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Investing in Agricultural Water Management to Benefit Smallholder Farmers in West Bengal, India

AgWater Solutions Project Country Synthesis Report

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Investing in Agricultural Water Management to Benefit Smallholder Farmers in West Bengal, India

AgWater Solutions Project Country Synthesis Report

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Evans, A. E. V.; Giordano, M.; Clayton, T. (Eds.). 2012. *Investing in agricultural water management to benefit smallholder farmers in West Bengal, India. AgWater Solutions Project country synthesis report.* Colombo, Sri Lanka: International Water Management Institute (IWMI). 28p. (IWMI Working Paper 148). doi: 10.5337/2012.210

/ water management / agricultural production / investment / research projects / smallholders / farmers / groundwater resources / water use / reservoirs / watersheds / electrification / pumps / rain water management / water harvesting / irrigation / technology / West Bengal / India /

ISSN 2012-5763
ISBN 978-92-9090-755-8

Please direct inquiries and comments to: *IWMI-Publications@cgiar.org*

A free copy of this publication can be downloaded at
www.iwmi.org/Publications/Working_Papers/index.aspx

Acknowledgements

The editors would like to thank all the people whose work contributed to the content of this report. Special thanks go to Dr. Partha Banerjee (Independent Consultant), who undertook much of the research on groundwater, rural electrification and *hapas*; to the team from the non-governmental organization (NGO), Professional Assistance for Development Action (PRADAN), especially Manas Satpathy, who provided vital information about *hapas*; and to the Centre for the Development of Human Initiatives, Jalpaiguri, in particular, Dhananjay Rai, for providing support to the study on treadle pumps. The research was undertaken in collaboration with the International Water Management Institute (IWMI), including Aditi Mukherji, Ravinder P. S. Malik and Durba Biswas. We are also grateful to Charlotte de Fraiture (UNESCO-IHE Institute for Water Education, formerly IWMI) for her overall guidance and the contributions made to these studies. For work carried out in the Jaldhaka watershed, we are grateful to the team from the Stockholm Environment Institute (SEI), including Annemarieke de Bruin, Devaraj de Condappa, Steve Cinderby, Christian Stein, Jennie Barron, Monique Mikhail, Sat Kumar Tomer and Sekhar Muddu. We would also like to thank International Development Enterprises (India) (IDEI) for contributing to this work. We would like to extend our gratitude to the team from the Food and Agriculture Organization of the United Nations (FAO), namely Guido Santini, Livia Peiser and Jean-Marc Faurès, who undertook the work to identify suitability domains for agricultural water management and the number of potential beneficiaries. For the work associated with stakeholder engagement through the dialogue process, we would like to thank the FAO dialogue leader, Domitille Vallée, and her colleague, Bernadete Neves. We appreciate, especially, the invaluable contribution of the dialogue facilitator, Saikat Pal, and his colleagues from the NGO, PRASARI, in particular, Rajeev Sharma, as well as the support provided by Elizabeth Weight (IWMI, formerly iDE). We would also like to recognize the important work of the AgWater Solutions Project Secretariat, especially Mala Ranawake and Wendy Ells, who contributed to various pieces of writing that supported this report. None of this work would have been possible without the involvement and support of the local communities, experts, authorities and NGOs. We are indebted to all of them. This report is based on research funded by the Bill & Melinda Gates Foundation. The findings and conclusions contained within are those of the authors and do not necessarily reflect positions or policies of the Bill & Melinda Gates Foundation.

Project

The AgWater Solutions Project was implemented in several countries in Africa and Asia between 2009 and 2012. The objective of the project was to identify investment options and opportunities in agricultural water management with the greatest potential to improve incomes and food security for poor farmers, and to develop tools and recommendations for stakeholders in the sector including policymakers, investors, NGOs and smallholder farmers. This report synthesizes the research findings and contributions made by the team and stakeholders in West Bengal over the project period.

The leading implementing institutions were the International Water Management Institute (IWMI), the Food and Agriculture Organization of the United Nations (FAO), iDE, the International Food Policy Research Institute (IFPRI) and the Stockholm Environment Institute (SEI). The organizational partner in West Bengal was PRASARI.

For more information on the project or for detailed reports, please visit the project website (http://awm-solutions.iwmi.org/) or contact the AgWater Solutions Project Secretariat (AWMSolutions@cgiar.org).

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Summary

This Working Paper summarizes research conducted as part of the AgWater Solutions Project in West Bengal between 2009 and 2012. Agriculture is the main livelihood for 70% of West Bengal's population of 91 million. The state's high population density and low per capita landholding make it important for farmers to grow two to three crops a year for survival, hence the critical role of agricultural water management. Researchers from the AgWater Solutions Project conducted studies on rainwater harvesting with small ponds (known locally as *hapas*), improving access to groundwater through rural electrification and diesel subsidies, and the adoption dynamics of agricultural water management technologies. Research methodologies included rapid rural appraisals, interviews, survey questionnaires and literature reviews.

Research suggested that pump rental markets would benefit a large number of poor smallholder farmers. West Bengal has ample groundwater resources, but restrictive policies and high costs make access difficult. Studies on the adoption dynamics of agricultural water management technologies suggested that adoption of irrigation technology does not necessarily follow a linear path from simple manual methods to 'advanced' motorized technologies, and that cost is not necessarily the main driving factor. Rental markets have emerged as a natural response to demand from those who are unable to own a pump.

Wider access to groundwater through the use of electric and diesel pumps could benefit anywhere from one to four million households. When farmers are able to access groundwater they cultivate the more high-value *boro* paddy and diversify their crop mix. Counterproductive policies and rising costs are forcing farmers to cut back on their groundwater use. In areas where groundwater is abundant, easing some of the legal constraints could help to reverse this trend.

Rainwater harvesting could benefit from nearly 400,000 to over 600,000 farming households at a 50% adoption rate. The introduction of small rainwater harvesting reservoirs has resulted in benefits, including cultivation of fallow land, higher crop intensity due to cropping in the dry season, new crops, more livestock and aquaculture.

INTRODUCTION: SMALLHOLDER AGRICULTURAL WATER MANAGEMENT

Across Africa and Asia, a growing number of smallholder farmers are finding ways to better manage water for agriculture to increase yields and income, and diversify their cropping and livelihood options. Farmers buy or rent irrigation equipment, draw water from nearby sources, and individually or collectively build small water storage structures. This development is often overlooked by external investors, yet the smallholder agricultural water management (AWM) sector is contributing to food security, rural incomes, health and nutrition. While small-scale AWM practices could potentially benefit hundreds of millions of farmers, this potential is far from being realized.

The AgWater Solutions Project examined this trend together with the opportunities and constraints associated with smallholder AWM in two states in India, West Bengal and Madhya Pradesh, and five countries in Africa, Tanzania, Burkina Faso, Ghana, Ethiopia and Zambia. Through this, the project identified a number of ways in which the potential of the smallholder AWM sector can be realized, including:

- **Building supportive institutional structures:** Existing governing bodies typically cater for public irrigation systems and are often not adapted to capitalize on the opportunities and to handle the challenges posed by this alternative mode of irrigation development. Traditional agricultural institutions rarely focus on market-oriented smallholder crop production, such as high-value vegetable production in the dry season.
- **Overcoming value chain inefficiencies:** Market inefficiencies negatively affect farmer decision-making and access to technology. Inefficiencies include: poorly developed supply chains; high taxes and transaction costs; lack of information and knowledge on irrigation, seeds, marketing and equipment; and uneven information and power in output markets.
- **Improving access to technology for all sectors of society:** Better-off farmers have greater access to information and technology than their poorer counterparts and women who face several hurdles: high upfront investment costs, absence of financing tools, and limited access to information to make informed investment and marketing choices.
- **Managing potential trade-offs:** While smallholder AWM can be beneficial for an individual farmer, its uncontrolled spread can have unexpected consequences. If not managed within the landscape context, the many small dispersed points of water extraction, can negatively impact downstream users and cause environmental damage.

Addressing these challenges requires a fresh look at new and existing AWM technologies, products and practices to enhance the potential of the smallholder AWM sector and find solutions.

