Water for wealth and food security

Supporting farmer-driven investments in agricultural water management

Edited by
Meredith Giordano, Charlotte de Fraiture, Elizabeth Weight and Julie van der Bliek

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Synthesis Report of the AgWater Solutions Project

AGWATER SOLUTIONS

Improved livelihoods for smallholder farmers

IWMI International Water Management Institute

FAO

iDE

IFPRI International Food Policy Research Institute

SEI Stockholm Environment Institute

Funded by

Bill & Melinda Gates foundation

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Meredith Giordano, Charlotte de Fraiture, Elizabeth Weight and Julie van der Bliek

Credits and acknowledgements

This report synthesizes findings from the AgWater Solutions Project (see project website at: http://awm-solutions.iwmi.org).

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Project consortium

The project was conducted by the following lead organizations:

International Water Management Institute (IWMI)

Food and Agriculture Organization of the United Nations (FAO)

iDE

International Food Policy Research Institute (IFPRI)

Stockholm Environment Institute (SEI)

Project Steering Committee

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Foreword from sub-Saharan Africa

Sub-Saharan Africa is blessed with significant land and water resources and diverse agro-ecosystems but agricultural productivity is low and hunger and malnutrition persist, particularly in rural areas. The area under irrigation in sub-Saharan Africa is the lowest of any region in the world. Making effective use of available water can help to improve productivity and reduce poverty. Smallholder farmers attracted by the benefits of irrigation are already investing in small-scale irrigation as documented in this report. The report is significant because it provides practical recommendations and tools for governments, the private sector, donors and organizations to effectively support these farmer-led initiatives to improve the lives of millions of families sustainably and equitably.

These recommendations are timely. With national and international attention focused on how we can feed the world's growing population in a sustainable way, it is an opportune time to re-examine the critical role of water in achieving food and nutritional security.

Behind this book lie four years of research, together with the voices of governments, farmers, finance institutions, and local and international organizations, gathered through interviews, data collection and discussions held in Burkina Faso, Ethiopia, Ghana, Tanzania, Zambia and the Indian states of Madhya Pradesh and West Bengal. This rich input is supported by the combined significant expertize of the project team: IWMI, FAO, iDE, IFPRI and SEI. The resulting recommendations reflect substantial experience regarding smallholder agricultural water management in Africa and India. By supporting farmers' initiatives, interests and successes, we have the potential to turn the detailed findings of the AgWater Solutions Project into real benefits for farmers on the ground.

In Nigeria, we will build on the lessons in this book to inform our strategy to address climate change through better water management. With climate change, water-use efficiency becomes even more critical, and maximizing crop yield per drop of water must play a larger role in achieving sustainable increases in food production.

By combining the practical improved water management systems and approaches in this book, with expanded use of modern agricultural technologies, better policies and market incentives for farmers, Africa will be able to accelerate food production to feed itself.

Dr. Akinwumi A. Adesina
Honourable Minister of Agriculture and Rural Development, Federal Republic of Nigeria

Foreword from India

India's smallholder farmers comprise 78% of the country's farming population and produce 41% of the country's food grains. Yet, this sector of the agricultural community owns only 33% of the total cultivated land and, together with landless agricultural laborers, constitutes the bulk of India's rural poor. Moreover, despite agriculture's significant contributions to India's economic growth, smallholder farmers, including many female farmers, continue to face a number of critical challenges to produce food in a sustainable and profitable manner, particularly in the context of climate change.

Nowhere in India is this situation more pronounced than in West Bengal and Madhya Pradesh, which are predominantly agrarian states dominated by smallholder farmers and complex agrarian systems. Addressing the challenges of agricultural production in these two states requires an approach focused on smallholder agriculture. In this context, it is highly commendable that IWMI - in collaboration with FAO, IFPRI, iDE and SEI as well as numerous local partners including the Indian Council of Agricultural Research - conducted an intensive study and produced recommendations for investments to improve small-scale agricultural water management in the Indian states of West Bengal and Madhya Pradesh. These investments include rainwater harvesting, drip irrigation, rural electrification and refinements to the Mahatma Gandhi National Rural Employment Guarantee Scheme.

The results of this collaborative research effort – synthesized in this report – deliver an original and substantive contribution to our knowledge of beneficial avenues to increase incomes and agricultural production through improved agricultural water management not only for West Bengal and Madhya Pradesh but also for India, generally. The recommendations of the study produced are practical, actionable and supported by key stakeholders on the ground.

Finally, I wish to congratulate the researchers from IWMI and their partners for this monumental effort. I do hope that this provides the pathway to enhancing smallholder farmers' livelihoods, sustainable food security and contribution to climate change mitigation in the study's focal regions of South Asia and sub-Saharan Africa.

Dr. S. Ayyappan
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and Director General, Indian Council of Agricultural Research
New Delhi, India

Main findings and recommendations

Smallholder irrigation could change the lives of millions of people

Smallholder farmers in sub-Saharan Africa and South Asia are increasingly using small-scale irrigation to cultivate their land. Individually owned and operated irrigation technologies improve yields, reduce risks associated with climate variability and increase incomes, allowing farmers to purchase food, health care and education. There is great potential for many more farmers to benefit from small-scale irrigation. This report presents governments, donors, lending institutions, the private sector and farmers with the opportunity to make well-informed decisions about investments in agricultural water management (AWM) that could change the lives of millions of rural people.

Small-scale AWM is outpacing the use of large-scale irrigation

The proliferation of small-scale private irrigation is an established trend in South Asia that is now gaining ground in sub-Saharan Africa. In many African countries, water management by smallholders is already more important for irrigation than the public irrigation sector, in terms of the number of farmers involved, the area covered and the value of production. For example, in Ghana, private irrigation by smallholders employs 45 times more individuals and covers 25 times more land than public irrigation schemes.

Water at the right time can make a big difference to farmers' incomes and nutrition

Small-scale private irrigation provides millions of poor farmers with additional income during the dry season. Having access to water at this time means they can cultivate crops and earn money outside of the main season when other agricultural opportunities are limited. In Madhya Pradesh, incomes of farmers who constructed on-farm ponds to irrigate pulses and wheat have risen by more than 70%; as a result, they have also been able to improve and expand their livestock herds. In Tanzania, half of the dry-season cash incomes of smallholders come from growing irrigated vegetables. In Zambia, the 20% of smallholders who cultivate vegetables in the dry season earn 35% more than those who do not.

Smart investments in AWM could benefit farmers across sub-Saharan Africa

As small-scale water management technologies become more accessible, the potential to expand private irrigation is enormous. This is especially so in sub-Saharan Africa, where there is significant scope to extend the area of land that is irrigated or under improved agricultural water management. Investment costs of small-scale irrigation technologies are affordable, and implementation is relatively straightforward when compared to large-scale irrigation, so the potential for up-scaling and reducing poverty is high. For example, investments in dry-season irrigation for rice could improve yields between 70% and 300% across sub-Saharan Africa. Investments in motorized pumps, specifically, could benefit 185 million people and generate net revenues up to USD 22 billion per year. In Tanzania, investments to improve community-managed irrigation schemes are resulting in income and yield improvements on a par with government-managed irrigation schemes, but at a lower cost. Similarly, on-farm rainwater management and conservation agriculture could yield significant returns.

New investments would be supporting an existing, farmer-driven trend

Smallholder farmers demonstrate a genuine interest by financing and installing irrigation technologies and investing their own resources in their agricultural businesses. Small-scale AWM could expand significantly if

farmers were able to overcome key constraints, such as high upfront investment costs; poorly developed supply chains; high taxes and transaction costs; difficulty accessing information and knowledge on irrigation, seeds, marketing, equipment and other inputs; and imbalances of power that leave farmers at a disadvantage when selling their produce.

Smallholder AWM lacks supportive institutional structures

The adoption of small-scale irrigation technologies by many individual farmers is a new dynamic, which presents opportunities and challenges that differ from conventional irrigation development. Smallholder AWM requires new organizational models because existing governing bodies concerned with water management are often not adapted to handle the challenges posed by this alternative, dispersed mode of supplying water. Irrigation departments tend to oversee large-scale canal irrigation, while agricultural departments are concerned with rain-fed farming. Small-scale private irrigation falls between the two and, therefore, lacks an institutional 'home'. As a result, opportunities for improving small-scale private irrigation are often lost.

