Energy checklist for Asia's irrigation projects: increasing crop water productivity without increasing energy use in agriculture

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1. Abstract

Asia accounts for more than two thirds of irrigated area in the world, much of it still gravity-fed; about 85 percent of all water withdrawn in the region is used for irrigated agriculture. Given growing pressures from industries and cities, and incipient demands for enhanced environmental flows, there is increasing pressure to modernize Asia's irrigation systems to increase efficiency and to move water toward additional irrigation, but also increasingly urban-industrial uses. However, irrigation managers in charge of modernizing systems are seldom aware of the full range of energy linkages of existing and planned irrigation systems, and heavily energy-dependent modernization projects might fail to meet expectations if the many demands on energy sources, such as for pumping water and applying it to the field, for agricultural chemicals and machinery services, and for ensuring that outputs can be profitably brought to market cannot be fulfilled. To address these potential tradeoffs, an energy checklist for irrigation managers was developed and tested on high-value crops in the Central Highlands of Vietnam.

2. Context and challenge, including key interactions (range and nature) the case study addresses

Global water demand is projected to grow rapidly, including in Southeast Asia, one of the world's most dynamic regions. Competing demands for finite water resources are putting pressure on the agriculture sector, the major water user in the region. To address water challenges in irrigated agriculture, the installation of High-Efficiency Irrigation Systems (HEIS) such as drip and sprinkler irrigation systems is increasingly promoted. Most of the investments in modernizing Asian irrigation systems include some form of HEIS. Globally, one-fifth of all irrigated area is now under HEIS, mostly in Europe and the Americas (Table 1). Shares are much lower in Asia, but are increasing. HEIS systems are typically pressurized and require more energy. Thus, reducing water use per unit of output in irrigated agriculture might

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effectively increase energy use for the same output. On the other hand, in the case of groundwater irrigation, using HEIS might reduce energy use as less water needs to be lifted. Energy requirements vary across irrigation technologies, and associated costs may play an important role in the adoption decision of HEIS. The case study assesses energy-irrigation linkages in the Central Highlands region of Vietnam and develops an energy checklist for irrigation projects for the Asian Development Bank (ADB) that is currently tested in additional Asian countries.

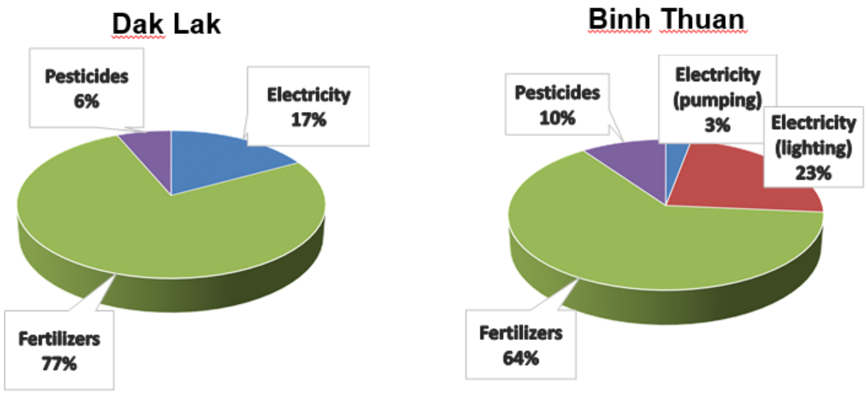
Table 1. *Net Irrigated Area and Share of High-Efficiency Irrigation Systems*

	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

Source: ICID (2015).

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. We find that for an ADB project site in the Central Highlands of Vietnam, irrigated dragon fruit production inherently uses more energy than coffee production. Average farm size in the study area is 1.3 ha for coffee in Dak Lak and 0.7 ha for dragon fruit in Binh Thuan province. All (conventional and HEIS) farmers are equipped with electric pumps (1-7.5kw) to pump groundwater. Almost all farmers use groundwater as the only source of irrigation water; no water tariff is charged. The depth of groundwater ranges from shallow to very deep groundwater and HEI systems cost US$1000-3000/ha. We find that the largest electricity cost component is not for pumping irrigation water. Moreover, in the case of dragon fruit in Binh Thuan province, artificial lighting consumes, on average, eight times more electricity than pumping groundwater.