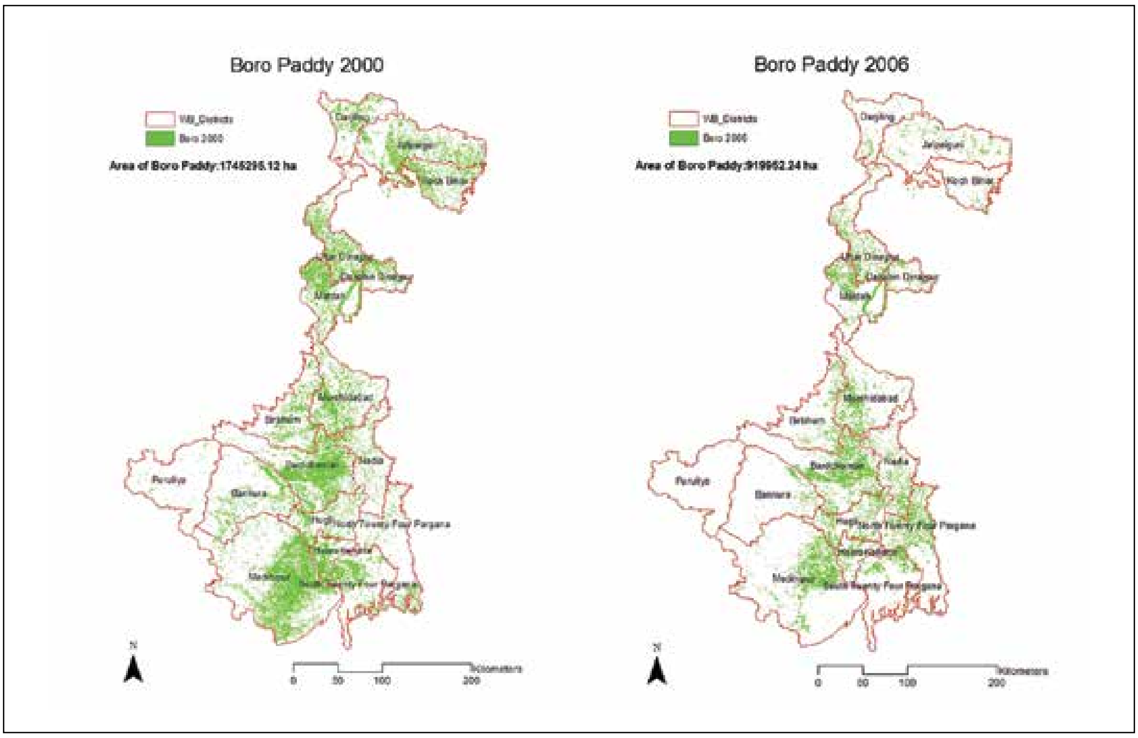
WHY INVEST IN SMALLHOLDER AWM IN WEST BENGAL?[1]

Agriculture is the main livelihood for 70% of West Bengal's population. The state's high population density, high rates of rural poverty and low per capita landholdings make it essential for farmers to grow two to three crops a year to survive. Good AWM is a critical element in achieving this. However, policies introduced in the early 1990s had the unintended consequence of stifling agricultural growth, which fell to under 2% from nearly 6% in the previous decade

[1] Based on AgWater Solutions Project 2010; Banerjee 2010; and Mukherji et al. 2011.

(Mukherji et al. 2011). Under these policies, irrigation costs increased dramatically, while the market price for paddy remained the same. The low growth rate in agriculture and the decline in *boro* paddy production (Figure 1) are of considerable concern as West Bengal has not yet attained food security (Mukherji et al. 2011). Recent surveys by the National Sample Survey Office of India suggest that 11% of rural households do not have enough food some months of the year. Thousands, mostly men, migrate out of the state in search of work.

FIGURE 1. *Boro* paddy production in West Bengal before and after policy changes.

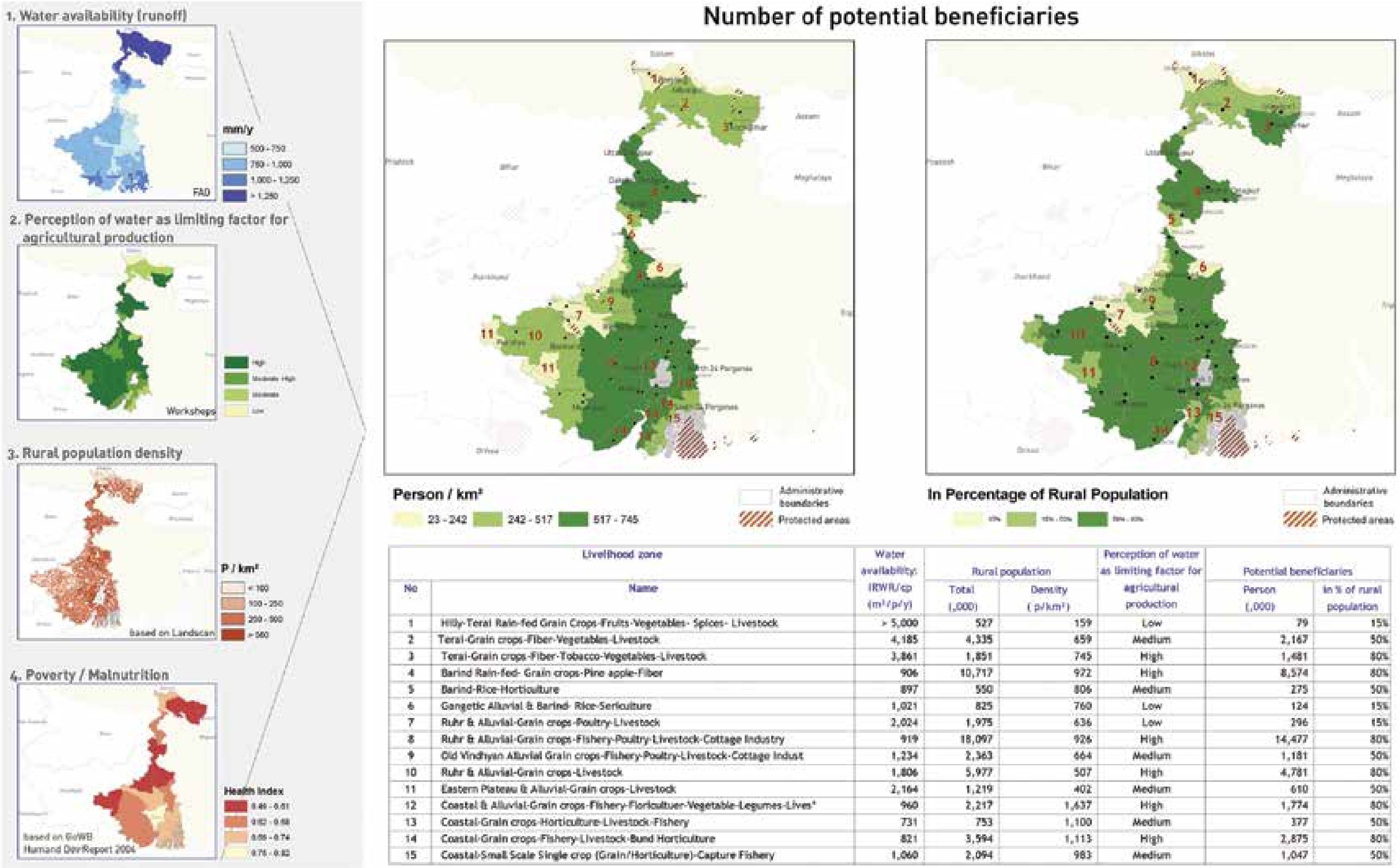


Source: Maps generated for this study using remote sensing data by the International Water Management Institute (IWMI). *Note*: changes in the extent of *boro* paddy depicted here differ from official statistics, which are not calculated using remote sensing data.

West Bengal has enough land and water resources to sustain more agricultural growth. Many tributaries of the Ganges River flow through the state and rainfall is high (between 1,200-3,000 millimeters (mm) a year) (Indian Meteorological Department). Water and other natural resources are unevenly distributed across the state, which means that different locations require different AWM solutions (AgWater Solutions Project 2010). One challenge facing state planners is the small farm size - three-quarters of the land is suitable for agriculture, but over 3.3 million hectares (Mha) are divided into plots of 2 hectares (ha) or less (Directorate of Agriculture 2005). Small plots require appropriately scaled AWM inputs, technologies and practices.