Un-regulated and expanding small-scale irrigation poses new challenges

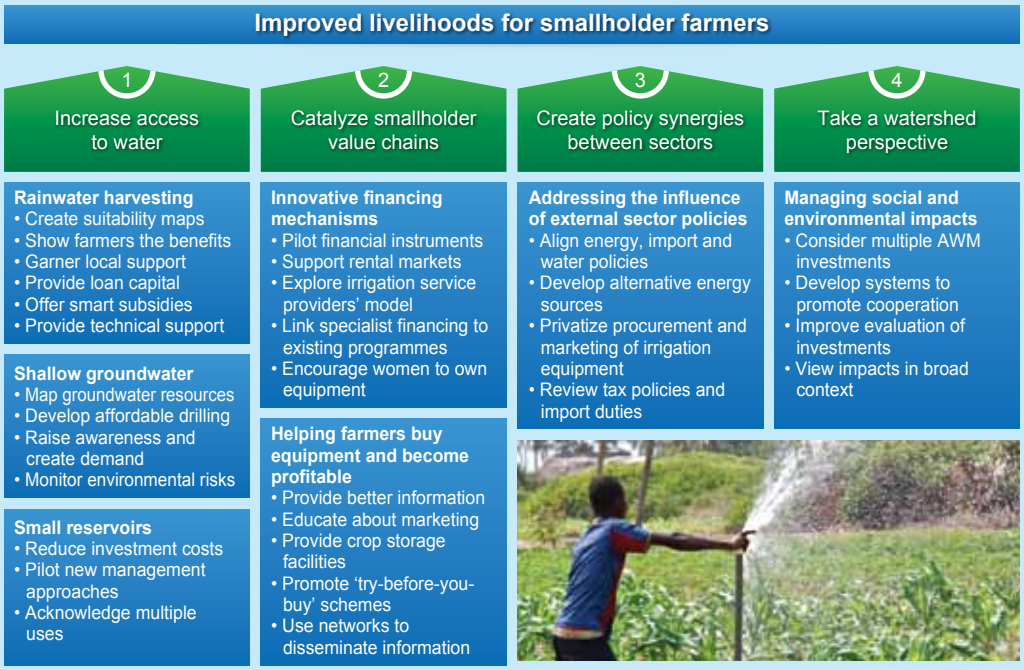
Small-scale private irrigation poses several challenges related to social equity and environmental sustainability. First, poor farmers (often women and young people) cannot always afford the upfront investment costs for AWM technologies and the associated agricultural investments needed to generate higher profits. While all farmers face agricultural risks, poorer farmers are often less able to access resources and assume proportionally larger financial risks. Second, investments in irrigation, whether small-, medium- or large-scale, are associated with the relatively more intense use of agrochemicals, which can have a negative impact on water resources and food safety. Finally, competition between upstream and downstream users, and the depletion of groundwater, may be aggravated by the unchecked or un-regulated nature of small-scale private irrigation.

Many opportunities exist to address constraints and unlock the sector's potential

With food security back on the international agricultural agenda, and climate change increasing the uncertainty of rainfall, it is an opportune time to reconsider investments related to irrigated agriculture. With appropriate support that recognizes the need to minimize negative social and environmental impacts, small-scale AWM can realize its potential to reduce poverty.

The AgWater Solutions Project produced recommendations for supporting the AWM sector, which include making investments to: increase access to water sources and irrigation technologies; address market inefficiencies; rethink policies; and adopt a watershed perspective to address potential social and environmental issues (Figure 1).

Figure 1: Pathways to improving the lives of smallholder farmers using AWM
(Source: This study)



Investments made via any of these pathways must recognize that different people have different needs and they demand different responses. No solution is universal. The actions that will have the best impacts are those taking into account, at the planning stage, the livelihood contexts in which smallholder farmers operate. Understanding farmers' needs will ensure that actions to support them are beneficial.

It is vital to plan for, and adequately finance, regular engagement among stakeholders, including farmers, investors, agricultural-support organizations, the private sector, policymakers and government officials. Involving key actors early on, and throughout the design and implementation stages of interventions, will ensure that the decisions taken lead to effective policy changes to help smallholder irrigation flourish.

Context of the AgWater Solutions Project

The majority of the world's poor live in South Asia and sub-Saharan Africa. Of these 1.7 billion people (Chen and Ravallion 2007), some 860 million are considered 'food insecure'; that is, they don't consistently have sufficient quantities of nutritious food to live healthily. According to Molden (2007) and IFAD (2010), the number of food-insecure people in sub-Saharan Africa nearly doubled from 125 million in 1980 to 240 million in 2010.

A key question for planners is how to reverse this trend and improve food security and livelihoods for the most vulnerable people. Around 70% of the poor in sub-Saharan Africa and South Asia live in rural areas, with few options except to work in agriculture. For the near-to-medium term, the challenge will be to transform the agricultural economy in these regions from a source of poverty to an engine for economic growth.

Although the agricultural sector in some parts of South Asia has grown considerably in the last 50 years, large areas of eastern India and Bangladesh lag behind. Meanwhile, sub-Saharan Africa's agricultural productivity remains the lowest in the world. Poor water availability, access and management are among the manifold reasons why these areas have performed poorly.

Millions of poor men and women find it difficult to access water, and many farmers face water scarcity even when resources are available. Of sub-Saharan Africa's abundant renewable water resources, only 3% are withdrawn for agriculture. About 4% of arable land is equipped for irrigation, of which less than 10% is serviced by groundwater (FAO 2011).

Lack of access to water also hinders agricultural productivity in South Asia, even where water is relatively abundant. The Terai that spans eastern India, Bangladesh and Nepal hosts some of the world's most abundant surface water and groundwater resources. However, not only do frequent droughts take place, but the Terai is also intensely flood-prone and subject to prolonged surface waterlogging after normal monsoons.

Cycle of poverty

Consequently, the region experiences low agricultural productivity, which in turn perpetuates rural poverty. Some 500 million of the world's poorest people live here in South Asia's "poverty square" (Shah et al. 2000). Despite there being further potential to exploit groundwater to grow more crops and alleviate poverty, economic and political reasons are preventing pump-based irrigation from expanding.

Farmers' inability to access or control water has an obvious direct impact on potential yields and income. It also has an indirect impact by reducing potential payoffs from investments in fertilizers, improved seed varieties and learning technical skills. Not only does this cause agricultural productivity growth to stall, but it also means that farmers, and even entire nations, are reliant on the vagaries of weather for their well-being.

After decades of underinvestment in water management in sub-Saharan Africa, governments and development agencies are turning to irrigation to help improve this situation. The continued rise in food prices has prompted fresh interest among investors in large-scale irrigation schemes, which, given that very little irrigation infrastructure exists in sub-Saharan Africa, is relevant and warranted. However, even

doubling the area under large-scale irrigation would only increase the contribution of irrigated agriculture to food supply from 5% at present to 11% by 2050 (Molden 2007). In addition, large-scale investments are expensive (Inocencio et al. 2007) and only reach smallholders who farm close to where the systems operate. Small-scale, farmer-driven investments in irrigation (that use locally available water) exist alongside large-scale, public-sector-financed irrigation schemes (that distribute water collected in major dams). However, the focus is often on large-scale investments in irrigation, and much less attention is given to the smallholder AWM sector. AWM has increased recently thanks primarily to expanding market opportunities and decreased costs, together with the increased availability of AWM technologies. Independent of formal irrigation infrastructure, many farmers now use their own resources to procure irrigation equipment (buckets, pumps, drip systems, pipes and sprinklers) either individually or in small groups.

Taking the initative

Rather than waiting for water to be delivered, these enterprising farmers now access shallow groundwater, rivers, lakes, reservoirs, plus irrigation and drainage canals in public schemes wherever they find access. They directly benefit when they grow more staple and high-value crops, as they can potentially increase their own consumption and sell any surplus, thereby improving household food security and income. More reliable access to water and growing domestic, regional and international markets, also give farmers the confidence to invest in productivity-enhancing fertilizers, agricultural management strategies and agrochemical inputs, thus supporting intensification and diversification. It increases the scope for creating wage-paying jobs in farming, and can reduce poverty indirectly by increasing non-agricultural rural and urban employment (Castillo et al. 2007). Successful, cheap and adaptable, private irrigation is now spreading rapidly.

Although AWM provides significant direct and indirect benefits to low-income farm households, it is proceeding in an un-regulated and unplanned manner. Because they operate without support from institutions or investors, smallholder farmers face several challenges. These include difficulties in accessing land and credit, insufficient information, poor markets, and negative environmental impacts caused by the collective and un-regulated actions of many smallholders. Investing in AWM technologies is costly, and in the absence of risk-reducing measures small farmers' exposure to financial risks may be very high. However, these challenges are not insurmountable. Therefore, taking action to support the farmers that make up the smallholder AWM sector represents a significant investment opportunity that could help to alleviate poverty and ensure food security.

