also operation. Timing of hydropower generation may generate significant perturbations to canal irrigation supplies service that tend to propagate chaos throughout system deliveries, and need to be managed.
(iv) Clarify, for pumping, official/public pumping versus pumping done privately by farmers. A project objective may try and decrease farmers' energy costs by providing improved surface service (at a lower cost).
(v) Sensors are not necessarily associated with high-efficiency irrigation but may have to do with Supervisory Control and Data Acquisition or automation, i.e., operation.
(vi) Include pollution considerations due to the higher energy cost in water treatment.
(vii) Consider the possibility of using crop residues on irrigated fields for energy generation.
(viii) Clarify if irrigation is needed and what are environmental flow requirements and potential competition at the basin level.
(ix) Identify the share of renewable energy sources for electricity generation.

The implementation of the energy checklist could follow a framework and sequence similar to that of ADB's Climate Risk Management (Figure 1). As such, it would include different steps at different time phases of the project cycle, with the checklist (focus of this activity) used during the project design stage. If the project were deemed to not be at risk regarding energy use or dependency, then it would proceed as usual; if a medium or high risk or dependence on energy were identified, then a screening report would be developed. During the project preparation phase, if the activity would still be considered medium or high risk, an energy risk and vulnerability assessment would be implemented that would include energy-related

Figure 1: Process for Energy–Irrigation Monitoring along the Project Cycle



Source: ADB.

mitigation measures. During project implementation, these measures and indicators would need to be monitored, and after project completion, insights from the analysis and monitoring would feed back into future project design and preparation.

The checklist was applied to the two study sites in the central highlands of Viet Nam. Based on the checklist, key energy-related differences for the two project areas relate to the type of intervention—Binh Thuan focused on upgrading of a canal system (Binh Thuan) and Dak Lak focused on reservoir-serviced irrigation. Other energy-related differences relate to the cropping pattern (dragon fruit versus coffee). Based on the draft documents on the case study sites, it was not possible, however, to fill in all sections of the energy checklist conclusively. For example, it remained unclear if the ADB suggested interventions and investments would substitute fully for ongoing groundwater based irrigation.

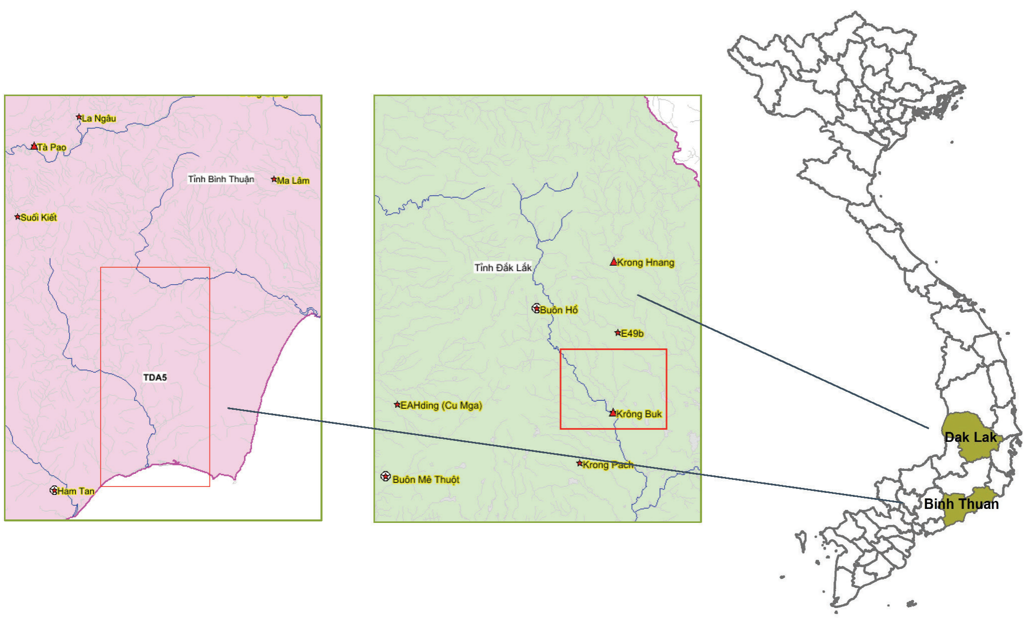
Links between High-Efficiency Irrigation and Water and Energy Productivity

3

A. Overview on Study Sites and Main Activities Linking Energy with Irrigation

To improve knowledge of energy and water use in irrigation activities in Viet Nam, two sites that form part of the Water Efficiency Improvement in Drought Affected Provinces (WEIDAP) project in Viet Nam were examined. WEIDAP aims to improve irrigation water use efficiency for high value crops in the most severely drought-affected provinces of the South Central Coastal and Central Highland Regions. The potential irrigation subprojects to be upgraded are located in Khanh Hoa, Ninh Thuan, Binh Thuan, Dak Nong, and Dak Lak provinces. The proposed project will undertake institutional strengthening of irrigation agencies to improve system management, upgrade irrigation infrastructure and introduce high-efficiency irrigation systems. Among these provinces, Binh Thuan and Dak Lak were selected, specifically the Du Du–Tan Thanh Irrigation Canal and various small reservoirs in Dak Lak Province (Figure 2).

Figure 2: Study Sites in Dak Lak and Binh Thuan Provinces



Source: ADB.

The Dak Lak subproject aims to improve water use efficiency of irrigation works in the five component areas to ensure reliable supply for 9,172 hectares (ha) of high value crops (e.g., coffee and pepper), representing an expansion of 1,710 ha that can be achieved through pumping from existing reservoirs. The subproject would finance pump stations and associated equipment to bring water from existing reservoirs to upland areas selected according to their potential for improved production of high economic value crops, with particular emphasis on areas with ethnic minority people and a high proportion of poor households. The subproject also targets institutional capacity building in project implementation activities and operation and maintenance of irrigation works (DARD Dak Lak undated).

The Binh Thuan subproject would add a new canal (Du Du–Tan Thanh canal) to the system to irrigate an area of 1,000 ha (and to overcome domestic water shortages that occur each dry season) in and around Tan Thanh commune in Ham Thuan Nam district. The objective of the subproject is to improve livelihoods and reduce poverty for 1,500 households (7,500 people) in the Tan Thanh and Ham Minh communes, Ham Thuan Nam district through the provision of reliable year-round water supply for irrigation of 1,000 ha. In addition, about 350 households (2,000 people) would benefit from access to water for domestic needs and the raising of cattle and poultry. The following outcomes are expected:

(i) improved agricultural production supported by reliable water supply;
(ii) improved access to markets and services, enhanced employment opportunities, and improved conditions for business development;
(iii) improved living conditions of people due to assured domestic water supply;
(iv) enhanced skills in agricultural production, land preparation, water management and construction of roads, canals and structures;
(v) greater community participation and self-reliance in water management and regulation; and
(vi) replenishment of ground water tables (DARD Binh Thuan undated).

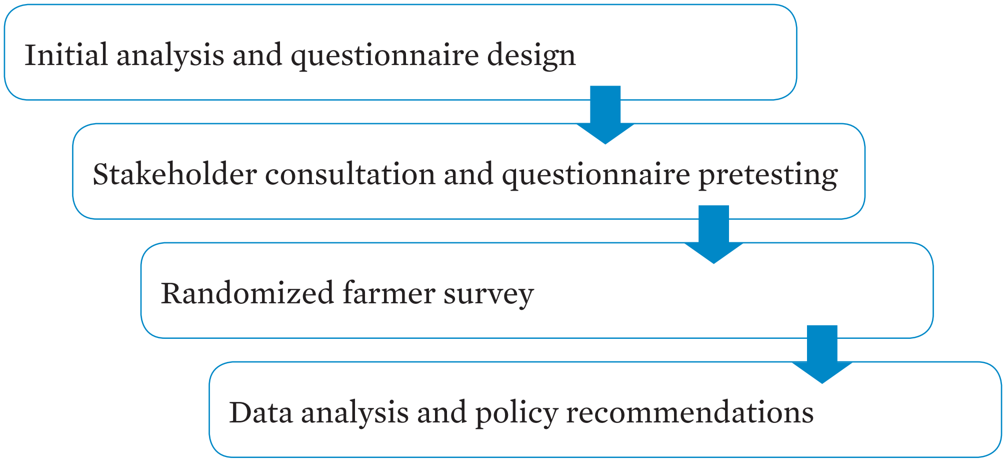
Major crops and associated areas of the two districts in which the study sites are located are presented in Table 2. Viet Nam is one of the world's largest coffee producers (*Robusta* variety) and is now the world's largest exporter of *Robusta* coffee. The Central Highlands and specifically Dak Lak is currently the largest coffee-producing area in Viet Nam. Pepper, another high value crop, is also cultivated in Dak Lak often on the same farm with coffee. Viet Nam is the world's largest pepper exporter and the largest producer, together with India. Binh Thuan is located on the country's south central coast and the main crop in the WEIDAP subproject area is dragon fruit. Dragon fruit production in Viet Nam is concentrated in Binh Thuan Province but areas are also significant in two other southern provinces: Long An and Tien Giang (Phong 2016).

Table 2: Main Crops in the Study Areas

			Area (ha)		
No.	**District**	**Main crops**	**2005**	**2010**	**2015**
1	Krong Pac, Dak Lak	Pepper	161	172	639
		Coffee	16,193	17,950	17,732
2	Ham Thuan Nam, Binh Thuan	Dragon fruit	3,657	7,026	11,719

Source: ADB.

Figure 3: Work Flow of Irrigation Water–Energy Linkage Study for Two Study Sites



Source: ADB.

The main activities of the irrigation water–energy linkage component of the study are shown in Figure 3.

Irrigation water–energy linkage assessment is informed by stakeholder and farmer interviews.[1] The focus of WEIDAP and of this study are smallholder irrigators where adoption of HEIS is highly uncommon. HEIS is more prevalent in large public and private sector-owned plantations in the region and overall adoption of HEIS is around 5%–10% for coffee in the Central Highland region of Viet Nam.