Better AWM for smallholder farmers offers a flexible and economically feasible strategy for raising both farm productivity and the living standards of poor rural farmers. The Agwater Solutions Project mapped the potential for AWM to improve the livelihoods of smallholder farmers in West Bengal and found that just over 40 million people (70% of the rural population) could benefit from AWM (Figure 2).

FIGURE 2. Potential beneficiaries of agricultural water management.



Livelihood zone		Water availability: IRWR/cp (m^3/p/y)	Rural population		Perception of water as limiting factor for agricultural production	Potential beneficiaries	
No	Name		Total (,000)	Density (p/km²)		Person (,000)	in % of rural population
1	Hilly-Terai Rain-fed Grain Crops-Fruits-Vegetables- Spices- Livestock	> 5,000	527	159	Low	79	15%
2	Terai-Grain crops-Fiber-Vegetables-Livestock	4,185	4,335	659	Medium	2,167	50%
3	Terai-Grain crops-Fiber-Tobacco-Vegetables-Livestock	3,861	1,851	745	High	1,481	80%
4	Barind Rain-fed- Grain crops-Pine apple-Fiber	906	10,717	972	High	8,574	80%
5	Barind-Rice-Horticulture	897	550	806	Medium	275	50%
6	Gangetic Alluvial & Barind- Rice-Sericulture	1,021	825	760	Low	124	15%
7	Ruhr & Alluvial-Grain crops-Poultry-Livestock	2,024	1,975	636	Low	296	15%
8	Ruhr & Alluvial-Grain crops-Fishery-Poultry-Livestock-Cottage Industry	919	18,097	926	High	14,477	80%
9	Old Vindhyan Alluvial Grain crops-Fishery-Poultry-Livestock-Cottage Indust	1,234	2,363	664	Medium	1,181	50%
10	Ruhr & Alluvial-Grain crops-Livestock	1,806	5,977	507	High	4,781	80%
11	Eastern Plateau & Alluvial-Grain crops-Livestock	2,164	1,219	402	Medium	610	50%
12	Coastal & Alluvial-Grain crops-Fishery-Floricultuer-Vegetable-Legumes-Lives*	960	2,217	1,637	High	1,774	80%
13	Coastal-Grain crops-Horticulture-Livestock-Fishery	731	753	1,100	Medium	377	50%
14	Coastal-Grain crops-Fishery-Livestock-Bund Horticulture	821	3,594	1,113	High	2,875	80%
15	Coastal-Small Scale Single crop (Grain/Horticulture)-Capture Fishery	1,060	2,094	983	Medium	1,047	50%

Source: FAO 2012a.

AWM Investment Opportunities in West Bengal

The AgWater Solutions Project identified many existing AWM practices that could support the realization of the estimate that over 40 million people could benefit from AWM. The type of AWM options being utilized in the state varies by agroecological zone, and this should be taken into account when developing AWM solutions. In North 24 Parganas, shallow tube wells with diesel pumps are the main source of irrigation; in Hugli, deep tube wells with submersible pumps are prevalent; in Uttar Dinajpur, diesel shallow tube wells and occasional treadle pumps were found; and in the drier district of Purulia, tanks and ponds were the most important source of water for agriculture. An initial scoping of several AWM options was made and after stakeholder consultation three areas of research were selected. These were, the mechanisms to improve crop production through access to groundwater, factors affecting adoption of water-lifting devices and the *'hapa'* model of rainwater harvesting. A series of recommendations were made on how to increase adoption and sustained use by smallholders (Table 1).

TABLE 1. Review of AWM options, recommendations and potential beneficiaries.

AWM solution	Solution statement	Beneficiary households (% of rural households)*	Area in hectares (% of total agricultural land)*	Estimated investment costs
Access to groundwater through rural electrification	Groundwater has emerged as the main source of irrigation for smallholder farmers in India and much of it has been through private investments. When farmers are able to access groundwater they cultivate the more high-value *boro* paddy and diversify their crop mix. Restrictive groundwater policies and rising diesel costs are forcing farmers to cut back on groundwater use. In areas where groundwater is abundant and of good quality, easing some of the legal constraints and improving access to electrification could help to reverse this trend.	2,166,000-4,358,000 (3.8-7.6%)	866,000-1,743,000 ha (13.2-26.6%)	Not calculated
Diesel pumps to access groundwater	Where electrification is not possible, diesel pumps are still an option.	1,123,000-3,727,000 (2.0-6.5%)	449,000-1,491,000 (6.9-22.8%)	Not calculated
Rainwater harvesting	Certain districts are dry and receive limited rainfall or do not have suitable groundwater aquifers. The introduction of small rainwater harvesting structures has provided benefits, including higher crop intensity, new crops, more livestock and fish.	393,000-626,000 (0.7-1.1%)	589,000-939,000 (9.0-14.3%)	USD 1/cubic meter (m^3) of water stored

Source: This study; all data: FAO 2012a.

Note: *Figures assume that out of the total potential beneficiary households calculated, 50% adopt the AWM option.

Details of the approach and related studies undertaken to arrive at these conclusions are given in Box 1 and elaborated in subsequent chapters. Further information, including case studies and mapping data can be found on the project website (http://awm-solutions.iwmi.org).

Box 1. AgWater Solutions Project approach.

Situation analysis and selection of AWM options: An initial analysis was undertaken of the conditions in each country and the AWM practices already being undertaken. These were reviewed with stakeholders and some of the most promising practices were selected.

Field-scale and community-level case studies: Researchers used a participatory opportunity and constraint analysis and methodology to understand the complex interaction among social, economic and physical factors that influence the uptake and success of AWM options, and to identify technologies appropriate to different contexts in each of the project countries.

Watershed-level case studies: Researchers used a multi-disciplinary approach to look at how the natural resource base impacts on, and is impacted by, AWM in four watersheds in Tanzania, Burkina Faso, West Bengal (India) and Zambia. The analysis concentrated on the hydrological impact of current and potential AWM interventions; the current resource-based livelihoods and dependencies on sources of water and water management practices; an impact assessment of potential AWM scenarios; and a review of formal and informal institutional capacity to deal with AWM interventions and potential emerging externalities.

National AWM mapping: Maps were developed to help assess where AWM will have the greatest impact within a country or state, and where specific interventions will be most viable. The steps followed were to use a participatory process in which experts defined the main livelihood zones based on farming typologies and rural livelihood strategies, and the main water-related constraints and needs in the different rural livelihood contexts. Using this, the potential for investment in water to support rural populations could be mapped based on demand and availability of water. A further step was to map the suitability and demand for specific AWM interventions, such as motor pumps or small reservoirs, and to estimate the potential number of beneficiaries, application area and investment costs. These allow investors to choose entry points and prioritize investments in AWM that will have the most beneficial impacts on rural livelihoods.

Regional AWM analysis: Researchers used geographic information system (GIS)-analysis, crop mix optimization tools and predictive modeling techniques to assess the regional potential for the 'best-bet' AWM technologies in South Asia and sub-Saharan Africa in terms of: potential application area (in hectares), number of people reached, net revenue derived and water consumption. Scenarios were also developed to factor in climate change and potential changes in irrigation costs.

Stakeholder engagement and dialogue: An integral part of the entire project was the engagement of stakeholders from the initial assessment of AWM opportunities through to the identification of possible implementation pathways. The dialogue process was used to ensure that project results reflected stakeholder perceptions and addressed their concerns. State consultations, dialogues, surveys and interviews were fed into all stages of the project.

AWM OPTIONS REVIEWED

Improving Access to Groundwater through Rural Electrification[2]

Groundwater has emerged as the main source of irrigation for smallholder farmers in India and much of it has been through private investments. West Bengal is no exception. Revising groundwater policies in the State, as well as the provision and pricing of electricity, could propel smallholder farmers on a path to higher agricultural growth and poverty alleviation.