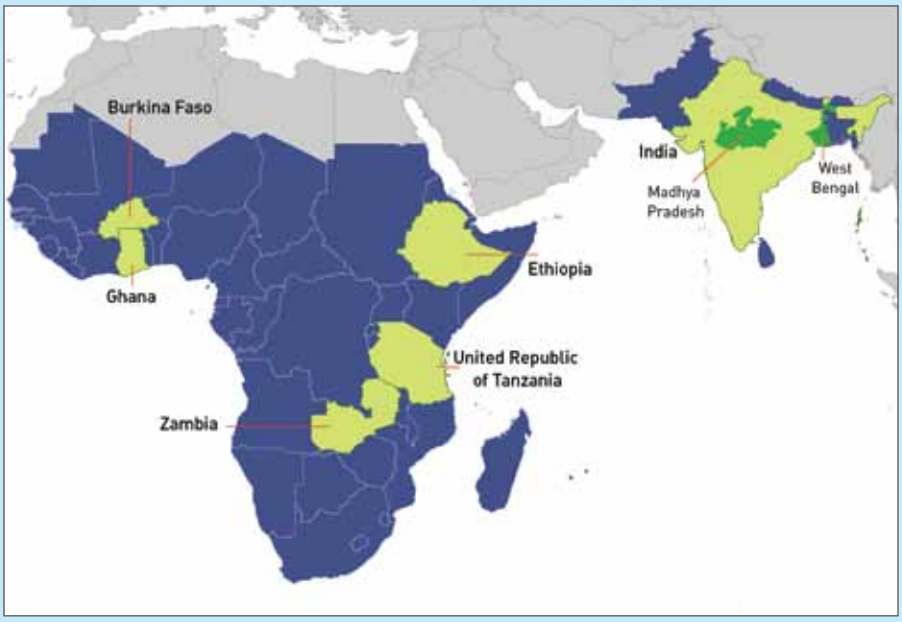
About the AgWater Solutions Project

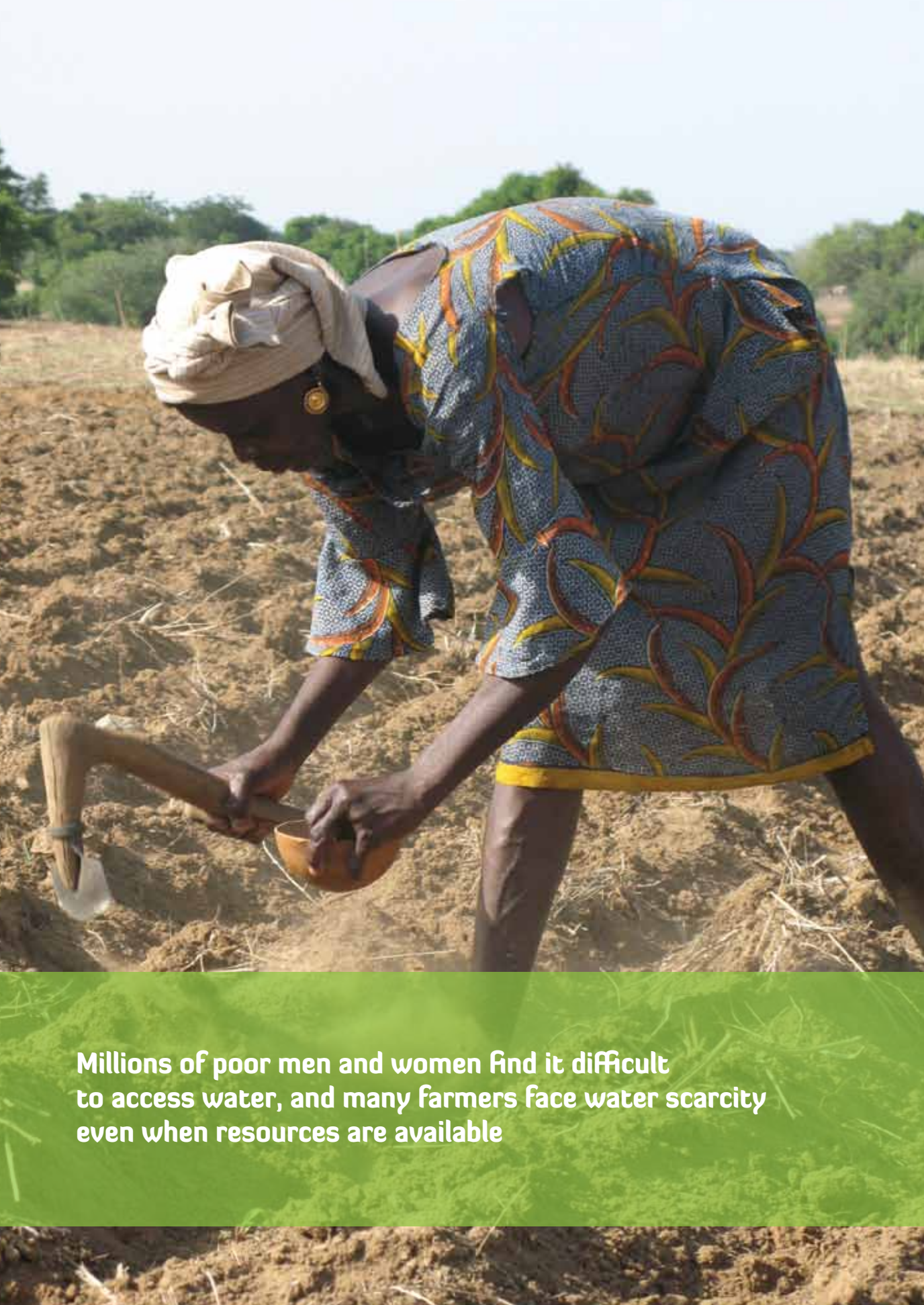
The AgWater Solutions Project, carried out between 2009 and 2012, focused on resolving water issues faced by smallholder farmers. The project examined existing AWM methods and technologies, together with factors that influence their adoption and scaling-up. Specifically, the project:

- assessed the potential of various water management technologies, in terms of the types and number of beneficiaries and their geographical distribution;
- examined the possible social, environmental and institutional implications of scaling-up the most promising water management technologies;
- developed business models and plans for disseminating the most promising agricultural water management technologies in the project countries; and
- initiated a dialogue among policymakers, implementers, private-sector representatives, donors and farmers to promote discussions and feedback on project findings, recommendations and business models.

The project aimed to identify investment opportunities in AWM that have high potential to improve the incomes and food security of poor farmers. The project also aimed to develop tools and recommendations for stakeholders, including policymakers, investors, non-governmental organizations (NGOs) and smallholder farmers. This report synthesizes the findings of the project. The research was undertaken in the African countries of Burkina Faso, Ethiopia, Ghana, Tanzania, Zambia, and in the Indian states of Madhya Pradesh and West Bengal.

The countries and states in which the AgWater Solutions Project carried out its research *(Source: This study)*





Millions of poor men and women find it difficult to access water, and many farmers face water scarcity even when resources are available

A bright future ahead for smallholder AWM

Smallholder AWM differs from conventional irrigation schemes in that farmers largely initiate and finance their supply of irrigation equipment individually or in small groups. Small areas of typically less than 2 hectares (ha) – and often much smaller – are watered with low-cost technologies. Farmers cultivate staple foods as well as high-value crops for the market, providing much-needed cash income during the dry season. Although this is a spontaneous and un-regulated phenomenon that is growing rapidly, it has great potential for promoting economic growth and reducing poverty.

The water sources supporting smallholder AWM are varied. In South Asia, smallholder farmers largely rely on groundwater sources but pumping from surface water, including rivers, lakes, reservoirs, plus irrigation and drainage canals, is not uncommon. There is renewed interest in rainwater harvesting, especially where groundwater supplies are declining. In sub-Saharan Africa, the opposite is true; here, the majority of farmers rely on rainwater directly falling on their fields. Some also have access to surface water flows for irrigation or use shallow, hand-dug wells constructed by family members.

Technologies used by farmers include buckets; watering cans; electric, diesel and treadle pumps; drip systems; and conservation agriculture techniques, such as terracing and in-situ rainwater harvesting. In South Asia, small, motorized pumps have become the technology of choice, particularly as lighter-weight imported and local varieties have come on to the market. The more energy- and cost-efficient electric pumps are favored, but these are unrealistic in many remote locations with irregular power supplies or limited connections to the electricity grid.

Our surveys found that more than 80% of farmers who use irrigation in sub-Saharan Africa employ manual lifting and watering methods using buckets and cans. However, the demand for more mechanized options is growing. The majority of farmers with pumps purchased them using their own resources. Most farmers in Ghana, Tanzania and Zambia, who said they presently use buckets or rely on rain-fed cultivation,

expressed the strong desire to buy a motorized pump but lacked resources to do so. Some farmers said they accessed pumps by renting or borrowing them from others. Dealers in small towns in all the study areas indicated that the demand for small, motorized pumps had risen in recent years, in part due to the influx of cheap pumps from China.