Following the results of the pretest, the questionnaire was revised and was then implemented by IWRP for this study. The final version of the questionnaire is in Appendix 1. The questionnaire was separated for conventional irrigators and HEIS farmers to elicit their respective attitudes and preferences toward or experience with HEIS adoption.[2]

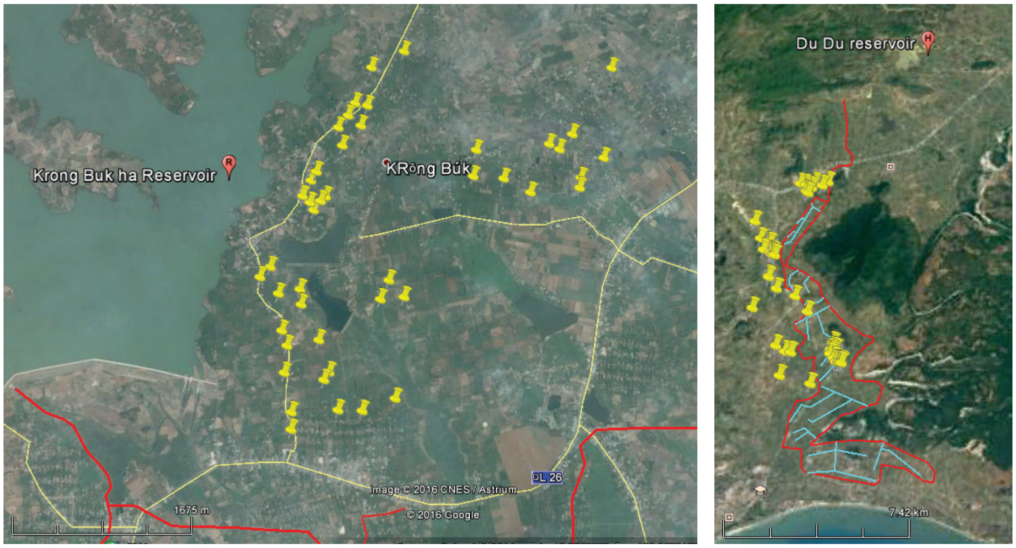
The irrigated crop survey was implemented from 10–20 August 2016 in the proposed command areas of the identified subprojects: Du Du–Tan Thanh channel and Krong Buk Ha reservoir. Irrigating farmers were randomly selected for participation. As the sample did not include HEIS irrigators, nonrandomly selected HEIS farms were added in consultation with Department of Agriculture and Rural Development officers and HEIS providers in the two provinces.

Locations of surveyed farms are shown in Figure 4. A total of 59 farmers were interviewed in Dak Lak, consisting of 49 conventional irrigators and 10 HEIS farmers. Similarly, in Binh

[1] Stakeholder consultations and the questionnaire pretest took place on 6–11 June 2016. During this field mission, Hua Xie, IFPRI and Nguyen Van Manh, IWRP, travelled to the two proposed study locations in Dak Lak and Binh Thuan provinces and held meetings with governmental officials who are in charge of agriculture, water resources, and irrigation development and management, to learn about their thoughts and insights on HEIS development.

[2] The questionnaire underwent an ethics review with the IFPRI Institutional Review Board.

Figure 4: Location of Surveyed Points in Krong Buk Ha Subproject and Du Du–Tan Thanh Subproject



Source: ADB, based on Google Map images.

Thuan, 49 irrigators were interviewed, including 47 farmers using conventional irrigation and 2 farmers who had adopted HEIS (Table 3).

Table 3: Sample Size of Farmer Interviews

	Dak Lak	Binh Thuan
Conventional	49	47
HEIS	10	2
Total	**59**	**49**

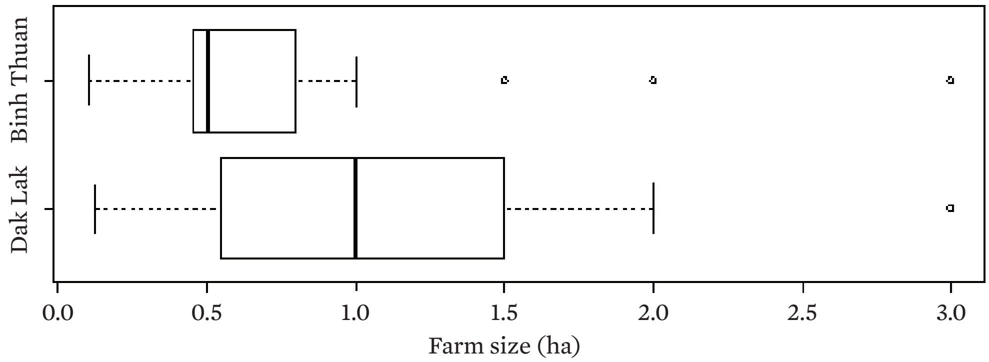
HEIS = high-efficiency irrigation system.
Source: ADB.

B. Analyses Based on Irrigated Crop Survey Data

The average size of surveyed farms is 1.3 ha in Dak Lak and 0.7 ha in Binh Thuan province (Figure 5). The interviewed farmers share the following common characteristics:

(i) All (conventional and high-efficiency) farmers are equipped with electric pumps (1.0 kilowatt (kW) to 7.5 kW).
(ii) No water tariff is charged.
(iii) Farmers use no machinery apart from motorized pumps.
(iv) Most farmers (94%) use groundwater as main source of irrigation water (Table 4).
(v) Conjunctive ground and surface water use was uncommon (Table 4).

Figure 5: Farm Size Distribution in Dak Lak and Binh Thuan Provinces



Source: ADB.

Table 4: Water Sources for Irrigation (%)

	Dak Lak	Binh Thuan
Groundwater	52	40
Surface water	3	3
Groundwater + surface water	4	6

Source: ADB, based on survey data collected for this study.

Conventional irrigation. The conventional irrigation system involves the use of a motorized pump and rubber pipes. This system is in place for most perennial crops in the Central Highlands and coastal area (coffee, pepper, and dragon fruit). The water source can be shallow or deep groundwater, or surface water with a maximum distance of 2 kilometers (km). Water is typically applied directly to the tree or to a hole surrounding the tree. The system requires intensive use of labor for irrigation, weeding, and fertilizing but is not knowledge intensive and the cheapest conventional irrigation system in use. Two photos depict conventional irrigation for dragon fruit and coffee.

High-efficiency systems. These include the drip system, the sprinkler system, and the modified or micro sprinkler system.

Drip irrigation. This is the most common HEIS system found in the irrigated crop survey. Of the 12 HEIS farmers interviewed, 11 reported the use of drip irrigation. Fertilizers are generally applied together with irrigation water during drip irrigation, an important element for the cost–benefit analysis as will be seen in the later sections. Drip is knowledge intensive and the quality of available drip systems vary. More expensive systems (about $3,000/ha) ensure that pressure is maintained in the entire drip line. Capacity requirements are significant. Some farmers note that they would need to hire labor for drip irrigation; and prefer to continue to pursue conventional irrigation. As drip applies little water at high frequency, the reliability of the source is even more important than for conventional irrigation. While farmers could afford such a system by recouping investment cost over 3 years, there is a limited history of savings combined with significant price fluctuations for the agricultural commodities in question. Two photos depict drip irrigation for the two crops studied.

Sprinkler system. Sprinkler irrigation is the second HEIS technology in operation in the Central Highlands. Sprinklers are applied in some areas where the water source is close and ensured over a multiyear period. Sprinklers are the preferred technology for vegetable crops, for example, in Lam Dong Province, but are also commonly used for dragon fruit. This method consumes a lot of water as the watered area is large and thus also requires more labor for weeding but requires less labor for irrigation. This method is costly in terms of energy consumption for irrigation.

A modified sprinkler system is being tested by the Western Highlands Agroforestry Science and Technical Institute (WASI), with the microsprinkler close to the tree trunk and water transferred to the microsprinkler via a plastic pipe system. This system tries to overcome the challenge of traditional sprinklers by avoiding that too much of an area becomes wet and some of the challenges of drip irrigation, i.e., it allows to supply the root systems of mature trees and also includes some of the benefits of drip, such as fertigation. The plastic piping might require improvement to ensure that sufficient water is applied. Similar to the drip and sprinkler systems, continuous water availability is a constraint for this technology.

Nguyen Van Manh, IWRP

Conventional irrigation method for coffee and dragon fruit in the project area.

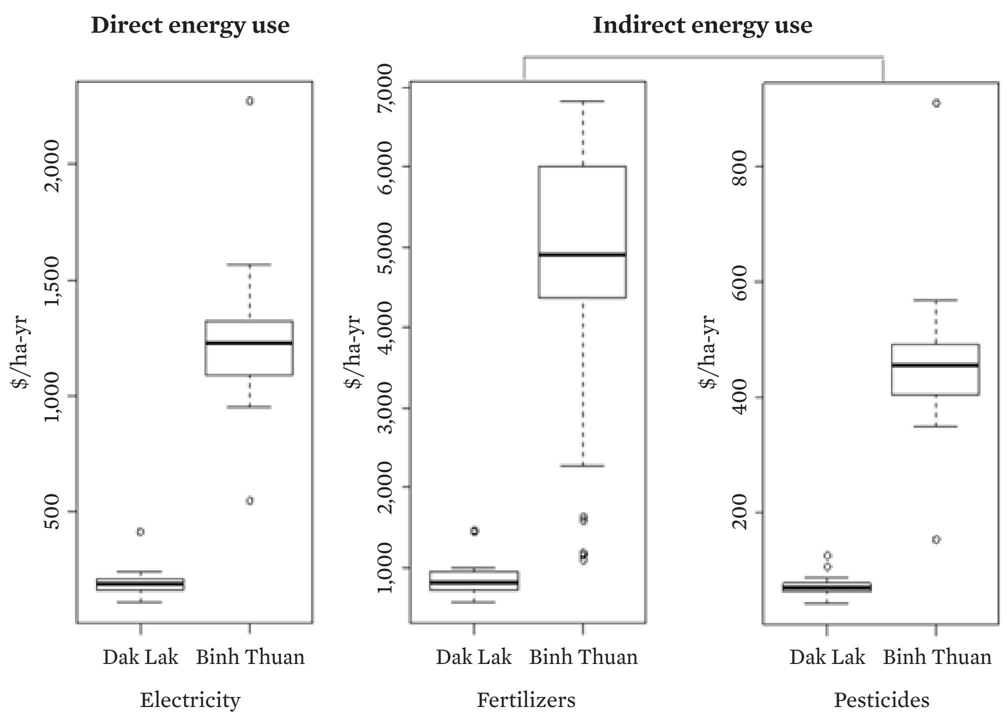
Nguyen Van Manh, IWRP

Drip irrigation systems for dragon fruit and coffee.

Energy consumption levels of irrigators

An assessment of the energy consumption patterns of conventional irrigators at the two study sites were carried out. Direct energy (electricity or diesel) and indirect energy use (fertilizers and pesticides) are included since changes in the irrigation technologies could lead to concomitant changes in indirect fertilizer use. The calculated distributions of electricity, fertilizer, and pesticide expenditures are shown in Figure 6, and the medians of the distributions are shown in Table 5.

Figure 6: Distribution of Energy Expenditures of Conventional Irrigators



ha = hectare, yr = year.
Source: ADB.