Where the opportunity lies

In some parts of West Bengal there is ample groundwater, yet less than half of it is being used. The main obstacles are policy restrictions and the widespread perception that groundwater is scarce. West Bengal has fewer electric pump sets in use than most other states. In a 2010 report, the Central Electricity Authority (CEA) estimated that the number of electric pump sets in use was less than one-fifth of the potential (CEA 2010). A better understanding of where and how groundwater resources are used can help inform policies that would in turn promote greater use without over-exploiting the resource.

The research

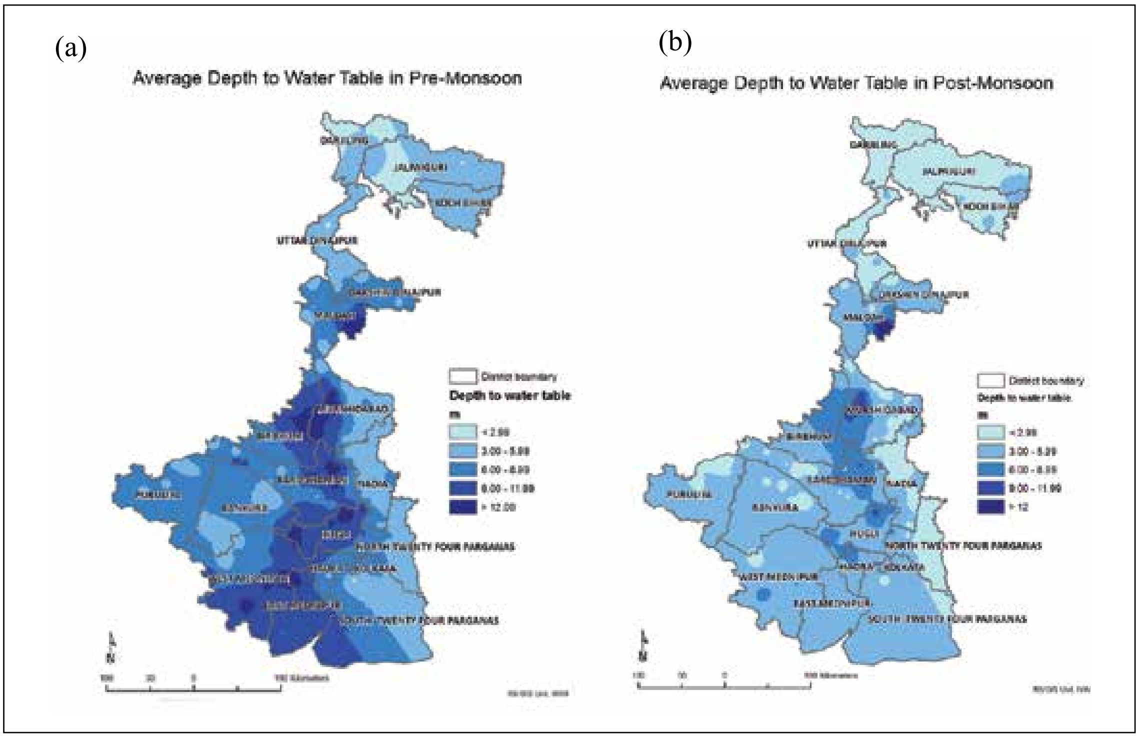
Nearly 900 farmers were interviewed in 59 villages in 10 districts. Researchers also interviewed private pump dealers, personnel at the State Water Investigation Directorate (SWID), Department of Water Resources Investigation and Development, which is responsible for implementing the Groundwater Act, and the West Bengal State Electricity Distribution Company Ltd., which is in charge of providing electricity connections to farmers and is also in the process of metering agricultural tube wells.

The AgWater Solutions Project found that only 42% of West Bengal's groundwater potential is currently being used. Fewer than 10% of blocks in the state are regarded as 'critical' and none are over-exploited. However, policies governing groundwater use, notably the Groundwater Act of 2005, have been restrictive with respect to permission for new wells. The Act was designed to control the number of new wells and create an inventory of groundwater structures. Permits and registration applications were routinely rejected even in districts where groundwater development was only 20-25% or where groundwater depth was less than 30 feet (9 meters (m)).

Groundwater data indicate that, in many areas of the state, restricting groundwater use is unnecessary and even counterproductive. Preliminary analysis of well data from 1990 to 2009 show that, in general, for every 1 m of drawdown in the pre-monsoon season, there is 0.85 m of post-monsoon recharge. This suggests that it would be more beneficial to productively use the groundwater in the dry season and thereby create storage space so that the subsequent monsoon rains can be captured for use in the next dry season rather than flowing out of the system unused (Figure 3). To compensate for any net depletion, this natural recovery process can be enhanced through rainwater harvesting (see study on *hapas* below).

[2] Based on Mukherji et al. 2011; and AgWater Solutions Project 2012a.

FIGURE 3. Groundwater depth in (a) pre-monsoon; and (b) post-monsoon.



Source: State Water Investigation Directorate (SWID), 2010.

Key factors constraining groundwater use and farmer investment are groundwater policies that restrict permits for electrical connections and the high cost of diesel, which is the main alternative if electricity is not available. When diesel is used for pumping the cultivation costs are almost twice that of farmers using electric pumps (Figure 4). Even farmers who purchase water from electric pump owners have lower cultivation costs than diesel pump users. As a result, farmers with diesel pumps tend not to grow profitable, water-intensive crops such as *boro* paddy and vegetables. Overall, electric pump owners earn more (Figure 4).

Where to invest

We propose introducing a one-time capital cost subsidy to electrify pumps and reduce the cost of irrigation. Where permanent connections are not feasible, we suggest providing temporary *boro* connections. Priority should be given to blocks with low levels of groundwater use, high rainfall and alluvial aquifers, and where electrification rates are low, such as in the North Bengal districts of Dinajpur and Jalpaiguri. Districts with known arsenic or fluoride problems should be avoided.

Since this study and presentation of related recommendations, a government order was passed whereby the West Bengal State Electricity Distribution Company Limited (WBSEDCL) will provide new electricity connections to farmers for a fixed connection fee ranging from INR 1,000 to INR 30,000 per connection, depending on the connected load. Previously, farmers were required to cover the cost of all infrastructure (wires, poles and transfers) based on the distance from the network.

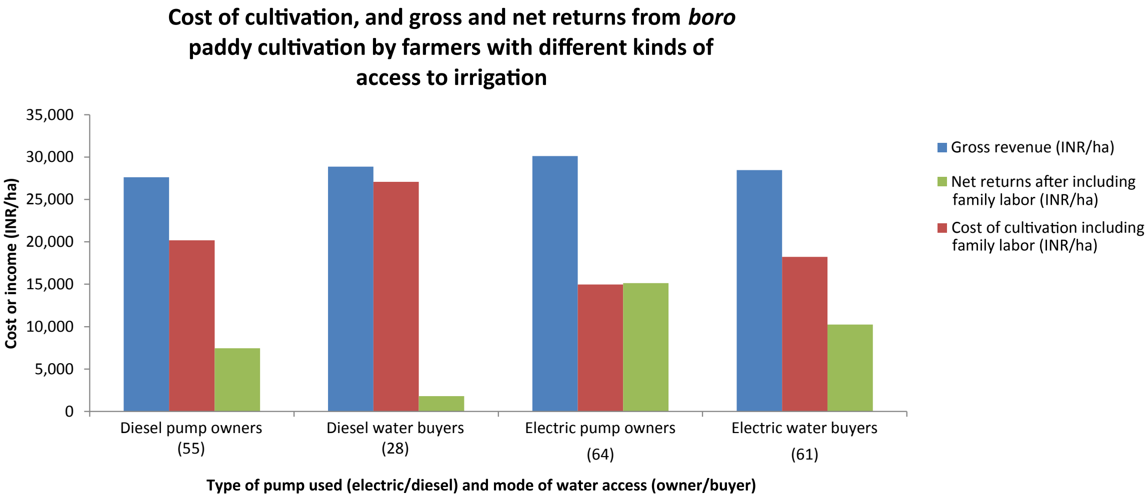
The state's Groundwater Act of 2005 was amended in November, 2011. The revision states that farmers in 301 safe blocks with pumps of 5 horsepower (HP) or less and a discharge rate of 30 m^3/hour or less will no longer require prior permission from the SWID to apply for an electricity connection.