A vibrant and growing agricultural sub-sector

Small-scale water management is fundamental to the food security of millions of poor farmers in South Asia and sub-Saharan Africa. In South Asia, smallholder AWM dominates the agricultural landscape; more than half of the region's irrigation is drawn from privately owned wells. In sub-Saharan Africa, the trend towards individual and community-managed AWM is picking up speed, which is due to the low performance and limited extent of public irrigation schemes and the increasing availability of relatively cheap irrigation equipment.

Our estimates from surveys in sub-Saharan Africa indicate that some 185,000 ha in Ghana are under private irrigation, benefiting half a million smallholders. In Burkina Faso, some 170,000 farmers, mostly smallholders, irrigate vegetable crops during the dry season using buckets, watering cans and small motorized pumps. Vegetable production nearly tripled in the country from 60,000 tonnes (t) in 1996 to 160,000 t in 2005 and is still growing (DSA 2005).

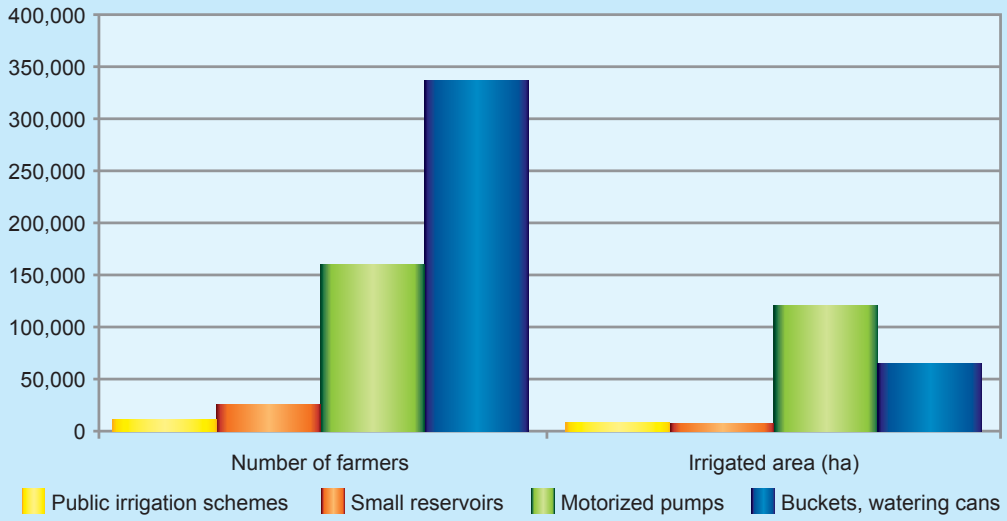
In Tanzania, we estimate that more than 700,000 farmers lift water from rivers and wells for irrigating vegetables, largely using buckets and watering cans. However, some 70,000 pumps are in use, benefiting more than 150,000 farmers, and our surveys indicate that motorized pump sales are increasing at a rate of more than 7,000 purchases annually. In Ethiopia, our case study conservatively suggests that 400,000 pumps were imported in the last decade (Table 1). Extrapolating from these figures, we estimate that over 5 million smallholder farmers currently use small-scale AWM technologies across sub-Saharan Africa. In India, more than 50% of all water for irrigation is drawn by pumps owned by smallholder farmers (Shah 2009).

Table 1: Estimates of land area irrigated by small-scale private initiatives in selected countries of sub-Saharan Africa *(Source: This study)*

	Area under small-scale private irrigation (ha)	Number of people involved	Water-lifting technology used			Number of motor pumps
			Buckets (% users)	Motor pumps (% users)	Treadle pumps (% users)	
Burkina Faso	10,000	170,000	85	13	2	20,000
Ethiopia	350,000	n/a	84	15	1	>400,000
Ghana	185,000	500,000	70	30	<1	160,000
Tanzania	150,000	750,000	91	8	1	70,000
Zambia	90,000	n/a	85	13	2	15,000

In some countries, the smallholder AWM sector is already more important in terms of land area, number of people and income than the public irrigation schemes. In Ghana, we estimate that nearly half a million farmers are using small-scale AWM technologies, harvesting nearly 200,000 ha (Figure 2), compared with some 11,000 farmers and 7,200 ha in the country's public irrigation systems. In Burkina Faso, the area irrigated privately around small reservoirs is often larger than the official command area downstream.

Figure 2: Many farmers use small-scale AWM technologies in Ghana
(Source: This study)

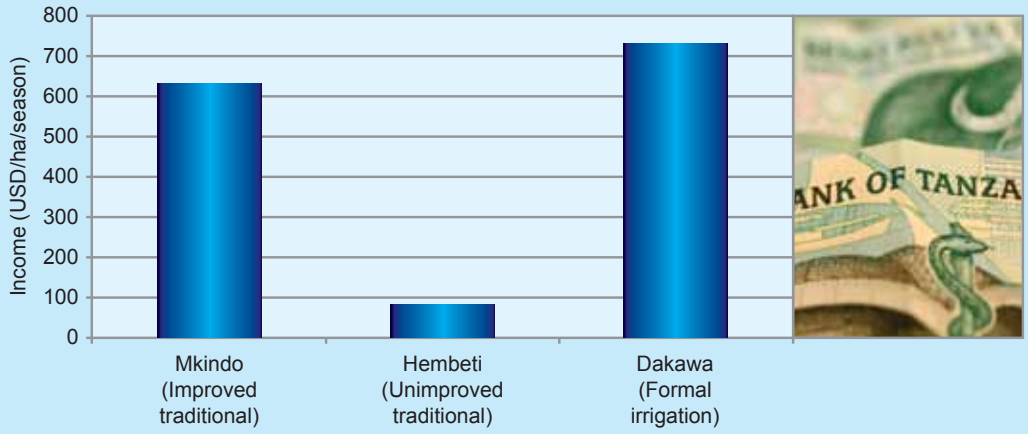


More reliable incomes for farmers when they need it most

Smallholder AWM provides additional income to millions of poor farmers in South Asia and sub-Saharan Africa, particularly during the dry season when other agricultural opportunities are limited. Farmers grow staple crops as well as high-value cash crops (such as vegetables in sub-Saharan Africa and *boro* rice in South Asia). In Ghana, private small-scale irrigation, primarily for cultivating vegetables in the dry season, adds between USD 175 and USD 840 annually to household income, depending on the technology used. In Zambia 20% of smallholder farmers grow dry-season vegetables, generating 35% higher incomes than those who rely solely on rainfall.

Farmers also use small-scale irrigation technologies to improve and expand the production of staple crops, such as gram, wheat and rice. In Madhya Pradesh and West Bengal, investments in individual rainwater-harvesting structures have allowed farmers to produce more staple crops, extend their cropping area, increase their dry-season cropping options, diversify into rearing livestock and fish, and increase incomes by as much as 70%. In Burkina Faso, farmers utilize small-scale irrigation technologies in conjunction with small reservoirs to cultivate rice and vegetables, thereby raising dry-season incomes by USD 200-600. This income is vital for smallholders as it allows them to buy food during times of a shortfall, to pay for health care and education, and invest in farm inputs. Farmers in Tanzania are experiencing improved rice yields and incomes thanks to small-scale, farmer-initiated and community-managed river diversions (Figure 3).

Figure 3: Community-managed river diversions have increased incomes in Tanzania *(Source: This study)*