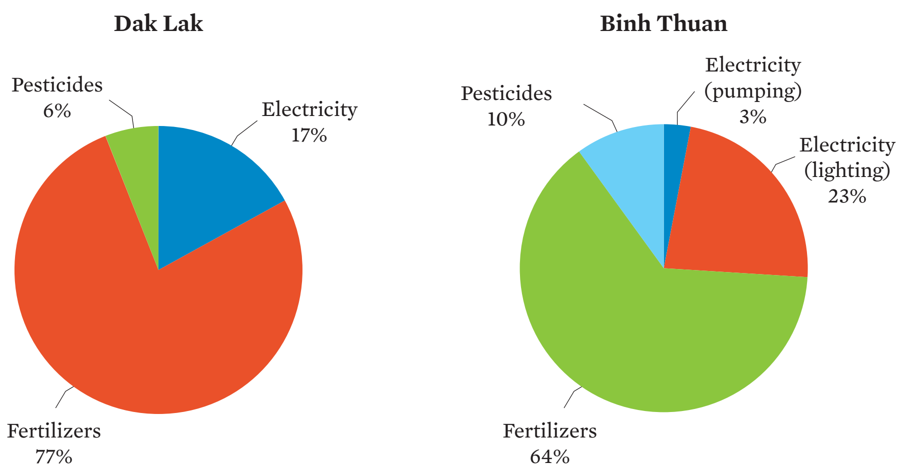
Table 5: Median Energy Expenditures of Conventional Irrigators ($/ha/yr.)

	Dak Lak	Binh Thuan
Electricity	182	136 (pumping) 1,091 (lighting)
Fertilizers	818	4,909
Pesticides	68	455
Total	**1,068**	**6,591**

Source: ADB.

More intensive energy consumption is observed in the production of dragon fruit in Binh Thuan than for coffee production in Dak Lak. There is a much wider spread across energy use components in Binh Thuan compared to Dak Lak (Figure 6). Farmers were generally reluctant to report on the use of pesticides. This could be due to the fact that some farms are certified as green or organic enterprises with restrictions on pesticide application levels. Another reason could be that pesticides are often not applied in standard quantities across years, but instead are used in direct response to an actual or perceived pest threat. While electricity expenditures in coffee cultivation refer exclusively to pumping costs, electricity expenditures for dragon fruit cultivation include costs for artificial lighting. The use of electricity for lighting is shown in Table 5. The shares of expenditures for different energy uses are shown in Figure 7. Indirect energy use, i.e., for fertilizers, accounts for the largest share of energy expenditures of conventional irrigators.

Figure 7: Share of Energy Expenditures of Conventional Irrigators



Source: ADB.

Energy expenditures of HEIS irrigators cannot be assessed directly from the study sites as farmers in these areas generally do not currently use HEIS. Table 6 presents the reported differences for the few observations from the field survey. For Dak Lak, energy use was reported to be lower for all three components of energy use assessed. For the two observations in Binh Thuan, reported energy use was higher under the HEIS system. Increased energy use under HEIS is feasible if the source of irrigation water is surface water. The number of observations is, however, too small to draw conclusions. This relates to a main challenge of the study which is to assess the potential for HEIS when there is limited HEIS irrigation in the study site.

Table 6: Comparison of Expenditures of Conventional with High-Efficiency Irrigation System Users ($/ha/yr.)

	Dak Lak		Binh Thuan	
	Conventional	HEIS	Conventional	HEIS
Electricity	182	136 (1)	1,227	1,864 (2)
Fertilizer	818	623 (4)	4,909	5,045 (2)
Pesticides	68	18 (5)	455	682 (2)

HEIS = high-efficiency irrigation system.
Note: Numbers in parentheses indicate number of responses.
Source: ADB.

C. Cost–Benefit Analysis for Irrigators

The limited sample size of HEIS farmers does not allow for quantitative estimates of energy use expenditures of HEIS. To address this challenge, a series of phone interviews were conducted with HEIS farmers only. HEIS farmers were asked to estimate their energy and labor use before and after adoption of HEIS, considering that labor savings is a major motivation of HEIS adoption. Farmers had difficulty providing such estimates in terms of absolute magnitudes; therefore, information was instead requested about the relative change in energy and labor use. By synthesizing the knowledge obtained from the irrigated crop survey, stakeholder consultations, the additional phone interviews, and a literature review, the following assumptions were developed and used for a benefit comparison analysis:

(i) The capital costs for building an HEIS is taken as D70 million per hectare (about $3,100 equivalent). A 5-year investment cycle is assumed, thus the annual capital investment is D14 million/ha (or about $636 equivalent). The annualized capital cost for building a conventional irrigation system is assumed to be D3 million per hectare per year (about $136 equivalent).

(ii) Research suggests that fertilizer use could be reduced by 50%–70% as a result of the adoption of drip HEIS, and also through appropriate fertigation in sprinkler systems, i.e., systems that apply water directly to the trees. Here, a 60% reduction in fertilizer use is assumed.

(iii) Based on discussions with experts and a review of existing literature, a 20%–30% decline in energy costs for pumping is assumed, largely as a result of the reduction in groundwater pumping. For the analysis, a value of 20% is used.

(iv) According to WASI, watering for coffee with traditional irrigation should take an average of 24 working days per hectare per year. When water saving measures are applied, the number of working days is reduced to about 15 days per hectare per year, or approximately a 60% reduction in labor costs. The daily wage rate is assumed to be D160,000 (or about $7 equivalent).

(v) No savings in pesticides use are assumed as several coffee farmers reported little pesticide use and could not describe changes in pesticide use across different irrigation technologies.

(vi) Water use for conventional versus HEIS is estimated using climate data from the two study sites (Table 7).

(vii) Currently, no tariff is charged for irrigation water use and thus none was assumed here.

(viii) Water savings incurred through HEIS at field level are assumed to be used for the expansion of irrigated area for coffee and dragon fruit production, assuming the same benefits accrue to existing production levels. The values of key parameters used in the cost–benefit analysis (CBA) are shown in Table 8.

Table 7: Estimated Irrigation Water Demand of Conventional versus High-Efficiency Irrigation Systems
(m^3/ha/yr)

	Dak Lak		Binh Thuan	
	Conventional	HEIS	Conventional	HEIS
January	551	312	660	308
February	626	312	624	431
March	755	312	655	492
April	539	312	293	492
May				185
June				
July				
August				
September				
October				
November			598	185
December	305	400	446	308
Total	**2,776**	**1,648**	**3,276**	**2,401**

ha = hectare, HEIS = high-efficiency irrigation system, m^3 = cubic meter, yr = year.
Source: ADB.

Table 8: Parameters Used for Economic Benefit Assessment of HEIS Adoption

	Price (D million/ ton)	Average yield (ton/ha)	Profit margin	Water saving (m^3 H_2O/ ha-yr.)	Estimated area increase (%)
Dak Lak: Coffee	33	2	0.6	1,128	68
Binh Thuan: Dragon fruit	1	25	0.6	875	36

D = Viet Nam dong, H_2O = water, ha = hectare, m^3 = cubic meter, yr = year.
Source: ADB.

The CBA results are presented in Table 9. Considering that electricity prices in Viet Nam are subsidized and the power industry is undergoing a reform that may lead to an increase in the power tariff (UNDP 2012), results are also provided for an alternative scenario where electricity costs are doubled.

Table 9: Estimated Benefit from Adoption of High-Efficiency Irrigation Systems ($/year)

(a) Dak Lak (baseline energy price)

	Conventional	HEIS	Δ*benefit*
Capital investment	136	636	–500
Electricity	182	145	37
Fertilizers	818	491	327
Pesticides	68	68	0
Labor	182	73	109
Water savings			1,227
Total			**1,200**

(b) Binh Thuan (baseline energy price)

	Conventional	HEIS	Δ*benefit*
Capital investment	136	636	–500
Electricity	136	109	27
Fertilizers	4,909	2,945	1,964
Pesticides	455	455	0
Labor	182	73	109
Water savings			2,500
Total			**4,100**

(c) Dak Lak (doubled electricity price)

	Conventional	HEIS	Δ*benefit*
Capital investment	136	636	–500
Electricity	364	290	74
Fertilizers	818	491	327
Pesticides	68	68	0
Labor	182	73	109
Water savings			1,227
Total			**1,237**

(d) Binh Thuan (doubled electricity price)

	Conventional	HEIS	Δ*benefit*
Capital investment	136	636	–500
Electricity	272	218	54
Fertilizers	4,909	2,945	1,964
Pesticides	455	455	0
Labor	182	73	109
Water savings			2,500
Total			**4,127**

HEIS = high-efficiency irrigation system.
Source: ADB.

For Dak Lak coffee irrigation, adoption of a high-end HEIS ($3,100 per hectare) would lead to a small negative benefit of –$27 per hectare. If water savings from the HEIS on farm were used to expand the irrigated area, net benefits would be positive, at $1,200 per hectare. The results of the CBA are based on several assumptions and discussions with experts and farmers and not on a large randomized sample of farmers. Results are sensitive to the parameters used in the analysis. Key elements driving the conclusion are (i) initial investment costs for the system, (ii) actual fertilizer savings, and (iii) the period for reinvestment into the system. Moreover, similar to electricity tariffs, fertilizer prices are subject to change. A doubling of the electricity tariff would not lead to a significant difference in results. Rather than a net cost of $27 per hectare, the investment would lead to a benefit of $10 per hectare, when water savings are not used to expand the irrigated area.

For the case of dragon fruit in Binh Thuan, the large potential savings of fertilizer through fertigation would make the investment into HEIS profitable. This is without expanding the irrigated area using water savings with a net benefit of $1,600 per hectare, if fertilizer savings can be achieved.

The conclusion here is that adoption of HEIS is unlikely to be driven by water savings. Overall changes in energy costs, and specifically changes in fertilizer costs and labor costs are more important incentives for adoption.

4

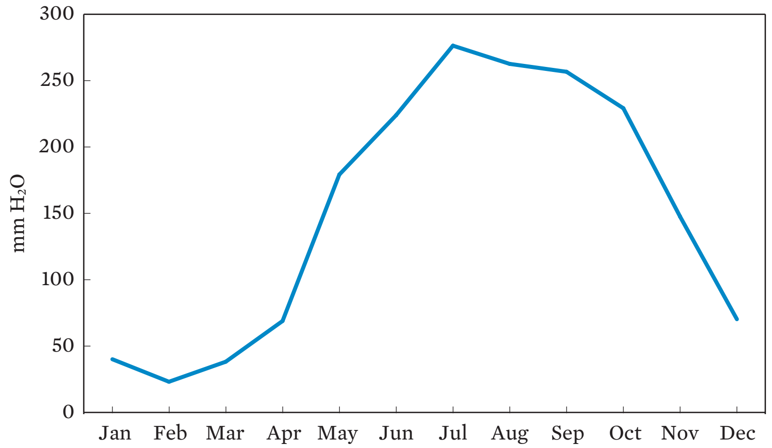
Elements of a Business Model

Limited detailed research has been undertaken to assess the viability of introducing high-efficiency irrigation systems (HEIS) and there is a tendency to provide a blanket approach to its adoption. The study highlights the importance of undertaking upstream research to determine the viability of introducing new technologies.