Following this change in the Groundwater Act, little has actually been done to implement it. Information campaigns are required so that farmers are alerted to the changes. Officials need to be made aware of the reasons for the change so that they can make more informed decisions. Campaigns should take place in all blocks, with the exception of critical and semi-critical blocks which are outside the purview of the amended Act. North Bengal should be a priority area.

Agricultural productivity can be improved by utilizing more groundwater, but there are challenges to ensure that the resource is managed equitably and to limit potentially negative social, health and environmental impacts. While strategies unroll, groundwater quality and quantity must be closely monitored (e.g., through detailed aquifer mapping) and corrective measures should be taken as required. Remediation measures in locations where arsenic is currently a problem or may become a problem could involve the provision of arsenic-free drinking water and folate supplements for vulnerable communities.

In-situ rainwater harvesting is also an important complementary measure, because recharge must be increased to make the best use of groundwater resources. Rehabilitating existing ponds and building new water capture and storage systems will be necessary.

FIGURE 4. Cost and profit of rice production.



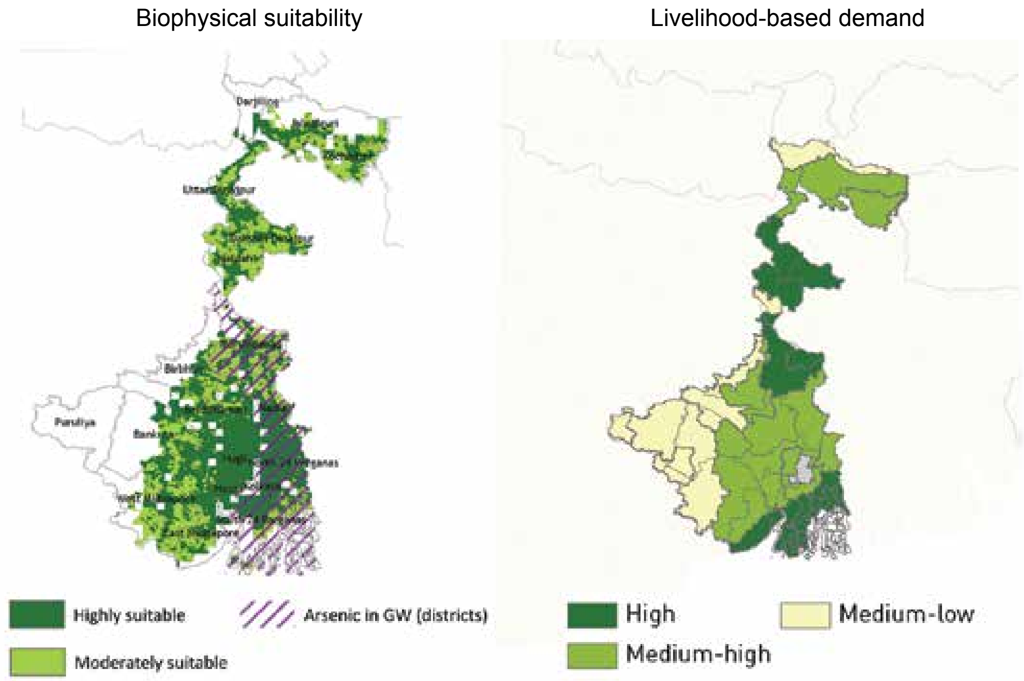
Source: This study.

Note: INR = Indian Rupee

Who benefits and where

Using the biophysical criteria of soil properties as a predictor of groundwater availability and night lights as an indication of electric grid connections, combined with livelihood-based demand, researchers from the AgWater Solutions Project estimate that rural electrification of pumps could benefit from 2 to 4.3 million households (4-8% of rural households) in West Bengal, at a 50% adoption rate (Figure 5). The potential application area is 866,000 to 1,743,000 ha (or 13.2 to 26.6% of the total agricultural land area).

FIGURE 5. Potential for rural electrification of groundwater pumping to improve livelihoods.



Source: FAO 2012a.
Note: GW = groundwater.

Stakeholder recommendations.

- Regional workshops were held in Cooch Behar, Maldah, Bankura, Hooghly and the South 24 Parganas, which included stakeholders from all the districts of West Bengal. Stakeholders recommended rural electrification for all districts in North Bengal (Cooch Behar, Jalpaiguri, Dinajpur and Maldah). Murshidabad was not proposed as being suitable for electrification of pumps for groundwater use, because eight of its blocks have groundwater that is contaminated with arsenic. Similarly, Nadia was not included, because groundwater in 85% of its blocks have arsenic beyond permissible limits for agricultural use. Parts of West Midnapur and Bankura (beyond the hard-rock aquifer) has been proposed for electrification.
- During field visits to the districts, farmers stated their interest in rural electrification and also prioritized electricity and diesel subsidies to reduce the cost of irrigation.
- A body of stakeholders, including members of government departments, researchers and NGOs are concerned about the implications of increasing groundwater use, and the potential for West Bengal to encounter the problems that other states like Punjab are facing.

Source: FAO 2012b; Saikat Pal, AgWater Solutions Project Dialogue Facilitator, July 2012, pers. comm.

Rainwater Harvesting with *Hapas*[3]

Small ponds on individual farms can store rainwater for the dry season, allowing households to diversify crops, produce fish, increase livestock numbers and have more water for domestic use.

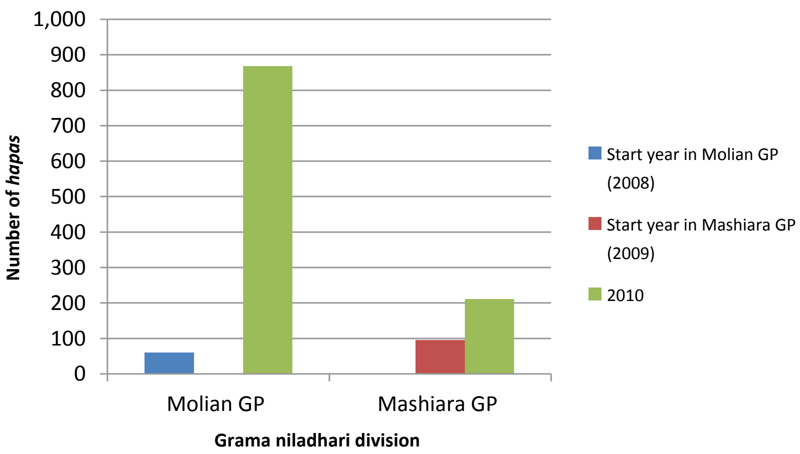
Where the opportunity lies

In dry districts like Bankura, collecting rainwater for use in the dry season has major implications for agriculture and livelihoods. In 2008, a program, funded by the Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS), was initiated by the NGO, PRADAN, to experiment with reservoirs to store rainwater[4]. Known locally as *hapas*, these storage ponds were initially designed to cover 5% of a farmer's land to provide supplementary irrigation for paddy. They were highly successful and farmers have modified them, by making them larger and deeper, so that they can be used for multiple purposes.

The research

This project investigated the impact of *hapas* by interviewing 64 beneficiary and 36 non-beneficiary households in three villages in the Hirbandh block. Interviews were also conducted with several government officials and the implementing organization, PRADAN. It was observed that the number of *hapas* being used in the study villages has grown steadily during a short period of time (2 to 3 years) (Figure 6).

FIGURE 6. Increase in the number of *hapas* in Molian Gram Panchayat (GP) and Mashiara Gram Panchayat.



Source: Banerjee 2011.

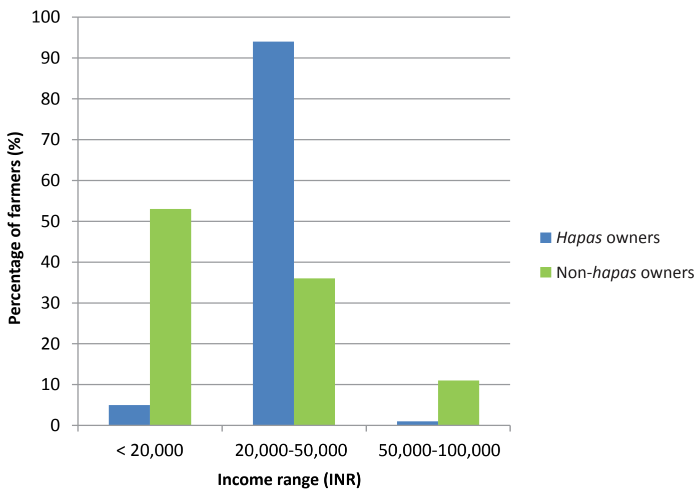
[3] Based on Banerjee 2011; and AgWater Solutions Project 2012b.