Farmers take the initiative to invest using their own resources

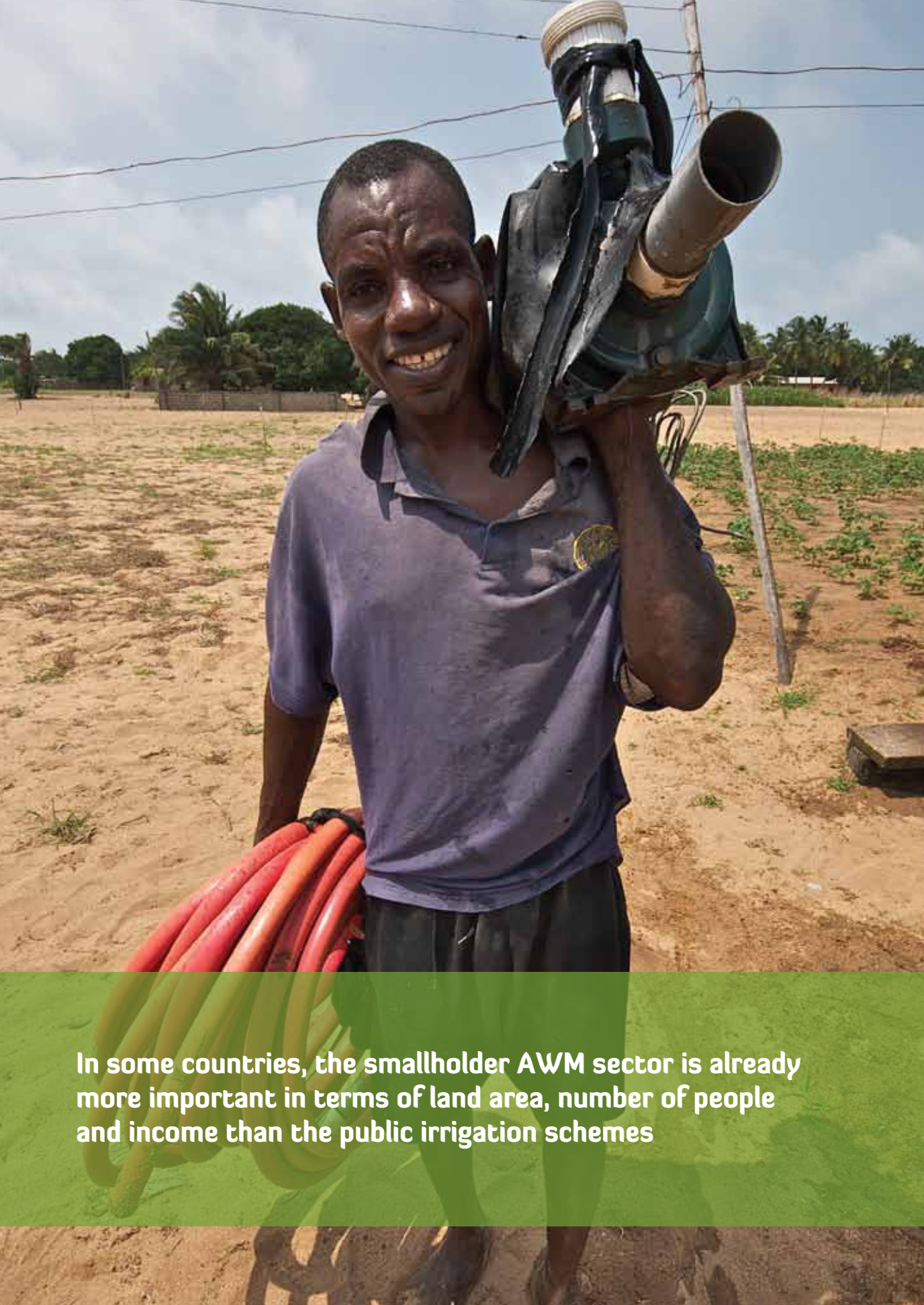
Farmers are increasingly initiating and financing small-scale AWM themselves. Surveys carried out in Ghana, Ethiopia and Zambia found that more than 80% of all owners of small-scale irrigation equipment used their own or their family's savings, as credit is rarely provided by banks or micro-credit organizations for buying irrigation equipment. Outside help from governments, NGOs or donors is also uncommon. Investment costs are relatively low. In South Asia, the fall in prices of motor pumps and well-drilling technologies in recent decades has placed them within financial reach of smallholders. Farmers' profit margins from investments in small-scale AWM can be high.

Buckets and watering cans suitable for irrigating a 0.1-hectare plot cost a few dollars, and operational costs are low. A treadle pump capable of irrigating 0.2 ha costs USD 50-100, with operating costs close to zero when family labor is employed. In sub-Saharan Africa, prices of motorized pumps that are capable of irrigating 1-2 ha vary by an order of magnitude, but the cheapest pumps are available for less than USD 250 (including accessories). Rental markets for motorized pumps are also beginning to emerge.

Great potential to increase incomes and improve food security

Within each of the project countries, and for South Asia and sub-Saharan Africa as a whole, we examined the potential for smallholder AWM to serve as an entry point for reducing poverty. We then assessed which technologies would have the greatest impacts on rural livelihoods. This assessment took into account river-basin hydrology, incremental yield improvements and investment costs, as well as farmers' access to markets. For sub-Saharan Africa, the impact of expanding crop production on local food prices was also taken into account.

This assessment concluded that the potential for growth in the AWM sector is enormous, particularly in sub-Saharan Africa where there is significant scope for expanding the area under irrigation. Estimates show that increasing the number of small reservoirs here could reach 369 million people and generate net revenues

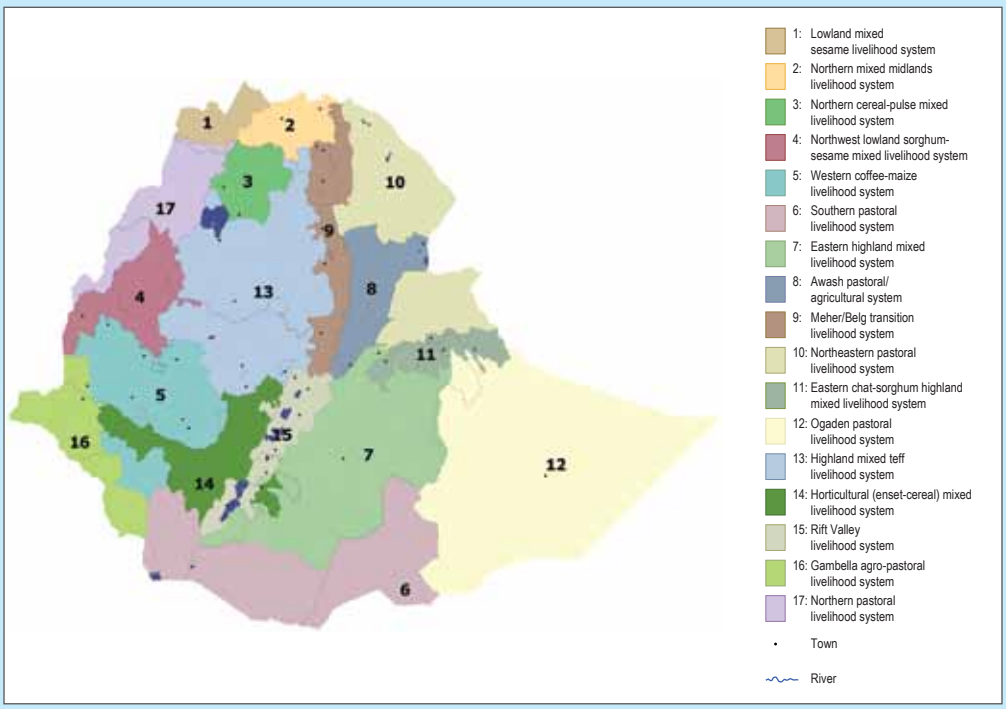


In some countries, the smallholder AWM sector is already more important in terms of land area, number of people and income than the public irrigation schemes

Mapping agricultural livelihoods

Different contexts create different needs, so water is more important for some people than for others. These variations require different types of support and investments. Using national consultations and data analysis, we created livelihood maps and profiles to identify where people would benefit the most from AWM interventions and the types of investments needed (Faurès and Santini 2008).

Livelihood zones identify where people in Ethiopia would benefit the most from AWM *(Source: This study)*



We identified areas where rural people share relatively homogeneous living conditions by assessing the following criteria:

- Livelihood activities providing the predominant source of income.
- Dominant farming systems.
- Natural resources available to people and the way they are used.
- Prevailing agro-climatic conditions that influence farming activities.

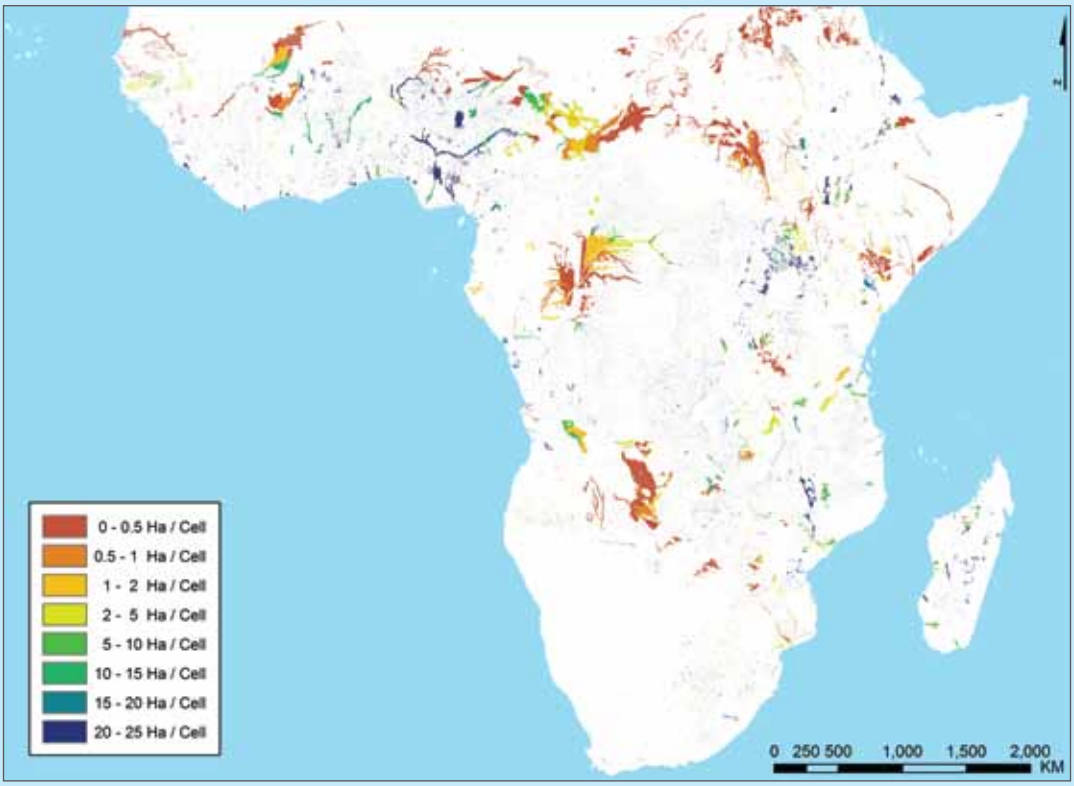
We then used the following criteria to produce maps highlighting areas with the highest number of potential beneficiaries:

- Where water is physically available.
- Where the target beneficiaries are mostly located, based on rural population density.
- Where people perceive water as being the main limiting factor for producing crops and supporting their livelihoods.

of USD 20 billion annually. Meanwhile, expanding the quantity of motor pumps could benefit 185 million people and generate net revenues of USD 22 billion annually (see Figure 4). Other promising AWM strategies in sub-Saharan Africa include communally-managed river diversions (with the potential to reach 113 million people and generate revenues of USD 14 billion annually); inland valley rice (with the potential to reach 53 million people and generate net revenues of USD 7 billion annually); and in-situ rainwater harvesting (with the potential to reach 147 million people and generate net revenues of USD 9 billion annually). For South Asia, estimates show that motor pumps have the potential to reach 40 million people and generate net revenues of USD 4 billion annually; electrification has the potential to reach 34 million people and generate net revenues of USD 4 billion annually; and ex-situ rainwater harvesting could reach 205 million people while generating net revenues of USD 6 billion annually.

Figure 4: The potential for expanding the use of small motorized pumps in sub-Saharan Africa *(Source: This study)*

Note: Taking river basin hydrology, environmental constraints, yield improvements, investment costs and price impacts of expanding crop production into account, the map identifies locations with potential to expand the number of motorized pumps. In total for sub-Saharan Africa, we estimate a potential area expansion of 29.6 million ha. The colors show the possible extent of expansion; areas marked in blue have the greatest potential.



In addition to the growth potential of the AWM sector, the project concluded that there is high potential for existing AWM technologies, including those that are privately and communally managed, to double, or possibly triple, rain-fed crop yields in many parts of sub-Saharan Africa (Table 2).

Table 2: Potential yield improvements that could be obtained from AWM investments in sub-Saharan Africa *(Source: This study)*

Note: Yield improvements differ between in-situ rainwater harvesting and full-irrigation technologies. Yields are area-weighted across sub-Saharan Africa.

Crop	Low-input rain-fed yield (t/ha)	High-input irrigated yield increase (%)
Sweet potato	4.3	200-212
Maize	1.4	141-195
Paddy rice	1.1	270-283
Groundnuts	0.7	238-251
Tomatoes	20	76-79

The risks of AWM need to be addressed

Despite the clear advantages of smallholder AWM, its un-regulated growth poses a number of risks. These relate to the following:

Equity: Women and resource-poor farmers face several challenges in accessing available AWM technologies: high upfront investment costs, absence of proper financing tools and limited access to information that would enable them to make informed investment, management and marketing choices.

Efficiency: Market inefficiencies negatively affect farmers' ability to make good decisions about water management and access beneficial technologies. These inefficiencies include: poorly developed supply chains; high taxes and transaction costs; lack of information and knowledge on irrigation, seeds, marketing and equipment; and the uneven distribution of information and power in output markets.

Sustainability: While smallholder AWM can be beneficial for an individual farmer, its uncontrolled spread can have undesirable consequences. Many watersheds are already affected by water quantity and quality concerns from agricultural intensification. If not managed within the landscape context, accelerated investments in smallholder AWM, together with greater use of chemicals such as fertilizers, pesticides, herbicides and fungicides, could further degrade water and soil quality and have a negative impact on downstream users.

Institutional structures: Smallholder AWM lacks supportive institutional structures; existing governing bodies typically cater for public irrigation systems and are often not adapted to capitalize on the opportunities and handle the challenges posed by this alternative mode of irrigation. For example, agricultural policies and institutions typically do not have the capacity to support farmers to grow high-value, dry-season vegetable crops. Also, multiple formal and informal actors exist at the national, basin and watershed scale, many of which are fragmented and include non-water players, such as local NGOs.

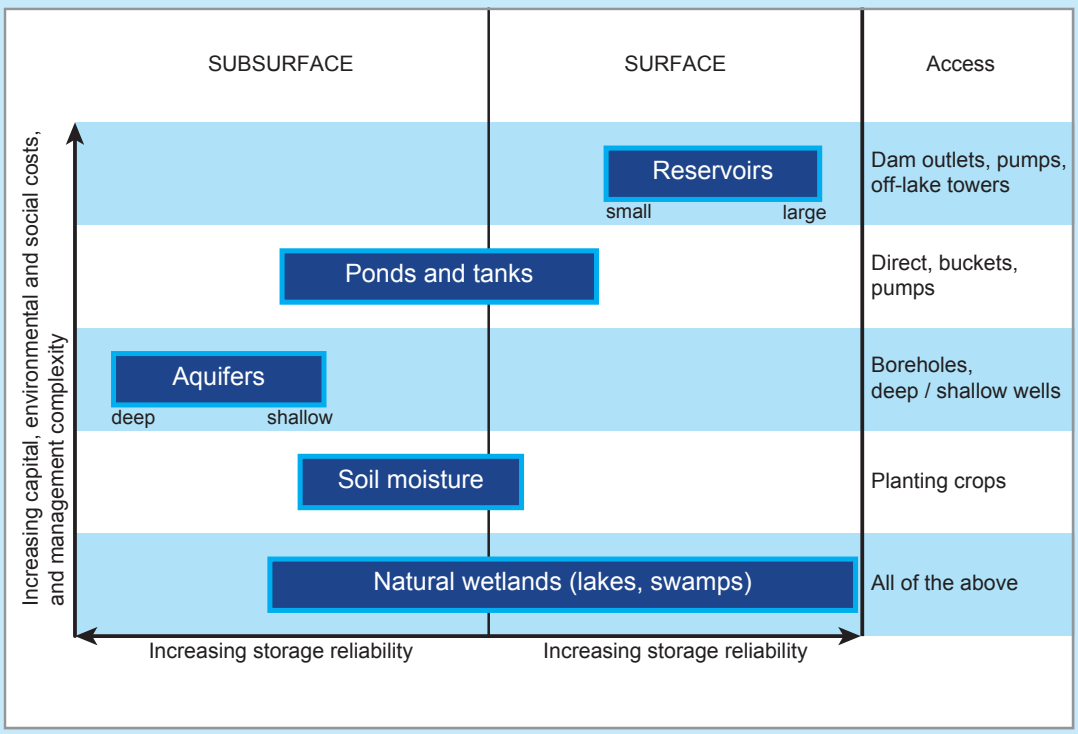
Opportunities for investing in smallholder AWM

Supporting the private irrigation initiatives of smallholders makes economic sense. It builds on farmers' own investments, accelerating an ongoing trend. In sub-Saharan Africa, in particular, further investments in smallholder AWM will lead to substantial increases in farm incomes, reduce poverty and improve food security for millions of smallholders. Achieving the market potential of small-scale irrigation technologies in sub-Saharan Africa will also benefit those involved in the equipment supply chain: manufacturers, retailers and local dealers. Moreover, technological innovations in motorized pumping, particularly pumps powered by renewable energy, will benefit other smallholders in the future. With appropriate actions tailored to the specific opportunities and constraints of the context in which farmers operate, small-scale AWM can realize the potential to reduce poverty while minimizing potentially negative social and environmental impacts.

Investments that improve the availability of water for farmers

Being able to store water for the dry season increases resilience and allows farmers to invest in their land and diversify agricultural activities. Cultivating cash crops during this time is profitable and provides smallholders with much-needed money when other income sources are scarce. Water can be stored in small and large reservoirs, on-farm ponds, shallow groundwater or wetlands (Figure 5). Meanwhile, water can also be stored in the soil. Techniques such as planting pits and on-farm bunds enhance the amount of surplus rainfall that is stored as soil moisture, and can be used by plants after the rains have stopped.