A. Overview of Water and Energy Resources in Viet Nam

Viet Nam has considerable temporal and spatial climate variation. The northern part of the country has a humid subtropical climate, and the climate in Southern Viet Nam is classified as tropical savanna. Annual rainfall in Viet Nam is close to 1,800 millimeters (mm), rendering the country abundant with water resources. Precipitation is concentrated in the summer monsoon. The large intra-annual variation of rainfall creates the demand for irrigation (Figure 8). Key challenges in the water sector include increased variability in the availability of water resources due to increased demand for water by nonirrigation users, chiefly cities and industries; growing demand for increased water control by irrigators; increased

Figure 8: Average Monthly Rainfall in Viet Nam, 1990–2012
(mm)



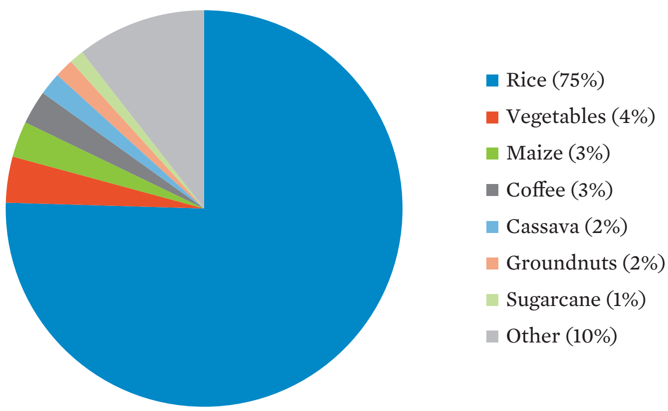
mmH_2O = millimeters of water.

Source: World Bank. 2016. Climate Change Knowledge Portal. http://sdwebx.worldbank.org/climateportal (Accessed 19 October 2016).

understanding of the need to support environmental demands; and growing, non-addressed water pollution challenges. The situation is further exacerbated by climate variability and change.

The total area equipped for irrigation in Viet Nam is 4.8 million hectares (ha).[3] The main irrigated crop is rice with smaller shares for vegetables, maize, coffee, cassava, and groundnuts (Figure 9). Of key interest for HEIS are high-value upland crops. The Government of Viet Nam is keen to increase adoption of HEIS to approximately 0.5 million ha. The particular focus is on the Central Highlands that are better suited to such upgrading compared to the large deltaic areas of the Mekong and Red River basins. Key challenges in the agriculture sector include the need for diversification of the sector away from rice and the continued need for increased quality and productivity for major crops with comparative advantage.

Figure 9: Major Crops Under Irrigation



Source: IFPRI. 2005. Spatial Production Allocation Model (SPAM) database.

Over the last decade the Government of Viet Nam has invested substantially in energy development and the national energy grid. As a result, all districts in the country have access to electricity. Viet Nam's rural access to electricity is one of the highest in the region (Table 10). Investments over the last decade have focused on reaching the "last mile," i.e., consumers who live in remote areas, such as mountains or islands. Energy supply has been able to keep up with rapid increases in energy demand. According to a report by the Asian Development Bank (ADB 2016), during 2005–2014, average annual growth in electricity demand was 12.1% and consumption grew from 45.6 terawatt-hours (TWh) to 128.4 TWh. Per capita consumption increased from 156 kilowatt-hours (kWh) in 1995 to 983 kWh in 2010 and to 1,415 kWh in 2014.

While energy sources overall are diversified, renewable energy resources are currently not highly diversified. In 2014, 46% of the energy generation mix was from hydropower (Figure 10), a share that is expected to decline over time as most suitable locations for hydropower have

[3] Food and Agriculture Organization of the United Nations (FAO). 2016. AQUASTAT. http://www.fao.org/nr/water/aquastat/main/index.stm (Accessed on June 2016).

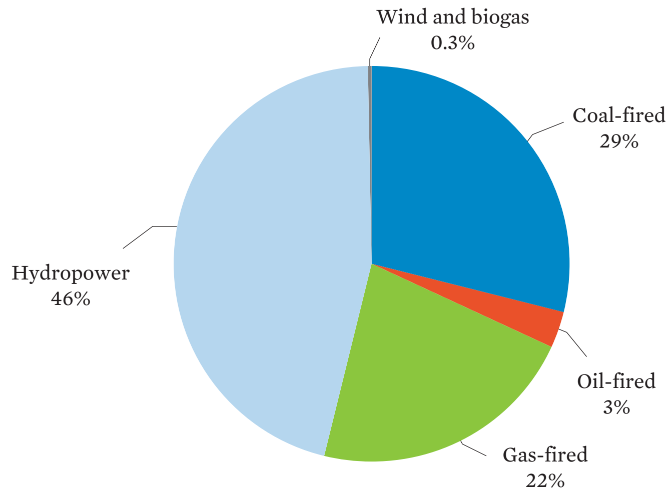
Table 10: Share Access to Electricity (Rural Areas)
(%)

Country/Year	2005	2012
Viet Nam	86.6	97.7
Cambodia	9.0	18.8
Indonesia	73.4	92.9
Lao PDR	40.0	54.8
Thailand	87.0	99.8

Lao PDR = Lao People's Democratic Republic.

Source: World Development Indicators. 2016. http://data.worldbank.org/data-catalog/world-development-indicators (Accessed on 14 October 2016).

Figure 10: Viet Nam Power Generation Mix, 2014



Source: Government of Viet Nam, Viet Nam Electricity. 2014. Annual Report. Ha Noi.

already been developed. Hydropower and associated reservoirs are important buffers under climate variability and change, but production might also be affected by climate extremes. Several reservoirs have multiple purposes supporting both hydropower and irrigation.

Key challenges in the energy sector include, among others, the need to reform electricity tariffs and to develop a competitive power market to attract investment in the sector. In 2009, the government embarked on tariff reforms with the goal to develop market-based retail tariffs. However, a cost recovery level has yet to be achieved. According to ADB (2016), as of early 2015, the average electricity retail tariff was D1,622 per kilowatt-hour (kWh, about $0.07t/kWh) without value-added tax, which covers only three quarters of the long-run marginal cost estimated at D2,100/kWh ($0.09 to $0.10/kWh). While the average retail tariff increased by 85% in nominal terms during 2007–2014, it decreased by 15% in real terms due to the weakening of the currency.

B. Overview of the Legal Background

The government is highly supportive of HEIS. In 2012, it embarked on a National Green Growth Strategy that includes various legislative elements that relate to HEIS. While some decisions and decrees include specific provisions in the irrigation sector, such as small irrigation development combined with hydropower development in mountainous areas; technological assistance and consulting services for water-saving methods; and to improve the efficiency of the management and exploitation of irrigation works, others directly focus on the development of advanced and water-saving irrigation with participation by the private sector and overall agricultural development to more high-value crops.

Decision No. 1788/QD-BNN-TCTL, 19 May 2015, Action Plan “Development of advanced and saving water technology in upland crop irrigation support for the restructuring program of the irrigation sector” is particularly useful. This decree describes how HEIS can support the restructuring of the agricultural sector towards higher added value and sustainable development and identifies high-value crops, such as coffee, pepper, tea, cashew, sugarcane, fruits, vegetables and flowers and proposes to achieve 0.2 million ha under HEIS by 2017 and 0.5 million ha by 2020 (Table 11).

Table 11: Selected Decrees and Decisions with Relevance to HEIS

Decision and Decrees	Date	Organization
Decision No. 824/QD-BNN-TT, approved the proposal to develop agricultural production to 2020, with a vision to 2030	16 April 2012	MARD
Decision No. 68/2013/QD-TTg, on supportive policies on reduction of losses in agriculture	14 November 2013	Prime Minister
Decision No. 899/QD-TTg, Project “Agricultural restructuring towards raising added values and sustainable development”	10 June 2013	Prime Minister
Decision No. 1384/QD-BNN-KH, issued an Action Plan toward implementing the “Restructuring of the agricultural sector the direction of higher added value and sustainable development.”	18 June 2013	MARD
Decision No. 794/QD-BNN-TCTL, Project “Agricultural restructuring towards raising added values and sustainable development”	21 April 2014	MARD
Decision No. 784/QD-BNN-TCTL, Decision toward improving the efficiency of the management and exploitation of existing irrigation schemes.	21 April 2014	MARD
Decision No. 1006/QD-BNN-TT, “The Action Plan for implementation of the restructuring crops productions in the period of 2014–2015 and 2016–2020”.	13 May 2014	MARD
Decision No. 1788/QD-BNN-TCTL, Action Plan “Development of advanced and saving water technology in upland crop irrigation support for the restructuring program of the irrigation sector”	19 May 2015	MARD
Decree No. 55/2015/ND-CP, supports credit policies for agricultural and rural development	9 June 2015	Central Government

MARD = Ministry of Agriculture and Rural Development.
Source: ADB, based on documents obtained from MARD.

In addition to the decisions and decrees from the Ministry of Agriculture and Rural Development (MARD), the Ministry of Natural Resources and the Environment (MONRE), the custodian of water resources in the country, also supports adoption of HEIS due to its water-saving characteristics.

Furthermore, two national standards have been developed on technical requirements for HEIS (drip and sprinkler irrigation).[4]

C. Current Status of High-Efficiency Irrigation Systems Adoption in Viet Nam

There is no conclusive information on the status of HEIS adoption in Viet Nam. This is because no agency is tasked with collecting information on this subject. There, however, are several estimates of the irrigated area equipped with HEIS systems. MARD estimates the area at around 60,000 ha, most of which is located in the Central Highlands (28,863 ha), the Southeast of the country (23,346 ha), and the Central region (6,124 ha). By contrast, estimates for HEIS areas in the Mekong Delta is 257 ha and Red River Delta is 158 ha only.

The provinces with the largest expansion of HEIS are Lam Dong (16,013 ha), Binh Phuoc (9,781 ha), and Dong Nai (nearly 7,000 ha). Table 12 shows information on the size of land where HEIS is used. Alternative estimates obtained through Key Informant Interviews suggest that application levels of HEIS technology are for about 28,447 ha of upland crops, including 21,207 ha of drip irrigation and 7,240 ha for sprinkler irrigation. A third estimate suggests that upland crops served with HEIS occupy about 143,800 ha. The areas are found in the Southeast Region (58,400 ha), the Central Highlands (35,700 ha), the Central Region (18,500 ha), the Mekong Delta (around 19,500 ha), and Northern Midlands and Mountains (above 14,200 ha).