[4] Many organizations are implementing rainwater harvesting through various structures, including small ponds. The AgWater Solutions Project chose to work closely with PRADAN to understand the model that they use for this purpose.

While farmers were initially reluctant to give up land for rainwater harvesting structures, the farmer surveys carried out by the project highlighted a number of benefits from their adoption, including:

- higher average annual incomes as a result of increased production. This averages INR 5,792 after costs (Figure 7);
- diversified crop mix (*hapas* owners now grow maize and vegetables);
- multiple-use options, including domestic purposes, livestock and fish;
- better nutrition and social status;
- more livestock;
- reduced migration and more children attending school;
- more agricultural labor jobs (in-field and for excavating ponds); and
- reduced risk associated with climate variability and groundwater overdraft through storage and recharge.

FIGURE 7. Comparison between the incomes of farmers who own and do not own *hapas*.



Source: Banerjee 2011.

Where to invest

The adoption rate of *hapas* has been most striking in villages with a high percentage of scheduled (officially listed) castes and tribes, who have small farms and need only set aside small portions of the land they cultivate. Research tells us that further scaling-up of the initiative requires involvement of all the villagers and engaging all political parties to minimize politicizing of the approach.

Encouraging local officials in other districts to use MGNREGS to fund *hapas*, and offering demonstration programs for government officials that are responsible for MGNREGS funds are likely to increase adoption. Under the project and hosted by PRADAN, the state MGNREGS team members accompanied by the District Nodal Officers from 10 districts visited the Bankura

MGNREGS site. They interacted with the villagers and the Bankura District Administration and MGNREGS cell.

To make best use of their *hapas*, farmers need some sort of water-lifting technology. Among the farmers in our survey, about 40% use their own pumps or hire a pump. Encouraging pump rental markets or 'irrigation service providers' (Box 2) could help to reach more farmers.

Box 2. Irrigation service providers.

Irrigation service providers are private entrepreneurs who rent out small pumps and offer support services to farmers who want to irrigate crops. The service provider rents a pump set to an individual or a group of farmers for a fixed period of time, and takes care of the running costs, and operation and maintenance of the pump set. Farmers pay a fixed rate per hour that covers all costs and leaves a profit for the service provider. Depending on the need and the level of skill and motivation of service providers, they can extend their services to offer loans for agricultural inputs, agronomic advice and credit.

Benefits:

- For local entrepreneurs: a profitable business opportunity.
- For farmers: affordable access to motorized pumping as individuals (no need to organize into a collective); potentially related services (agronomic and marketing advice, and credit); and higher profits from vegetable farming due to larger areas and better water supply.

Stakeholder recommendations.

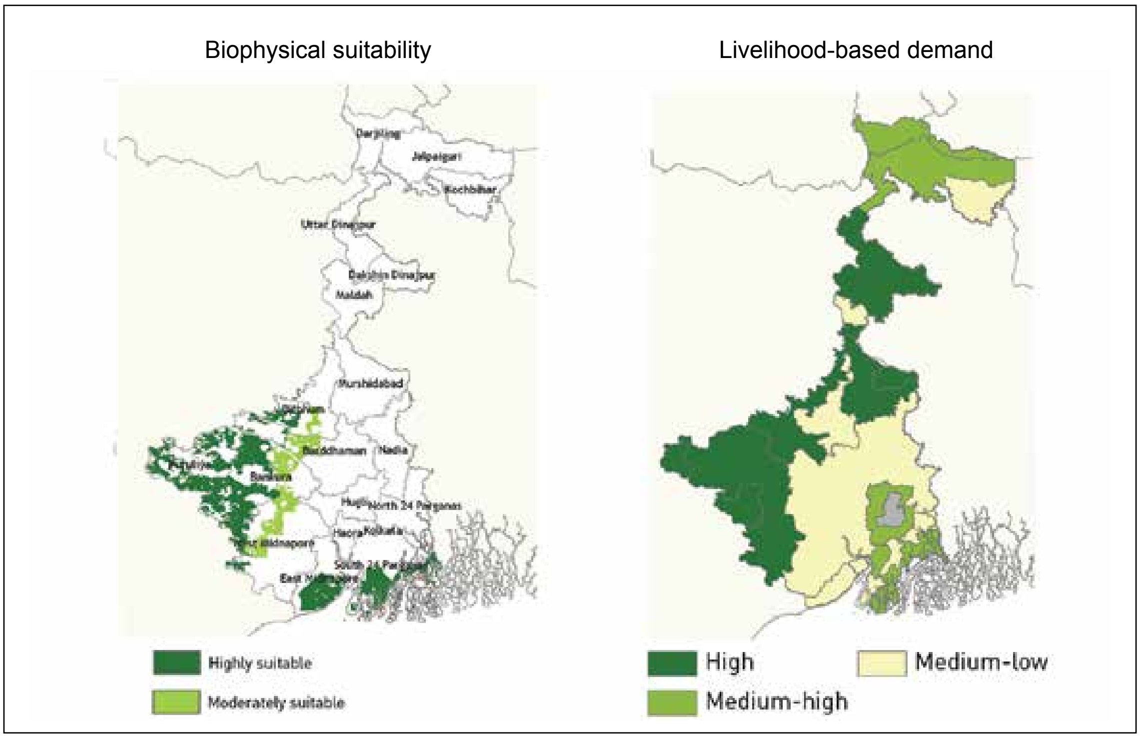
Workshops at state and district level and field visits with farmers identified rainwater harvesting as a priority in areas where there is limited scope for groundwater development and where farmers have sufficient land to allocate 10% to rainwater harvesting structures. Coastal areas were also highlighted because of salinity issues. Specific districts for which rainwater harvesting is suggested are Purulia, Bankura, West Midnapur and some of the coastal part of the South 24 Parganas, North 24 Parganas and Purba Medinipur.

Source: FAO 2012b; Saikat Pal, AgWater Solutions Project Dialogue Facilitator, July 2012, pers. comm.

Who benefits and where

Using criteria including low groundwater yield, lower population density, relatively short length of the growing period and occurrence of Thionic Fluvisols (as an indication of seawater intrusion) combined with livelihood criteria, researchers from the AgWater Solutions Project estimate that rainwater harvesting could benefit 393,000 to 626,000 households (0.7-1.1% of rural households) in West Bengal, at a 50% adoption rate. The potential application area is 589,000 to 939,000 ha or 9.0 to 14.3% of the total agricultural land area (Figure 8).

FIGURE 8. Potential for rainwater harvesting to improve livelihoods.



Source: FAO 2012a.

Understanding Adoption Dynamics of Water-lifting Technologies[5]

Despite falling sales and increasing abandonment of the treadle pump, they were once an important AWM technology in Cooch Behar and offer lessons about technology adoption. Investors must understand that AWM technology adoption is not a static process but rather one that is dynamic over space and time.

The Cooch Behar District provides a unique site for the study of adoption of water-lifting technologies for agricultural use. In the early 1990s, farmers in Cooch Behar were smuggling treadle pumps over the border from Bangladesh. By the end of the decade, the same farmers were among the first to benefit from the influx of cheap, lightweight Chinese diesel pumps, which were also smuggled across the border. Now, electric pumps are becoming more popular as the power grid expands. The range of available water-lifting technologies and the long history of adoption offered an ideal study site to examine adoption dynamics.

The research

Nearly 300 smallholder farmers were interviewed. The main findings from the interviews (Table 2) shed light on what motivates smallholder farmers to adopt new technologies or stick with ‘tried and true’ methods. Project planners and implementers, state policy lawmakers, university

[5] Based on Malik and Ray 2011; and AgWater Solutions Project 2011.

researchers, extension services and NGOs can use this information to design and fine-tune interventions that address the needs of farmers.