Figure 5: There is a continuum of water storage options
(Source: McCartney and Smakhtin 2010)



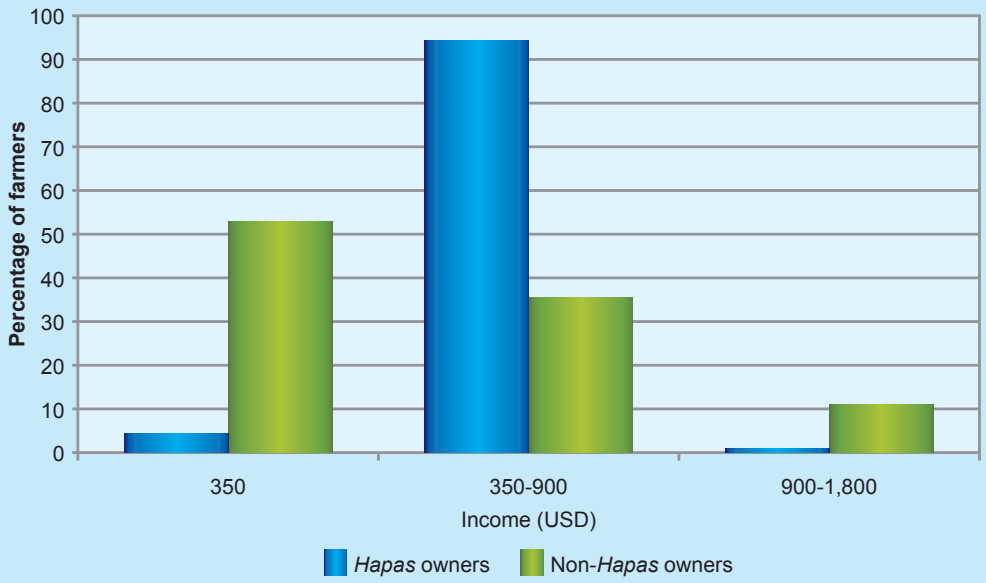
Small rainwater storage ponds bring farmers great benefits

Small ponds on individual farms store rainwater during the wet season for use in the dry season. They enable households to diversify crops, produce fish, increase livestock numbers and have water for domestic use. They are particularly useful in areas where rivers and lakes are scarce, and groundwater is not easily accessible.

An example of the successful use of on-farm ponds is the *hapas* of West Bengal. These deep, hand-dug ponds store rainwater and runoff during the monsoon season. Traditionally, ponds covered around 5% of the smallholding but, over time, farmers have increased the size of their ponds. In the wet season, the stored water supplements rainfall that is used to grow paddy; in the dry season, water that is remaining enables farmers to grow an additional crop. In qualitative surveys, farmers reported that their yields increased as a result of using the ponds. For example, these surveys showed that mustard yields doubled and paddy yields increased by 20% on some farms. Further, the ponds have proved so beneficial that an increasing number of farmers are shifting their attention away from growing wet-season rice to cultivating more, highly profitable, vegetables during the dry season. As well as being used for agriculture, the *hapas* supply water for gardening, watering livestock, raising fish and domestic uses.

Farmers have gained similar value from ponds in Madhya Pradesh. The cropping intensity has increased, and farmers with cattle have been able to expand their herd and produce more milk. Incomes have also risen among pond owners. In West Bengal, the income from agriculture alone is 34% higher when compared with incomes prior to the use of water supplies from *hapas* (Figure 6). This is significant because many of the *hapas* owners lived below the poverty line before constructing a pond. In Madhya Pradesh, incomes have risen by more than 70%.

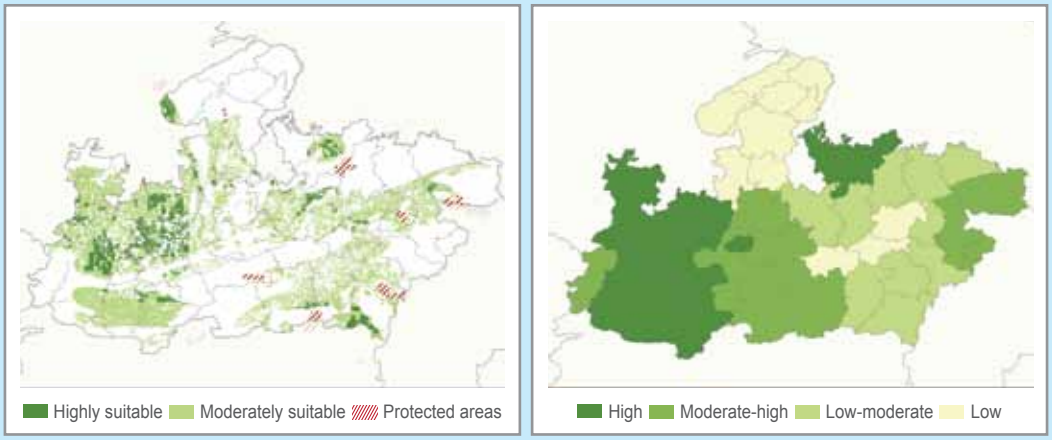
Figure 6: Farmers with better rainwater-harvesting structures have better incomes *(Source: Adapted from Banerjee 2011)*



How to store water from rainy days

In Madhya Pradesh, where more than 5,000 farmers have now constructed rainwater-harvesting structures, the AgWater Solutions Project has developed a business plan to support the scaling-up of this activity. The maps below show the most suitable areas for this.

Areas suitable for expanding the number of ponds (left), and livelihood-based demand for rainwater harvesting in Madhya Pradesh (right) *(Source: This study)*



We have designed three alternative lending models with different underlying assumptions in terms of the size and contribution of different lenders to the portfolio. Variations in the different financial models include government subsidies or lending through local financial institutions at the agricultural concessionary rate. For more information, visit the project website (awm-solutions.iwmi.org).

Despite the obvious benefits of building a water storage facility, the high upfront costs remain a major constraint for many smallholders. In Madhya Pradesh, for example, a typical on-farm pond of 1,780 square meters (m^2) and 2.20 meter (m)-depth (appropriate for a 2.0 ha landholding) costs around USD 2,600. For many poorer farmers this cost is not feasible, even after the provision of state subsidies. Also, farmers need to allocate part of their land to make space for the pond, and those with a small plot may be reluctant to do so. However, our case studies show that, after seeing the benefits of other farmers' ponds, many smallholders become convinced of their value. As a result, the number of rainwater-harvesting structures is growing, even among smallholder farmers.

How and where to invest wisely

1) Identify suitable areas

When considering investing in on-farm ponds, it is important to identify areas that can benefit the most from this type of storage. Rainwater harvesting is likely to be more successful in regions where land is moderately sloping, there is high rainfall during part of the year and soil properties impede infiltration when saturated. The 'black cotton soils' of Madhya Pradesh proved to be highly suitable. In Ethiopia, the government rolled out a blanket national programme to construct rainwater-harvesting structures. This was highly successful in some areas, such as Gursum. However, in other places, the structures proved unsuitable because of the terrain and climatic conditions. Targeted approaches are more cost-effective than 'one-size-fits-all' policies. Suitability maps can help governments, donors and NGOs better target their support initiatives.

No pond, no wife

The Ethiopian Government's initiative to help farmers acquire ponds in Gursum has been so successful that it is now known as the "No-pond-No-wife" sub-district. Rainwater harvesting was introduced to the area in 2002. By the end of June 2008, the Bureau of Agriculture and Rural Development counted a total of 4,689 ponds. Early ponds were built using a geo-membrane/plastic sheet to create sufficient storage for 143 cubic meters (m^3) of water. However, farmers later scaled-up the water-holding capacity of the ponds to 391.4 m^3 by joining two plastic sheets together. The number of ponds in this area continues to increase, hampered only by the lack of availability of lining materials. Farmers without ponds are said to have difficulty finding a wife, hence the area's nickname.

2) Show farmers the benefits of building their own tank

Providing farmers with accurate information on what the gains and potential risks are likely to be from a plot of their size, given that they have to sacrifice some land to install the pond, enables them to decide if it is worthwhile to invest in it.

3) Garner the support of local institutions

New initiatives on rainwater harvesting could be helped a great deal with the support from key players in the local administration. For example, the success in Madhya Pradesh is, to a large extent, due to a District Collector in the Dewas District who, in 2006, launched a campaign to promote rainwater harvesting among farmers. The initiative quickly took hold and moved forward as the Rewa Sagar Bhagirath Farmers' Movement.

4) Provide access to loan capital

Loan capital can help farmers overcome the constraint of high upfront investment costs. In India, in particular, loan funds are available but not yet tapped for rainwater-harvesting structures. In West Bengal, the NGO, PRADAN, convinced the Secretary of the Panchayat and Rural Development Department to make available funds from the Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS).