Table 12: Area Using High-Efficiency Irrigation Systems in the Central Highlands Region of Viet Nam

No	Province	Area of HEIS (ha)		
		2005	2010	2015
1	Khanh Hoa	–	–	150–200
2	Ninh Thuan	–	–	492
3	Binh Thuan	500	–	9,600
4	Dak Lak	–	–	–
5	Dak Nong	–	–	–
6	Lam Dong	–	–	16,000
	Viet Nam	–	–	60,000–70,000

– = no data available, ha = hectare, HEIS = high-efficiency irrigation system.
Source: ADB, based on data collected from MARD.

[4] TCVN 9169:2012: National technical standard on Hydraulic structure—Irrigation and drainage system—Drip irrigation process. TCVN 9170: 2012: National technical standard on Irrigation and drainage system—Technical requirements for spray irrigation method.

Despite the variation in estimates, there is consensus that the use of HEIS increased significantly over the last several years, supported by the government's strategies as part of its agricultural transformation strategy; that the application of HEIS is concentrated in the Central Highlands and the southeastern provinces of the country; and that the key crops where this technology is currently applied include perennials (coffee, tea, pepper, dragon fruit, and other fruit trees), vegetables, sugarcane, and to a lesser extent, groundnut and maize. As these crops are likely going to grow in area over time while rice area is expected to continue to decline (but not necessarily rice production), it is also likely that adoption of HEIS would increase. There is also a caution that a distinction needs to be made between water-saving irrigation technologies and HEIS, i.e., water-saving technologies might include Alternative Wetting and Drying for rice, for example.

Adoption of HEIS technologies is very limited in the Water Efficiency Improvement in Drought Affected Provinces (WEIDAP) project areas. The identified areas of HEIS application in each subproject are presented in Table 13.

Table 13: HEIS Application in Subprojects of Viet Nam: Proposed Water Efficiency Improvement in Drought-Affected Provinces

Subproject	Province	Existing irrigation	High-Efficiency Irrigation
Rehabilitation of South Main Canal Cam Ranh Reservoir and Main Canal System of Suoi Dau Reservoir	Khanh Hoa	Mainly mango and rice, conventional irrigation and drip irrigation using surface and ground water	Drip irrigation for mango, total area less than 50 ha
High-Technology Agriculture Production Zone in Thanh Son–Phuoc Nhon	Ninh Thuan	None	None
Construction of Water Supply System for Nhon Hai Production Zone	Ninh Thuan	None	None
Du–Tan Thanh Irrigation Canal	Binh Thuan	Mainly dragon fruit, conventional irrigation using natural surface and ground water	There are several farms using drip irrigation, total area is less than 30 ha
Upgrading Irrigation System of Tra Tan Reservoir	Binh Thuan	Mainly rice, conventional irrigation	None
Water Efficiency Improvement of Irrigation Works in Dak Mil District	Dak Nong	Mainly rice, coffee, and pepper, conventional irrigation using surface and ground water	None
Water Efficiency Improvement of Irrigation Works in Cu Jut District	Dak Nong	Mainly coffee and pepper, conventional irrigation using surface and ground water	None
Irrigation system upgrading and rehabilitation for upland crops, the upgrading includes the items below	Dak Lak		
Krong Buk Ha reservoir		Mainly coffee and pepper, conventional irrigation using surface and ground water	None

continued on next page

Table 13 *continued*

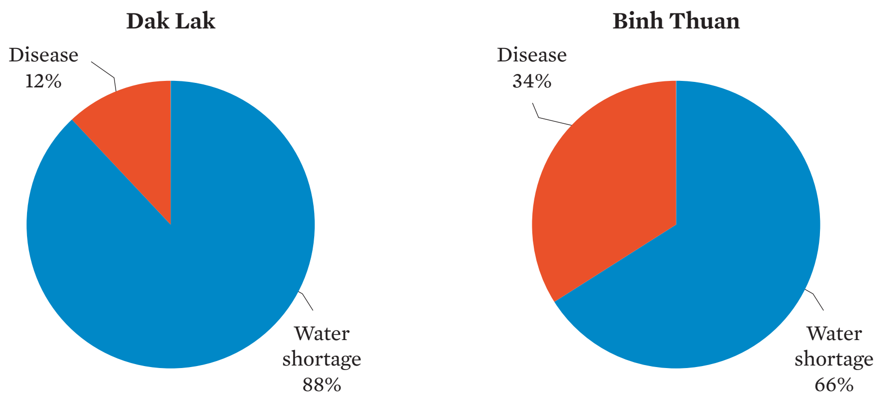
Subproject	Province	Existing irrigation	High-Efficiency Irrigation
Buon Yong reservoir		Mainly coffee and pepper, conventional irrigation using surface and ground water	None
Doi 500 reservoir		Mainly pepper, conventional irrigation using surface and ground water	None
Thi Tran reservoir		Mainly coffee and pepper, conventional irrigation using surface and ground water	None
Ea Kuang reservoir		Mainly coffee and pepper, conventional irrigation using surface and ground water	None

ha = hectare, HEIS = high-efficiency irrigation system.
Source: ADB.

D. Elements of a Business Model for High-Efficiency Irrigation Systems

Figures 11–14 and Table 14 summarize the survey results of farmers' perceptions about irrigation, and particularly about HEIS. The questions are multiple choice (Appendix 2) and farmers could thus choose several response options. Figure 11 shows the major production risks identified by irrigating farmers. Water shortage was most often identified as the key production risk. Surprisingly, while farmers are aware of price fluctuations and associated risks, this factor was not mentioned in survey responses.

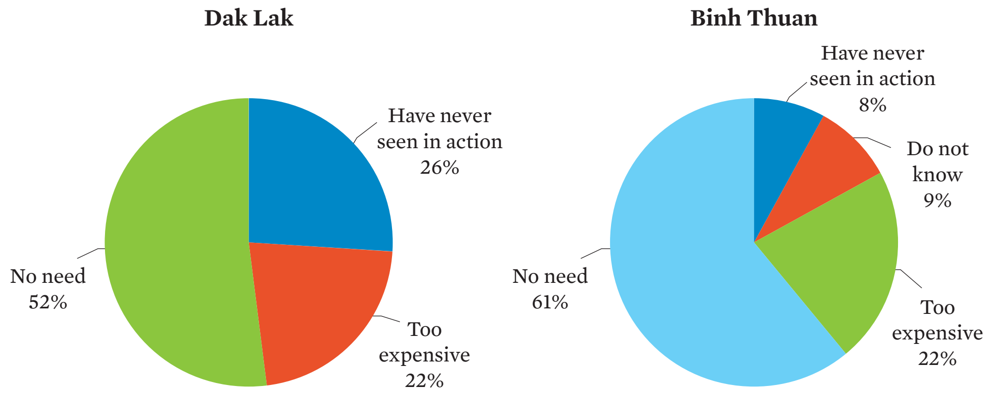
Figure 11: Farmers' Perception of Major Risks in Production



Source: ADB, based on survey data collected for this study.

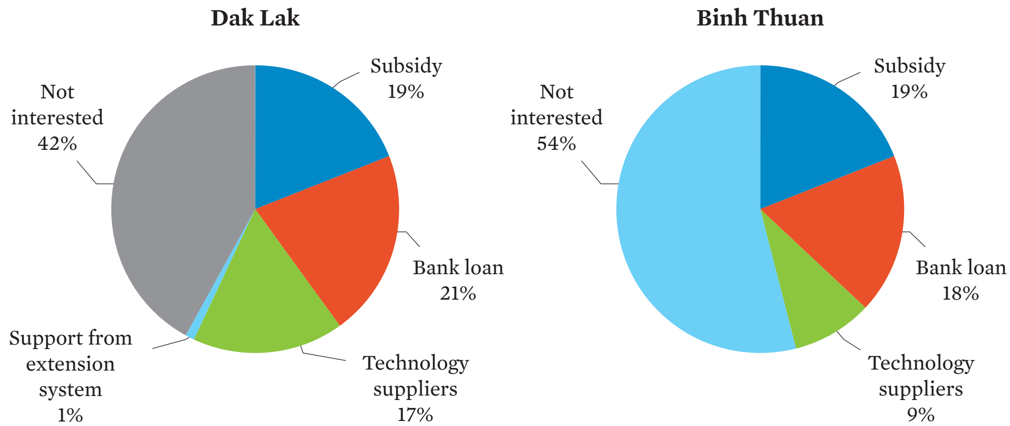
Results in Figure 12 describe some of the reasons of why conventional farmers have so far not adopted HEIS. The majority of farmers interviewed are satisfied with the performance of the conventional system and think that there is no need to switch to HEIS (52% of farmers interviewed in the case study site of Dak Lak Province and 61% of farmers interviewed in the case study sites in Binh Thuan). Moreover, in both locations about one-fifth of the farmers interviewed, or 22% mention the high cost of HEIS. The capital costs required to build an HEIS system was reported to range from D50 million to D80 million per hectare ($2,200/ha to $3,500/ha). One-fifth of farmers note that they have not seen such a system in action or do not even know the system.

Figure 12: Conventional Irrigators' Perception of High-Efficiency Irrigation Systems



Source: ADB, based on survey data collected for this study.

Figure 13: Support Needed for High-Efficiency Irrigation System Adoption

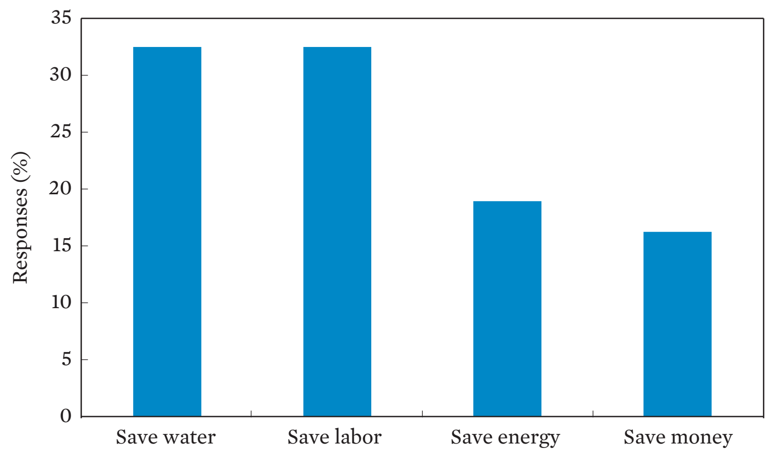


Source: ADB, based on survey data collected for this study.

A frequent response to the question of what kind of support farmers would need for adoption of HEIS was, "not interested" (Figure 13). About 42% of farmers gave this response in Dak Lak and an even larger percentage, 54% of farmers, gave this response in Binh Thuan, even though fertilizer application savings could be substantial based on the cost–benefit analysis. Almost one-fifth of respondents in both case study sites suggest that better access to bank loans or a subsidy could support the adoption of HEIS systems. Additionally, 17% of respondents in Dak Lak and 9% of respondents in Binh Thuan suggested a need for better access to technology suppliers. Dak Lak farmers also suggested a need for advice by the extension system. Clearly, the extension system is not considered a major entry point for adoption of HEIS at this point.