TABLE 2. Why farmers adopt new technologies.

Pump type	Reasons for adoption
Treadle pumps	Most pumps were purchased in the years between 1995 and 2002. Only five of the original 60 pumps are still in use. They were first purchased because of the low cost, easy operation and maintenance, and relative portability. Rising wages (treadle pumps require a lot of labor) and availability of alternative options have considerably reduced their popularity.
Electric and diesel pumps	Increased availability and affordability of diesel and electric pumps. Rental markets for motor pumps. Most farmers who owned treadle pumps now hire motor pumps.

Source: Malik and Ray 2011.

Lessons about technology adoption

Rethink the 'technology ladder'

The adoption of irrigation technology does not necessarily follow a linear path from simple manual methods to 'advanced' motorized technologies, a process sometimes referred to as the 'technology ladder'. The 'ladder' implies that manual watering methods, such as buckets followed by treadle pumps, are necessary stepping stones to gain finances and irrigation experience before progressing on to buying a motor pump. The reality is more nuanced. Most first-time motor pump owners relied entirely on rainfall before taking up irrigation. Nearly all former treadle pump users switched to pump rental markets rather than buying a motor pump and most farmers that relied on rental markets were first-time irrigators.

Promote rental and second hand markets

Ownership is clearly not a necessary precondition for technology access. If motorized pumps are too expensive for smallholders they can rent them or buy them second hand. Rental markets have emerged as a natural response to demand from those who do not own pumps. Markets for second-hand pumps and spares are also emerging as demand increases.

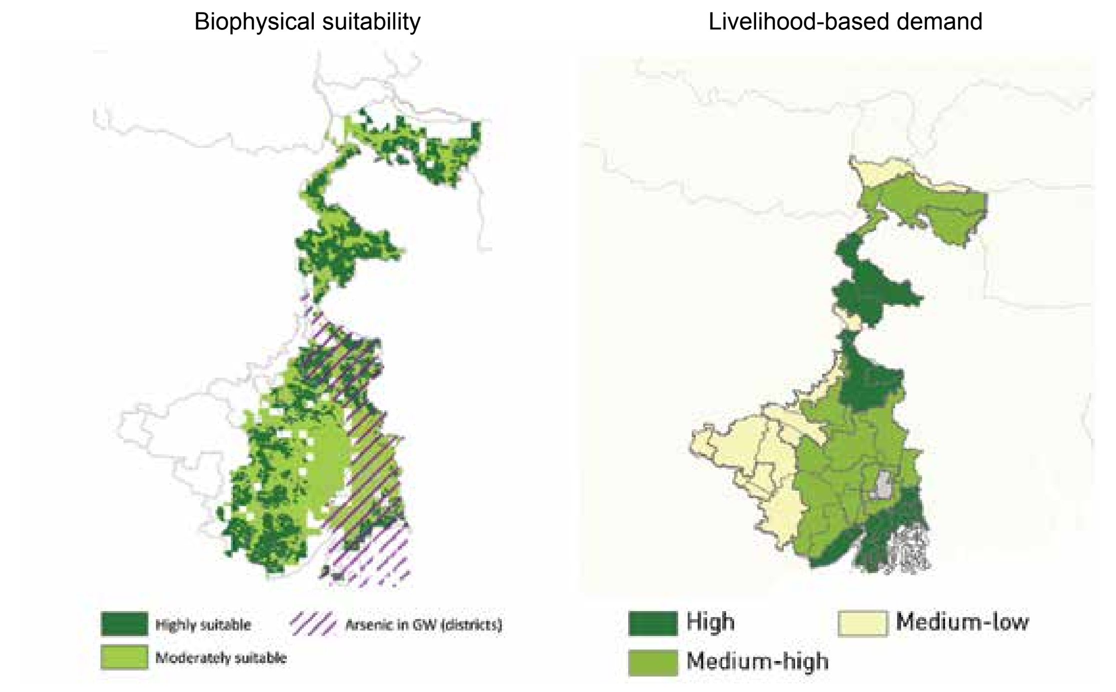
Provide alternatives

Low cost and affordability are not necessarily the determining factors that persuade smallholders to invest in a certain technology. Farmers seek other values such as pump weight or durability. For example, a lightweight pump can be used on many fields and can be carried home and stored under lock and key. Our surveys also showed that the majority of smallholders who could not afford to buy a motor pump did not invest in a treadle pump, but preferred to rent a motor pump even if it is slightly more expensive. The key is, therefore, to make alterative options available to meet different needs because every option has pros and cons.

Who benefits and where

Using the biophysical criteria of soil properties as a predictor of groundwater availability and night lights as an indication of electric grid connections, combined with livelihood-based demand, researchers from the AgWater Solutions Project estimate that non-electric motor pumps, especially diesel pumps, could be used by 1.1 to 3.7 million households (2 to 6.5% of rural households) in West Bengal, at a 50% adoption rate (Figure 9). The potential application area is 0.4 to 1.4 Mha or 6.9 to 22.8% of the total agricultural land area. This is in addition to the areas that could be served by electricity connections.

FIGURE 9. Potential application area for motorized pumps.



Source: FAO 2012a.
Note: GW = groundwater.

ASSESSING SOCIAL AND ENVIRONMENTAL IMPACTS OF AWM: LESSONS FROM THE JALDHAKA WATERSHED[6]

Agricultural water management interventions will impact social and environmental aspects within and beyond the area where they are implemented. They can increase food security and help to alleviate poverty, but re-allocation of water can potentially undermine other uses of the same water, for other livelihood purposes or, indirectly, by reducing availability to support different ecosystem services. Undertaking a baseline assessment and participatory scenario analysis helps to identify potential positive and negative impacts of future AWM interventions, which can help to mitigate or avoid negative impacts and increase the success of the intervention.

[6] Based on de Bruin et al. 2012; and SEI 2010.

In West Bengal, a baseline assessment and a participatory scenario analysis were undertaken in a stakeholder dialogue with local experts. One of the concerns raised was a drop in the groundwater level due to increased irrigation. The impacts of increased irrigation on yield and water resources were then modeled. The dialogue and modeling showed that irrigation in the watershed can increase with only local effects on groundwater levels. However, soil fertility and the use of agrochemicals need to be monitored to avoid further negative impacts.

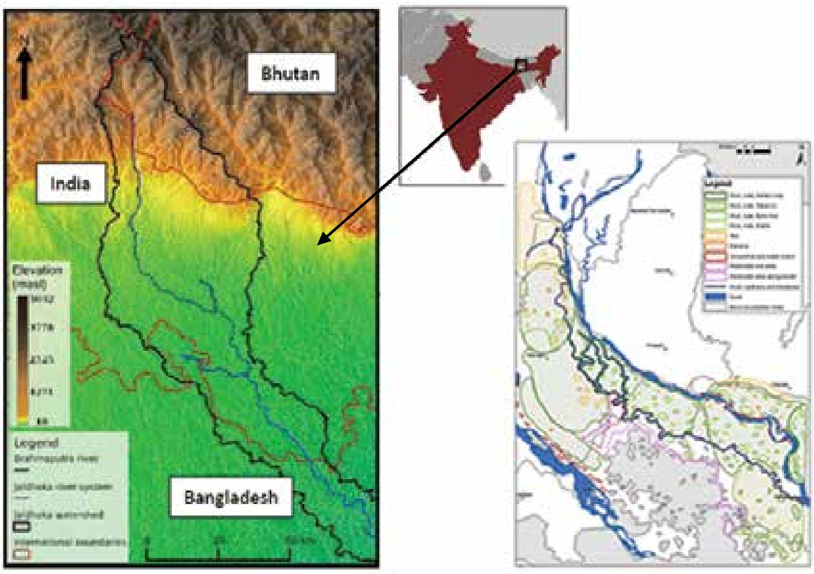
The Watershed

The Jaldhaka River is a tributary of the Brahmaputra River and flows through Bhutan, West Bengal, India, and Bangladesh. The area in India covers 6,410 square kilometers (km^2), which is 66% of the total watershed (Figure 10). This includes mountainous areas, a piedmont upstream and a flat middle and downstream area. Rainfall is high (3,180 mm/y) with 80% falling between June and September (de Condappa et al. 2011).