Figure 1. *Sources of energy use in irrigated agriculture (coffee, Dak Lak and dragon fruit, Binh Thuan provinces, case study sites)*



Source: ADB (2017).

A cost-benefit analysis comparing conventional and HEIS irrigation for coffee and dragon fruit finds small negative benefits for the adoption of drip by coffee farmers relying on groundwater in Dak Lak province as the capital costs outweigh the net benefits from lower electricity, fertilizer, and labour costs. Meanwhile, the CBA finds a positive net return from investment in HEIS for dragon fruit in Binh Thuan province, largely due to savings in fertilizers. If the water savings are converted into irrigated area expansion, then the investment in drip irrigation is also favorable for coffee production in the Dak Lak region. A doubling of the electricity tariff, which is currently subsidized in the country, does affect the results substantially.

Based on the case study findings, the first ever energy checklist for irrigation projects was developed to support ADB project officers and other stakeholders who work on irrigation design, development or modernization in ensuring that water and food security improvements through modernizing irrigation systems do not adversely affect energy security goals and that available energy resources do not constrain investments in irrigation modernization. The first ever energy checklist for irrigation projects 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 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 (Table 3).

Table 2. *Estimated Benefit from Adoption of High-Efficiency Irrigation Systems ($/year), coffee*

(a) Dak Lak (baseline energy price)

	Conventional	HEIS	$\Delta benefit$
Capital investment	136	636	-500
Electricity	182	145	37
Fertilizers	818	491	327
Pesticides	68	68	0
Labour	182	73	109
Water savings			1,227
Total			1,200

(b) Binh Thuan (baseline energy price)

	Conventional	HEIS	$\Delta benefit$
Capital investment	136	636	-500
Electricity (no artificial lighting)	136	109	27
Fertilizers	4,909	2,945	1,964
Pesticides	455	455	0
Labour	182	73	109
Water savings			2,500
Total			4,100

Reference: ADB (2017).

Table 3. *Energy checklist for Irrigation Projects*

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)?*		

No.	Category/Question	Yes/No	Remarks
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?		
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 (f.ex. 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?		

No.	Category/Question	Yes/No	Remarks
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)		
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)?*		

Reference: ADB (2017).

3. How did research efforts deal with the synergies and trade-offs?

a) in the development of the TOC and impact pathways

The ADB identified energy-irrigation tradeoffs as part of their ongoing irrigation investments. Irrigation modernization and rehabilitation in Asian member countries focuses on improving water use efficiency and productivity that generally leads to increased energy needs per unit of output. The case study and ensuing checklist, once used by those tasked with designing and modernizing irrigation projects, can help reduce the tradeoffs. The pathway is uptake by ADB of the energy checklist for irrigation projects as well as by other stakeholders involved in energy-intensive irrigation systems.

b) in the development of partnerships/delivery approaches

The partnership and delivery approach is a checklist that can be used by project managers tasked with modernizing irrigation projects.

c) in the development of metrics

No metrics were developed or used in this case study.

d) other

N/A.

4. What kinds of partnerships were critical?

The critical partnership was between ADB and IFPRI under the CGIAR WLE umbrella. ADB identified a need to better understand energy linkages in irrigation improvement efforts and IFPRI under the CGIAR WLE program had worked on various concepts and approaches to reduce the costs of tradeoffs across the water-energy-food nexus.

5. Lessons learnt, including knowledge gaps and good practices in employing these approaches at scale

Given growing natural resource shortages and inter-dependencies among efforts focusing on water, energy and food security, ensuring that achieving some goals and objectives does not reduce the likelihood of achieving others increases in importance. Understanding linkages and feedback effects between water, food and energy security and environmental sustainability and identifying measures to strengthen positive and reduce negative linkages through the development of checklists and guidance documents that are validated through case studies, is an important approach to address this challenge.

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References

Asian Development Bank (ADB). 2017. Quantifying Water and Energy Linkages in Irrigation: Experiences From Viet Nam. Manila: ADB