Figure 14 and Table 14 present insights from those irrigators who have adopted HEIS. Most systems were adopted during 2012–2015 and as such are still fairly new. HEIS adopters reported that they made the change to these advanced systems for chiefly four reasons: to

Figure 14: Reasons for the Adoption of High-Efficiency Irrigation Systems



Source: ADB, based on survey data collected for this study.

Table 14: How Do Adopters Think of High-Efficiency Irrigation Systems?

	Yes	No	Don't know
Did high-efficiency irrigation reduce your water use?	12		
Did high-efficiency irrigation reduce your energy use?	11		1
Was energy a consideration when you bought the technology?		12	
Did you need to take a loan and/or credit to obtain the technology?	2	10[a]	
Did you have any repair costs for this technology over the last 12 months? If yes, cost?		12	
Did you receive support from the HEIS vendor after the purchase?	12		

[a] Two farmers are subsized by government and received HEIS system for free.

Source: ADB, based on survey data collected for this study.

(i) save water, (ii) save labor, (iii) save energy, and (iv) save money. Water and labor savings were identified as the key reasons for adoption. It is unlikely that thoughts on energy savings always included expected changes in fertilizer applications.

While energy savings are listed as one of the motivations for HEIS adoption, energy is not perceived as a main constraint in the adoption decision (Table 14). Only one of the farmers interviewed noted that energy costs had declined. Other findings from interviewing HEIS farmers include: (i) 2 out of the 12 HEIS farmers interviewed took out loans for the HEIS investment and 2 other HEIS farmers received a subsidy from the government; (ii) there were no reportings of repair costs soon after adoption, i.e., over the last 12 months, with adoption during 2012–2015. Moreover, all farmers received support from HEIS vendors following the installation of their systems.

E. Field Information

Energy and irrigation are closely interlinked in the Central Highlands of Viet Nam. All farmers interviewed during the field visit used pumped irrigation with pumping supporting the extraction or distribution of water, applied fertilizers and sometimes pesticides, and used electricity to artificially light dragon fruit in Binh Thuan.

While energy access and use is essential to irrigation in the Central Highlands, energy access is not a limitation in any of the sites. Viet Nam has achieved a very high rate of rural electricity supply across the rural landscape. Electricity cost is not cited as a major cost concern. However, one Department of Agriculture and Rural Development member did mention that some farmers have switched from electric to diesel- or gasoline-powered pumps due to recent declines in prices for these fuels.

Farmers and the local government officials visited in the field showed a strong interest in government investment in irrigation (i.e., in the subprojects visited). Farmers mentioned that they would be willing to pay a fee for water for surface delivery if the fee would be lower than their current pumping costs (details would need to be further elaborated).

Researchers, government officials, and farmers have mixed messages on HEIS. Information remains fragmented on the research front. Local government officials are not very familiar regarding its role, benefits, and current extent. Farmers have limited information on the technologies and use a mix of imported and locally produced HEIS technologies. Some farmers develop their own HEIS systems and sell these to other farmers.

The capital costs for HEIS development are quite large—at least for imported systems—at up to D50 million per hectare (approximately $2,200/ha), and later quoted values were up to D80 million per hectare with potential need for reinvestment after 5 years. To evaluate the suitability of the investment in HEIS, it is therefore necessary to analyze the costs and benefits of HEIS adoption under the following aspects: (i) water savings, (ii) energy use, (iii) fertilizer savings, and (iv) labor savings. Some HEIS allow fertilizer to be applied with irrigation water. In this case, the adoption of HEIS may lead to a reduction in fertilizer use of up to 30% to 40% and sometimes larger savings might be feasible. Finally, several farmers cited labor savings as the key reason for the adoption of HEIS.

F. Stakeholder Feedback

The following questions were posed to key informants who were drawn from government, the private sector, and research agencies:

(i) What share of irrigation in Viet Nam (or in the provinces you are operating) currently uses HEIS (sprinklers or drip)?
(ii) How much will HEIS increase over the next 5 to 10 years in the country?
(iii) What are the main challenges for farmers to adopt HEIS?
(iv) What could be solutions to the identified challenges of HEIS in the country?
(v) Who are the main suppliers of HEIS equipment in the province and country?
(vi) Do farmers who obtain HEIS tend to use less or more energy?
(vii) Is there anything else you would like to add regarding HEIS?

Suggested rates of increase of HEIS adoption over the coming 5 to 10 years is an important element for the development of a business model for HEIS. If experts believe that adoption levels are already saturated then there is no need to provide information or awareness campaigns, subsidies, and access to bank loans or to scale up technology support from vendors for such systems. The key informants were generally reluctant to provide their own assessment of potential possible increases in adoption levels. One respondent suggested a potential area of adoption of 1.6 million ha based on suitable crops and agroecological zones but without a timeline of adoption.

Key informants provided a wide range of responses regarding the challenges of adopting HEIS in the Central Highlands of Viet Nam, in general, and specifically in relation to the adoption for coffee trees. The following are the key challenges for adoption that were identified by key informants:

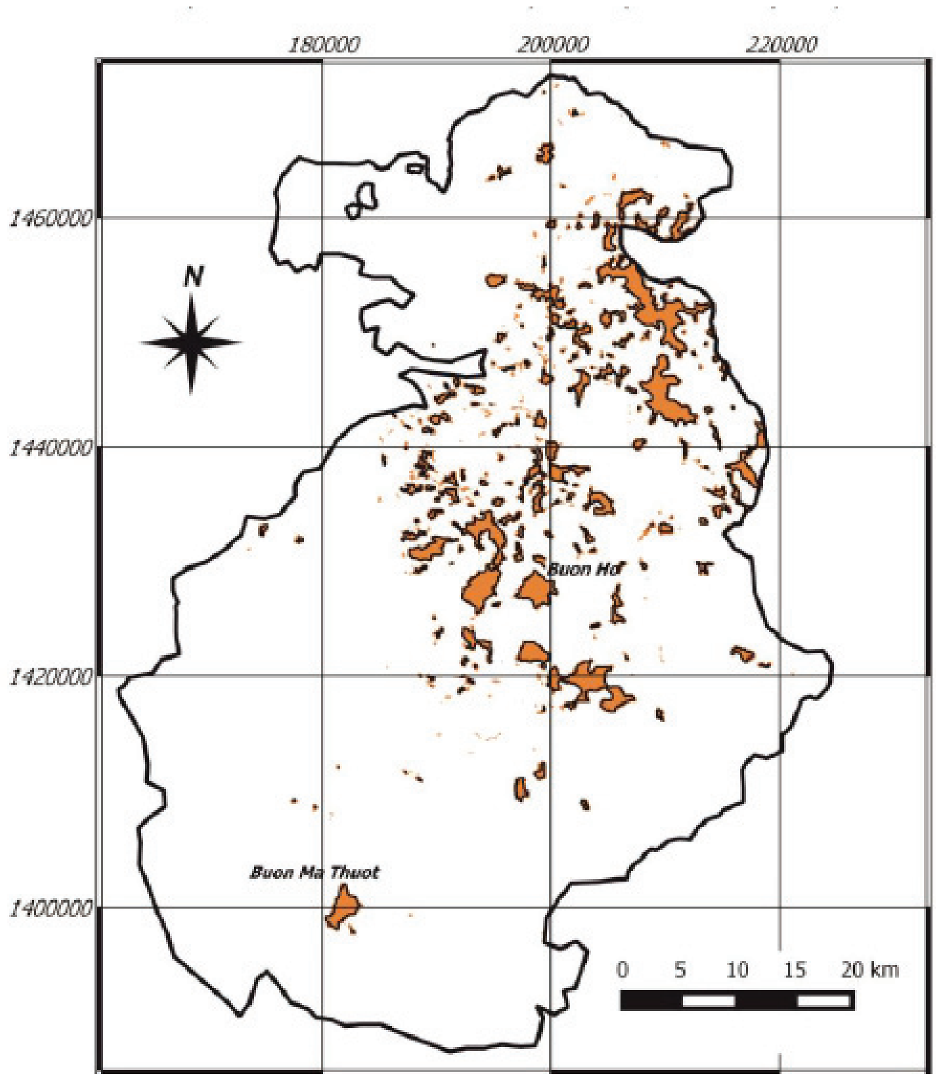
(i) The high cost of initial investment that is linked to a lack of history of savings across multiple seasons.
(ii) There is no shortage of labor that compels the adoption of advanced technologies.
(iii) There is no water shortage. Research suggests that there is no long-term depleting trend in groundwater at a regional scale. This suggests that increased groundwater pumping over the past decades has not had a negative impact on average groundwater availability. However, as groundwater recharge can take 60-100 days following the onset of the rainy season, over-irrigation still requires addressing because it is likely that excess irrigation water is retained in the unsaturated zone until onset of the rainy season. This is particularly an issue in areas where the unsaturated zone is thick and thus unnecessarily amplifying the seasonal groundwater shortages (Figure 15).
(iv) Electricity for pumping is not a major component of farm budgets, thus there is no incentive to reduce pumping fees through the adoption of HEIS.
(v) No water fees are charged, thus there is no incentive to reduce water usage through adoption of HEIS.
(vi) Highland perennial crops do not need year-round irrigation. For example, coffee only requires water application 3 to 4 times a year. A 12-month HEIS system would therefore be quite labor intensive to maintain.

(vii) There is a lack of knowledge on the full set of cost savings (direct and indirect energy, labor, water, quality, etc.).
(viii) There is a lack of awareness about HEIS.
(ix) Capacity to run advanced HEIS and understanding of true water needs for irrigation and fertilizer needs for perennial crops are limited.
(x) Agricultural commodity prices are known to fluctuate.
(xi) Linkages between smallholder farmers and markets are either insufficient or nonexistent.
(xii) There is a lack of appropriate technologies: sprinklers do not lend themselves well to fertigation (i.e., nutrients land on leaves) and water a large area; for drip irrigation, pressure is not always well-designed (at least for local systems), they are only appropriate for new plantations, and theft and rat damage are not uncommon. All these technologies are not necessarily appropriate for a system that only requires three to four applications per year and could even further reduce water availability during shortages. As a result, HEIS can be a risky proposition.
(xiii) The impact of water stress on yield and quality is still not sufficiently known, and the same is true for nutrients and pesticides.
(xiv) There is a lack of governance to support water sharing to address underground water thefts.