About 65% of the population of the watershed lives below the Indian poverty line (DHC 2002). Most people earn a living as multi-crop farmers, some as independent tea growers (financially the most well-off), and others with off-farm and non-farm activities (generally the least well-off).

Farmers grow up to three crops per year, including rice, jute, potatoes, vegetables and tobacco. The most common method of irrigation uses diesel pumps, followed by electric pumps, canals, river-lift irrigation, and then treadle and hand pumps.

FIGURE 10. Delineation of the Jaldhaka watershed and the river tributaries.



Source: SEI 2010; *Source for DEM:* Shuttle Radar Topography Mission (Jarvis et al. 2008).

Equity issues

In the Jaldhaka watershed, households depend on and manage their own resources. Few community based initiatives exist for livelihood strategies and farming. People without land or with small parcels are highly vulnerable to external shocks.

Limiting factors for agriculture

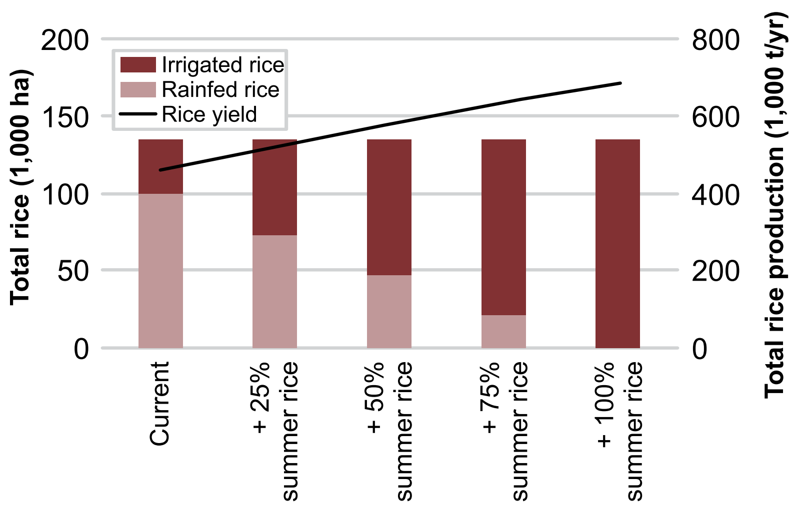
Agricultural production and development is not restricted by water resources but by land area per smallholder household, on average, only 0.8 ha per household. The other limiting factor is the lack of opportunity to intensify water use through better irrigation technologies and practices. Only a few farmers in each village own a diesel or electric pump and rent these out to other farmers. The limited availability of pumps means that farmers cannot access irrigation at the most appropriate time, which decreases crop yields. Despite the relatively high level of groundwater use, the volumes extracted are less than natural recharge, which means that there is room for increased irrigation for summer-season rice production.

Scenario

Rural electrification: Hydrologic and social impacts

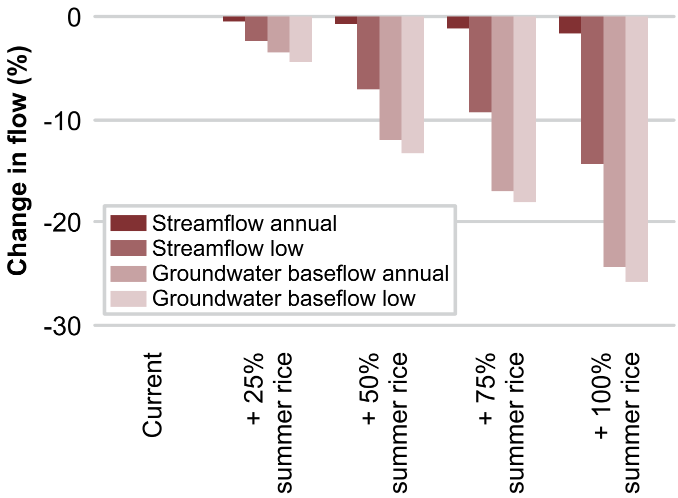
In the stakeholder consultation, a future AWM scenario, 'rural electrification', was discussed. This is a relevant future pathway in the Jaldhaka watershed according to a stakeholder dialogue held in Kolkata in 2010 as part of this project. The rural electrification scenario assumes that farmers would increasingly use electric pumps instead of diesel pumps and would start growing summer-season rice on fields currently only used for growing rainfed rice. Modeling showed that increased irrigation could improve rice yields by 13 to 25%, resulting in an additional 60,000 to 100,000 tonnes (t) per year (t/yr) (Figure 11). The impact of rural electrification on the current level of groundwater use would be small if less than 50% of the area producing rainfed rice is irrigated (Figure 12). An increase of more than 50% would disturb baseflow and groundwater levels, especially in already intensively cultivated areas (Figure 12).

FIGURE 11. Yield impact when fields that currently grow rainfed rice are increasingly irrigated.



Source: SEI 2010; de Bruin et al. 2012.

FIGURE 12. Water balance impact when fields that currently grow rainfed rice are increasingly irrigated.



Source: SEI 2010; de Bruin et al. 2012.

The rural electrification scenario has both positive and negative social and environmental impacts. An increased rice yield for farmers would provide them with more income, and tea growers would benefit by being able to use sprinkler irrigation and power sprayers for pesticide application. It is, however, likely that not all smallholder farmers will be able to afford electricity, limiting their ability to improve their livelihoods. Increased production is also likely to impact soil fertility, and the use of agrochemicals with potential negative effects on human health and the environment. These impacts can, however, be mitigated by ensuring equity of access and training to help farmers manage soil fertility in a sustainable way.

Stakeholder recommendations.

What Jaldhaka farmers and local experts say about enabling positive change:

"Ask us what we want and don't want. Help us get better access to credit. Provide training to mitigate existing negative impacts on health and the environment. Ensure good governance in the natural resources planning process."

CONCLUSIONS[7]

The AgWater Solutions Project did not undertake an exhaustive analysis of all the possible AWM options that are available to West Bengal, but it looked at three major 'groups' of AWM options that can have considerable influence over the smallholder irrigation landscape. Options for groundwater use and recharge were reviewed, specifically in relation to how and where to ease restrictions; surface water storage and collection was reviewed, focusing on the *hapa* model; and technology adoption was investigated to understand what motivates choice of AWM option.

Hapas appear to be a popular choice for smallholders including scheduled castes and tribes, because they can be constructed on small landholdings and can be used for multiple purposes. If rolled out across the state, *hapas* could benefit up to 626,000 households irrigating 14% of the total land area. The investment cost to reach this number of people could be up to USD 2,940 million. Investment in *hapas* can be supported by local governments, especially through MGNREGS. Officials should be given information about *hapas,* including construction and benefits. *Hapas* are suitable in most areas, especially where rainfall is sufficient and groundwater use is limited (e.g., due to aquifer type or water quality). They can also be used to recharge groundwater.

Electricity connections to utilize groundwater for irrigation could benefit up to 4.4 million households, irrigating nearly 27% of the total land area. Electricity is the cheapest way to power motor pumps in West Bengal (and many other places), but it can be hard and costly to get a connection. Easing policies that restrict access to the grid can offer much-needed access to groundwater which can enable farmers to grow high-value dry-season crops. This recommendation has been accepted by the state government but more needs to be done to make farmers aware of the change in the Groundwater Act.

Diesel pumps are an option if electricity is not available, but they are much more expensive to run and farmers are likely to need some sort of financial support. If supported, around 3.7 million households could make use of diesel pumps and 23% of the total agricultural land area could be irrigated. Combined with electrically powered pumps, some 14% of the rural population could make use of groundwater.

In all cases, an option for those that cannot afford the capital cost of a pump to make use of either surface water stored in *hapas* or groundwater, is pump rental markets.

Studies on the **adoption dynamics** of AWM technologies suggested that a rethink of the 'technology ladder' is in order. The adoption of irrigation technology does not necessarily follow a linear path from simple manual methods to 'advanced' motorized technologies. Instead, farmers should be offered a range of options so that they can select those that best suit their needs.

[7] All figures provided in this section assume that 50% of the total potential users adopt the AWM option. All figures are taken from FAO 2012a.

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ISSN: 2012-5763
ISBN: 978-92-9090-755-8