While key informants proposed a wide range of constraints to the adoption of HEIS, only a few proposed solutions to these challenges. The key solutions proposed include:

(i) Development of government policies to encourage water saving.
(ii) Cost reduction of HEIS.
(iii) Undertaking further study on full costs and benefits of HEIS.
(iv) Development of policies to promote public–private partnership in construction, management, and exploitation of HEIS infrastructures for key and marketable crops.
(v) Promotion of linkages between research organizations and enterprises for large-scale production and supply of HEIS equipment, facilities, and technologies.
(vi) Coupling of HEIS with appropriate moisture sensors.
(vii) Combining basin irrigation (i.e., conventional coffee irrigation) with drip irrigation using a piped system with a larger diameter, for example, made out of steel (rather than a plastic pipe) to increase water at the tail end of the system.
(viii) Combining drip with a rejuvenation program for coffee.
(ix) Focusing HEIS on pepper (instead of coffee).
(x) Raising awareness for water conservation regardless of the final technology—a change in mental models is needed.
(xi) Assessment of nutrient savings of alternative HEIS technologies.
(xii) Promotion of water sharing rather than pumping as much as possible when shortages occur.
(xiii) Establish linkages between farmers and markets so that they recognize the need for HEIS.
(xiv) Providing preferential bank loans or subsidies to coffee farmers.
(xv) Incorporation of a rainwater harvesting program together with HEIS.

Figure 15: Micro Catchments with Potential Water Shortages in Dak Lak Province



Note: Areas indicated include those with unsaturated zones close to or exceeding 30 meters where high water level amplitudes can be expected and which were also identified as water-scarcity hot spots based on current irrigation practices from a water balance and groundwater recharge perspective.

Source: E. Milnes et al. 2015. Hydrogeological study of the Basaltic Plateau in Dak Lak Province, Viet Nam.

Respondents clarified the importance of distinguishing between coffee and other perennials: both pepper and dragon fruit are substantially more profitable per hectare, which directly facilitates the adoption of HEIS. This is an insight that was also borne out in the CBA for coffee versus pepper.

Netafim is the major supplier of HEIS systems in the Central Highlands. There are also local suppliers, as well as imports from the People's Republic of China and the Republic of Korea, and the Central Highland research organization is developing local systems.

According to those interviewed there is a general agreement that while using HEIS also requires energy (largely for pumping), energy cost is lower than for traditional groundwater pumping as less water is used in HEIS. There is also an understanding that more measurements are needed and that not all HEIS relying on using groundwater save electricity costs. If surface systems are used, then electricity costs would be higher with HEIS compared to conventional systems that do not use electricity. Several respondents also suggested that labor costs would be lower under HEIS.

5

Looking Ahead

A. Energy Checklist for Irrigation

Despite the many clear and strong linkages between the water, energy, and food sectors, no checklist identifying challenges on and from the energy sector from changes in irrigation had been developed up to now. Experts who commented on the draft checklist suggested to differentiate between an irrigation system and basin focus and to identify all potential "stress points" between irrigation and energy, but generally with a focus on water for energy generation and not on water for food production.

A clear need was voiced to identify all sources of energy associated with irrigated farming. These include electricity or diesel use for groundwater or surface water pumping and energy needs for agricultural production. Energy savings through changes in irrigation technologies or water source may increase overall energy needs on farm through increased use of pesticides, fertilizers, other machinery, increased water pollution, or the need to use yield sensors, supervisory control and data acquisition or other energy-intensive operational devices. Energy–water tradeoffs occur along many different fronts.

The list will be further piloted and applied on a range of irrigation systems prior to finalization. This will be carried out in a subsequent pilot study to test the checklist on alternate cropping patterns and subregions of Asia.

B. High-Efficiency Irrigation Systems in the Central Highlands of Viet Nam

A business case for high-efficiency irrigation systems (HEIS) requires clear information on current levels of adoption of HEIS; on the potential of a specific technology, for example, based on a cost–benefit analysis; and a comprehensive understanding of the various constraints to adoption, based on which solutions to the constraints can be identified.

There is no conclusive information about current levels of adoption of HEIS in the Central Highlands of Viet Nam. What is conclusive is that the government would like to increase uptake to 0.5 million hectares as part of various strategies. In general, local and national government agencies, including the Ministry of Agriculture and Rural Development and the Ministry of Natural Resources and the Environment are supportive of HEIS.

Farmers as the main stewards of water are fully aware of the risks of water scarcity. There is some interest by farmers to invest in advanced irrigation but the level of interest is currently too limited to actually invest in HEIS. There is also a clear lack of awareness of what HEIS can and cannot deliver.

Direct energy use (electricity and diesel) currently accounts for a small share of total energy consumption and a small share of total production costs. Instead, fertilizer is the main source of energy expenditures.

While HEIS cost is high this is not a significant factor affecting adoption as areas and incomes for perennial crops (coffee and dragon fruit) allow for a better margin to finance the systems. Despite this, up to 40% of smallholders interviewed suggested a need for enhanced banking support or subsidies for the equipment.

Key constraints to adoption of HEIS in the study areas include:

(i) Limited lack of water shortages (shortage only for some farmers during a short time window in the dry season).
(ii) Electricity costs are not large enough to incentivize HEIS.
(iii) There are no water charges that might incentivize water savings and, in turn, HEIS.
(iv) Labor costs are not sufficiently high and shortages are not sufficient to incentivize HEIS.
(v) Adoption of HEIS could be profitable, largely from saving of fertilizers—if HEIS uses fertigation. Key other parameters that affect adoption include the cost of the technology (costs are expected to further decline as more competition is introduced into the market); the actual energy savings (particularly fertilizer savings, which could be affected by changes in fertilizer prices); the actual water savings; and the actual labor savings. A doubling of the electricity tariff would not make a significant difference for adoption in the study areas.

For sustained adoption HEIS systems would need to

(i) focus on new plantations as old trees do not respond well to drip irrigation,
(ii) be accompanied with capacity building—some farmers with drip enlarge drip holes as they do not believe that the drip system provides sufficient water (and it likely does not if applied on mature trees),
(iii) ideally be accompanied by fertigation, and
(iv) be linked to locations of real water scarcity.

As mentioned in the previous chapter, the only large international seller of HEIS identified in the two study sites is Netafim. There are several local producers, imports from the People's Republic of China and a local research organization developing systems. This is clearly not a competitive market. All HEIS adopters interviewed received direct support from vendors following the installation of the systems but did not report repair costs. All systems examined had only been adopted recently, i.e., from 2012 to 2015. Reinvestment costs and longer-term challenges of systems have to be studied in greater detail.

The following are the recommendations from this study:

(i) Raise awareness on water (and fertilizer) requirements for optimal yields (this could be supported by groundwater governance mechanisms; experimental games;

demonstration plots; yield monitors and soil moisture sensors; and educational tools, such as movies or radio shows).

(ii) Collect data on HEIS adoption levels (to be carried out by a designated government agency at district and province levels).

(iii) Assess the potential impact of a water service charge on HEIS adoption, including the modus operandi of such a charge.

(iv) Conduct additional studies on HEIS impacts on all energy components (pumping, agrochemical inputs, mechanization, post-harvest energy use, water treatment, operations) as well as on water use in the Central Highlands and across additional locations and crops in Viet Nam (i.e., beyond coffee and dragon fruit and the Central Highland location). A key question that needs to be studied here is whether or not HEIS contributes to resilience, i.e., yield stability.

(v) Based on these studies, develop a typology of key likely savings from the adoption of HEIS across labor, all forms of energy and water to provide farmers with better guidance on when to adopt or not.

(vi) In recommending adoption of HEIS, consider key energy savings, such as those from reduced fertilizer application (which also reduces water pollution levels, labor cost, etc.).

(vii) Assess the potential of an enhanced groundwater governance system to reduce overwatering and induce water savings. Elements of such a system include (i) involvement of water users, (ii) monitoring of groundwater levels and resource status, (iii) scientific assessment of safe groundwater yield, and (iv) establishing of a permit system to regulate groundwater withdrawals.

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APPENDIX 1

Elements of an Energy Checklist

No.	Category/Question	Yes/No	Remarks
A	**BASIC INFORMATION ON ENERGY ACCESS OF THE SITE**		
1	*Is the site connected to the electric grid?*		
1a	**IF NOT**, does it affect planned project performance?		
	IF YES, what are mitigation measures?		
2	*Is electricity reliable in the dry and wet seasons?*		
2a	**IF NOT**, does lack of year-round availability affect proposed project performance?		
2b	**IF YES**, what are mitigation measures?		
3	*Is electricity available 24 hours?*		
3a	**IF NOT**, does lack of year-round availability affect proposed project performance?		
3b	**IF YES**, what are mitigation measures?		
4	*Is the electricity tariff subsidized?*		
4a	**IF YES**, is project viable if a full cost recovery tariff is applied?		
4b	**IF NO**, what are mitigation measures?		
B	**BASIC INFORMATION ON THE PROJECT ITSELF**		
5	*Is this a multipurpose project (i.e., irrigation, water supply or hydropower generation)?*		
5a	**IF YES**, do you foresee competition for water or energy between irrigation and other uses, for example, in a drought year, such as from hydropower upstream?		
5b	**IF YES**, what are mitigation measures?		
6	*What is the source of irrigation water?*		
6a	Groundwater		
6b	Water pumped from canals		
6c	Water pumped from a reservoir		
6d	Water accessible without energy		
6e	IF groundwater what is the average water table depth?		
6f	IF groundwater, has the water table been declining over the last 10 years?		
6g	**IF YES**, what are mitigation measures?		
6h	Will energy be needed to manage high water tables or polluted water?		

No.	Category/Question	Yes/No	Remarks
6i	**IF YES**, what are mitigation measures?		
6j	IF a centrally pumped system, is it possible that farmers continue to pump privately as well in the system?		
6k	**IF YES**, what are mitigation measures?		
6l	IF water transfer to field requires energy, describe levels, tariffs, if any, and any cost implications for the project or end-user		
7	IF this is a canal system (with or without pumping) is there a possibility to generate energy through turbining canals? IF YES, please describe		
8	*How is water applied on the farm?*		
8a	Flood		
8b	Furrow		
8c	Sprinkler		
8d	Drip		
8e	Center Pivot		
8f	Other: ________		
8g	**IF YES**, are all incremental energy needs in place or in reach at no or low incremental cost?		
9	*What other methods are envisioned to increase water and energy use efficiency?*		
9a	Soil moisture sensors or similar		
9b	Sensors to support operation and efficiency of water supply		
9c	Yield monitors		
9d	Wetting front detectors		
9e	On demand irrigation supply		
9f	Other: ________		
9g	**IF YES**, are all incremental energy needs in place or in reach at no or low incremental cost?		
10	*Will the project likely lead to higher overall energy use in irrigated agriculture compared to the status quo (e.g., more pumping, pressurized irrigation, more fertilizer, more pesticides, additional growing season, more mechanization, etc.)*		
10a	**IF YES**, are there changes in the harvest index (for example, from single to double cropping) and do these changes imply increased energy requirements?		
10b	**IF YES**, are there changes in crops planted (for example, from rice to vegetables or perennial crops) and do these changes imply increased energy requirements?		
10c	**IF YES**, are there increases in agrochemicals (fertilizers or agrochemicals)		

No.	Category/Question	Yes/No	Remarks
10d	**IF YES**, are there changes in farm machinery use (tractors, harvesters, etc.)		
10e	**IF YES**, are there changes in postharvest energy needs (new mechanical equipment, or transportation of commodities to distant markets)		
10f	**IF YES**, other: ____________________		
10g	**IF YES**, are all incremental energy needs in place or in reach at no or low incremental cost?		
10h	**IF NO**, what are mitigation measures?		
C	**ENVIRONMENTAL IMPACTS (EXPLORATORY)**		
11	*Have GHG emissions associated with changes in energy use been calculated?*		
12	*Are crop residues (rice husks, etc.) used for biogas?*		
13	*Has solar energy been considered?*		
14	*If there is a grid connection, is it national or micro/local?*		
15	*Is the electricity grid part of a regional power pool?*		
16	*What is the share of renewable energy sources in electricity supply?*		
17	*Have remediation measures put in place for agricultural water pollution (which is energy-intensive to remediate)?*		

Source: ADB.

APPENDIX 2

Questionnaires

A. Short questionnaire on the use of High-Efficiency Irrigation: for High-Efficiency Irrigation Systems Users

"We are coming from the Institute for Water Resources Planning for a study with the International Food Policy Research Institute (IFPRI) in association with the Asian Development Bank on 'Quantifying Water and Energy Links in Irrigation for Improved Resource Utilization in Viet Nam.' We would like to talk to you about the role of energy use in agriculture and the potential and constraints of using high-efficiency irrigation in your farm. The survey is expected to take approximately 15 to 20 minutes to complete. If you agree to participate, the information you provide will be used for research purposes only. Your answers will not affect any benefits or subsidies you may receive now or in the future. Your responses to these questions will be anonymous and remain strictly confidential. Your name will not appear in any data that are made publicly available. However, we would like to write down your phone number in case some issues in the questionnaire are unclear and we need to follow up with you for more information or clarification. Do you consent to provide information for this study? You may withdraw from the study at any time and if there are questions that you would prefer not to answer then we respect your right not to answer them.

Has consent been given for THE RESPONDENT *(01=Yes, 00=No)* [__ __]

1. Date of Interview: ________ **Name of Interviewer:** ____________________ **Phone of Interviewee:** __________
2. Gender (M/F) ______
3. Location (suggest use of GPS to geo-referenced data source)

Province		District:	
Commune:		Expected to benefit from WEIDAP (yes/no)	

4. Please tell us about your farming practices – over the last 12 months

Plot No.	1	2	3
Size (ha or m^2)			
Crop grown on land (DX)			
Water source? **(code)**			
If you use groundwater, did you need to dig a new well in the last 10 years?			
If you use groundwater, did the water table decline in the last 10 years? If yes, by how much (in meters)?			
How did you apply the water? (**code)**			
Did high-efficiency irrigation reduce your water use? (yes/no)			
Did high-efficiency irrigation reduce your energy use? (yes/no)			
Do you use a pump? (yes/no)			
If yes, what kind of pump? **(code)**			

If yes, how many horsepower and approximately how many hours in use per day or per week	HP			
	Hours per day/week/month			
How much fertilizer was applied in the growing season (1 year for perennial)	Quantity (unit)			
	Type (code)			
If you used any pesticides, how many liters/costs per season?				
If you used or bought in machinery services for the plot, how many hours did they operate in the season?				
What was the crop yield (in ton/ ha or m^2)				
Total cost for electricity or diesel for agriculture during the year (excluding domestic activities				
Do you pay for irrigation water directly, if yes, how much?				
What is your largest production risk?				

Code for water source	Code for irrigation	Code for pump	Code for fertilizer
1. Deep Groundwater (> 7m)	1. Flood	1. Electric pump	1. Urea
2. Shallow groundwater (< 7m)	2. Hose	2. Diesel	2. NPK
3. Natural pond	3. Bucket	3. Other (write in cell)	3. DAP
4. Artificial pond/tank	4. Drip with fertilizer	4. Manure/organic	
5. River/Stream	5. Drip without fertilizer	5. Other (write in cell)	
6. Natural canal	6. Sprinkler for one tree		
7. Manmade canal	7. Sprinkler for multiple crops		
8. Other (write in cell)	8. Other (write in cell)		

5. Information on constraints and opportunities for High-Efficiency Irrigation

5.a.1 Since when do you use a HEIS technology? Response: ____________________

5.a.2 Where did you buy the technology? ____________ How far is this from your farm? ______ km.

5.a.3 Why did you decide to obtain a HEIS technology? Please list all codes ____________________

Code: 1. Save water; 2 Save energy; 3. Save labor; 4. Requirement from purchaser of my crops; 5. Neighbor is using it and seems happy; 6. Save money; 7. Better crops; 8. Higher yields; for other reasons, please write here: ____________________

5.a.4 Why did you purchase this specific technology and not another HEIS product? ____________________

____

5.a.5 What was the cost of the technology when you bought it? ____________________

5.a.6 Did you need to take a loan/credit to obtain the technology? (Yes/no) ____________________

5.a.7 If you did take a loan/credit, from whom? (Family/friends/local other) ____________________

5.a.8 Did you have any repair costs for this technology over the last 12 months? If yes, cost? __________

5.a.9 If you did have to repair the technology, was it easy (i.e. spare parts, etc.) ____________________

5.a.10 Was energy a consideration when you bought the technology (yes/no) ____________________

5.a.11 Did you receive any support after the purchase from the vendor of the HEIS equipment? (yes/no) ____

5.a.12. If yes in 5.a.11 – please explain if this was useful: ____________________

5.a.13 Would you purchase the same technology again? Please explain: ____________________

5.a.14 Did you change anything else in your crop production after adoption of HEIS? If yes, what? ______

____

6. What other support do you need to succeed in your farm business? ____________________

B. Short Questionnaire on the use of High-Efficiency Irrigation: for Traditional Irrigators

"We are coming from the Institute for Water Resources Planning for a study with the International Food Policy Research Institute (IFPRI) in association with the Asian Development Bank on 'Quantifying Water and Energy Links in Irrigation for Improved Resource Utilization in Viet Nam.' We would like to talk to you about the role of energy use in agriculture and the potential and constraints of using high-efficiency irrigation in your farm. The survey is expected to take approximately 15 to 20 minutes to complete. If you agree to participate, the information you provide will be used for research purposes only. Your answers will not affect any benefits or subsidies you may receive now or in the future. Your responses to these questions will be anonymous and remain strictly confidential. Your name will not appear in any data that are made publicly available. However, we would like to write down your phone number in case some issues in the questionnaire are unclear and we need to follow up with you for more information or clarification. Do you consent to provide information for this study? You may withdraw from the study at any time and if there are questions that you would prefer not to answer then we respect your right not to answer them.

Has consent been given for THE RESPONDENT *(01=Yes, 00=No)* [__ __]

1. Date of Interview: _______ **Name of Interviewer:** ________________ **Phone of Interviewee:** ________
2. Gender (M/F) _____
3. Location (suggest use of GPS to geo-referenced data source)

Province		District:	
Commune:		Expected to benefit from WEIDAP (yes/no)	

4. Please tell us about your farming practices – over the last 12 months

Plot No.		1	2	3
Size (ha or m^2)				
Crop grown on land (DX)				
Water source? **(code)**				
If you use groundwater, did you need to dig a new well in the last 10 years?				
If you use groundwater, did the water table decline in the last 10 years? If yes, by how much (in meters)?				
How do you apply the water? (**code)**				
Do you use a pump? (yes/no)				
If yes, what kind of pump? **(code)**				
If yes, how many horsepower and approximately how many hours in use per day or per week	HP			
	Hours per day/week/ month			
How much fertilizer was applied in the growing season (1 year for perennial)	Quantity (add unit)			
	Type (code)			
If you used any pesticides, how many liters/costs per season?				
If you used or bought in machinery services for the plot, how many hours did they operate in the season?				
What was the crop yield (in ton/ ha or m^2)				
Total cost for electricity or diesel for agriculture during the year (excluding domestic activities				

Do you pay for irrigation water directly, if yes, how much?			
What is your largest production risk?			

Code for water source	Code for irrigation	Code for pump	Code for fertilizer
1. Deep Groundwater (> 7m)	1. Flood	1. Electric pump	1. Urea
2. Shallow groundwater (< 7m)	2. Hose	2. Diesel	2. NPK
3. Natural pond	3. Bucket	3. Other (write in cell)	3. DAP
4. Artificial pond/tank	4. Drip with fertilizer	4. Manure/organic	
5. River/Stream	5. Drip without fertilizer	5. Other (write in cell)	
6. Natural canal	6. Sprinkler for one tree		
7. Manmade canal	7. Sprinkler for multiple crops		
8. Other (write in cell)	8. Other (write in cell)		

5. Information on constraints and opportunities for High-Efficiency Irrigation

5.b.1 Please let us know why you currently do not use a HEIS technology (sprinkler or drip system)? List all codes: ____________________

Code: 1. Have never seen in action; 2. Do not know; 3. Too expensive; 4. No replacement parts; 5. No need; 6. Too difficult/complex to operate. For other reasons, please write here: ____________________

5.b.2 What support would you need to be able to adopt a HEIS technology? List all codes: ____________________

Code: 1. Subsidy; 2. Bank loan; 3. Technology suppliers; 4. Support from extension system; 5. Support from neighbors; 6. Not interested. For other support reasons, please write here: ____________________

5.b.3 If there is another drought or if more water is diverted to urban or industrial uses, that is, if you have less water available in the future, what would you do with your current farm business? Please respond: ____________________

6. What other support do you need to succeed in your farm business? ____________________

Quantifying Water and Energy Linkages in Irrigation
Experiences From Viet Nam

While Asia has the world's fastest-growing economy, 29 of 48 countries assessed by the Asian Water Development Outlook 2016 are water-insecure, posing a threat to the region's continued growth. As economies develop, increasing demands will be placed on water for food and water for energy. In the irrigation subsector, energy is required for ground and surface water pumping, as well as for fueling on-farm irrigation technology and other farm machinery. Water and energy are intrinsically linked, yet there is limited information on quantifying energy use in irrigation systems. This publication summarizes the results of a pilot study to quantify water and energy use in high-efficiency irrigation systems within drought-affected provinces in Viet Nam.

The study and publication have been supported by the Water Financing Partnership Facility.

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