5) Where appropriate, offer smart subsidies

Subsidies to partially compensate smallholders for the high cost of building rainwater-harvesting structures might induce farmers to construct them. Sometimes, however, when funds for subsidies are too limited, they may hinder up-scaling. Where only a limited number of farmers can benefit, the remainder may be reluctant to invest as they would rather wait until they can obtain subsidies. This is happening in Madhya Pradesh. Investors may, therefore, consider combining subsidies with no- or low-interest-rate loans to extend the reach of AWM financing options for smallholder farmers.

6) Provide technical support

Engineering expertize and construction advice can ensure that the farmers build their ponds well. For example, in Ethiopia, the government provides materials and technical support.

Shallow groundwater is often the farmer's preferred water source

Shallow groundwater is an efficient way of storing excess rainfall and runoff, and has a number of advantages: there is no loss from evaporation, it is available in many locations, and its supply fluctuates less over the year than surface water reserves. In many areas, it is the farmer's preferred water source. In South Asia, the majority of smallholders access groundwater for irrigation. Of the water used for irrigation in India and Bangladesh, 60% and 86%, respectively, comes from groundwater. In sub-Saharan Africa, this figure is probably less than 10%, although reliable statistics are lacking. Large-scale studies suggest there is a significant potential but detailed surveys are needed to relate this to practical use by smallholders.

Some farmers dig wells by hand to access shallow groundwater to water their crops. These wells provide water but often in insufficient volumes for effective irrigation. Mechanized drilling can reach water-rich strata at greater depths, but this option is too expensive for the majority of individual smallholder farmers and communities. Where soils and hydrogeological conditions are appropriate, manual well drilling (where village craftsmen charge for manual labor to drill down to shallow groundwater resources) can be an affordable alternative.

In many Asian countries, including Bangladesh, India, Nepal, Myanmar and Cambodia, manual well drilling is widespread. Once drilled, the tubes are lined with a pipe casing and fitted with a pump to draw water for irrigation. Private-sector manual drilling is also utilized in African countries, such as Sudan, Chad, Nigeria and Niger. In some countries, such as Ethiopia, this way of accessing water remains unknown to farmers. In such areas, demonstrations of manual drilling and other extension services can help create demand for manually drilled wells. Once smallholder farmers become aware of manual drilling, pump options and potential income opportunities of higher-value irrigated crop production, they are far more likely to invest in the technology.

How and where to invest wisely

1) Map groundwater resources at a scale that is useful for small farms

The hydrogeological maps currently produced are too coarse and lack detailed information on parameters that are relevant to agricultural use, such as aquifer depth, yield and transmissivity.

2) Develop affordable drilling techniques that are suited to the local conditions

Where manual well drilling is technically feasible, in soft soils and relatively shallow aquifers, it is the most appropriate and affordable method for smallholders. Where soils are hard and rocky and aquifers are deep, mechanical methods may prove to be more time saving and cost-effective.

3) Raise awareness and create demand from farmers for wells

Organizing demonstrations to farmers of the technologies available for accessing groundwater can help them realize the benefits of investing.

4) Monitor environmental risks

Take note of any groundwater depletion and impacts on water quality associated with drilling. Maintain a national database on the availability and quality of water resources, along with manual well-drilling conditions.

Small reservoirs support a variety of livelihood benefits

Larger storage structures in villages are often managed communally. Small reservoirs are generally earthen or cement dams that are below 7.5 m high. Because of high investment costs, small reservoirs are often built with government and/or donor support. After construction, farmers maintain and manage the water. Small reservoirs provide significant opportunities for conserving soil and water, guarding against drought and initiating small-scale, individual or community-based irrigation schemes. In South Asia, small reservoirs or 'tanks' have traditionally been an important source of irrigation.

Well-designed reservoirs support multiple water uses from watering livestock and raising fish to fulfilling domestic needs and those of small businesses such as brick-making and handicraft activities. In sub-Saharan Africa, they are in high demand among local communities, fit in with national strategies and policies, and continue to attract funding from international development partners. However, despite an increase in investment in water development, tank irrigation is in decline across Indian states and most tanks are now being used to replenish groundwater.

A critical look at the current performance of small reservoirs shows that many perform well below expectations in relation to crop productivity. This is a result of: infrastructural factors (low water reliability, low water availability, wasted seepage from dams and damage to dams); environmental factors (siltation, soil erosion and agrochemical pollution); agricultural factors (lack of access to credit, plant diseases, low market prices and poor transport); and organizational factors (availability of funds and organizational problems).

Inefficiencies and lack of transparency in planning and construction also affect small reservoir projects in many countries. These lead to spiraling costs, delays in implementation, poor construction and the failure of small reservoirs to perform as planned. Performance is typically measured in terms of downstream (formal) irrigation, when, in fact, small reservoirs provide multiple benefits to many users, including those living and farming upstream.

There are many small reservoirs in Burkina Faso, for example, and there is still scope for more. In recent years, farmers have started pumping water directly from upstream reservoirs to irrigate small vegetable plots. This unforeseen and un-regulated activity has proved very profitable. Now, so many smallholders are following suit that at some reservoir sites the informal area upstream is larger than the officially recognized area downstream. In some cases this has led to conflicts between users and uses.

How and where to invest wisely

1) Improve efficiency and transparency of contracts to reduce investment costs

A good starting point is to understand the incentives and disincentives of actors and their potential conflicts of interest in a particular situation. Complementary approaches include establishing pre-qualification standards for contractors and increasing attention on contract awards.

2) Adopt new management approaches to improve performance

Top-down management models for communal storage often do not match the reality on the ground and, in particular, do not take into account the variety of stakeholders and beneficiaries. The development of customized arrangements that are anchored in the local context, coordinated with traditional and 'informal' authorities, and linked to national planning bodies, could help ensure the structures and their management fit the local context. A transition to better agricultural water management is needed to ensure that the spread of individual and communal irrigation along banks does not threaten water quality and quantity.

3) Take a broader perspective to account for multiple benefits

A multiple-use perspective needs to be incorporated from the pre-investment feasibility stage through to design, construction and management. This could involve incorporating multiple-use benefits in initial cost-benefit analyses; developing related guidelines for contracts on the design of multiple-use reservoirs; and introducing formal management mechanisms to coordinate, support and integrate a variety of water users both spatially (upstream and downstream of small reservoirs) and temporally (in different seasons).

Investments that catalyze smallholder agricultural value chains

Supporting innovative agricultural financing mechanisms

Ownership of motorized pumps is nearly always financed from personal savings. Although prices of motorized pumps have come down considerably, the lowest upfront cost found during this study in sub-Saharan Africa was USD 250. Making such an investment brings considerable risks: farmers can lose out if their pump malfunctions, yields are lower than expected or market prices fall. Rising fuel costs also have an impact on farmers' decisions to embrace new technologies. Pump owners in Ghana belong to 20% of the richest farmers.

Farmers are aware of, and interested in, AWM technologies but often lack financing. In sub-Saharan Africa, our studies revealed that over 90% of farmers know of someone using buckets or motor pumps to irrigate crops, and over 80% of farmers within areas where NGOs have promoted treadle pumps are aware of this technology. However, the micro-credit facilities and financing options that would enable poorer smallholders to invest in better water management facilities are often absent or inaccessible.

Gender, too, has an influence on access to technologies. In sub-Saharan Africa, only better-off male farmers tend to have enough money to invest in small-scale irrigation. Some 20% of bucket and watering-can users in sub-Saharan Africa are women, but less than 5% of the motor-pump owners are female. However, women are often the sole decision makers. This inequity means that poverty prevails where it need not.

How and where to invest wisely

1) Develop financial instruments geared to AWM technologies

A possible entry point for overcoming financial constraints of individual farmers is to pilot financial instruments designed for purchasing pumping equipment and other necessary inputs. Examples of financial instruments include vouchers for women, equipment leasing with buying-option arrangements, rural credit cards, micro-finance and savings groups. Financial instruments are also needed to support communal irrigation schemes. Strengthening micro-credit facilities to enable infrastructure improvements, such as community-managed river diversions, can help improve water productivity and boost livelihoods. In Tanzania, micro-credit organizations are experimenting with delayed bulk selling; they give credit at the beginning of the season and farmers repay the debt in bags of rice. The organizations store the paddy and sell it later in the season when prices are higher.

2) Support rental markets

Pump rental markets are already widespread in parts of India and gaining ground in sub-Saharan Africa. Smallholders who cannot afford to buy a pump can rent one by the day or for a season. As much as 20 million hectares (Mha) of land in India may be irrigated through informal groundwater markets (Mukherji 2008). There is room to improve existing models by increasing the number of pumps available for rent and extending rental services to remote rural areas.

3) Pilot new models, such as irrigation service providers

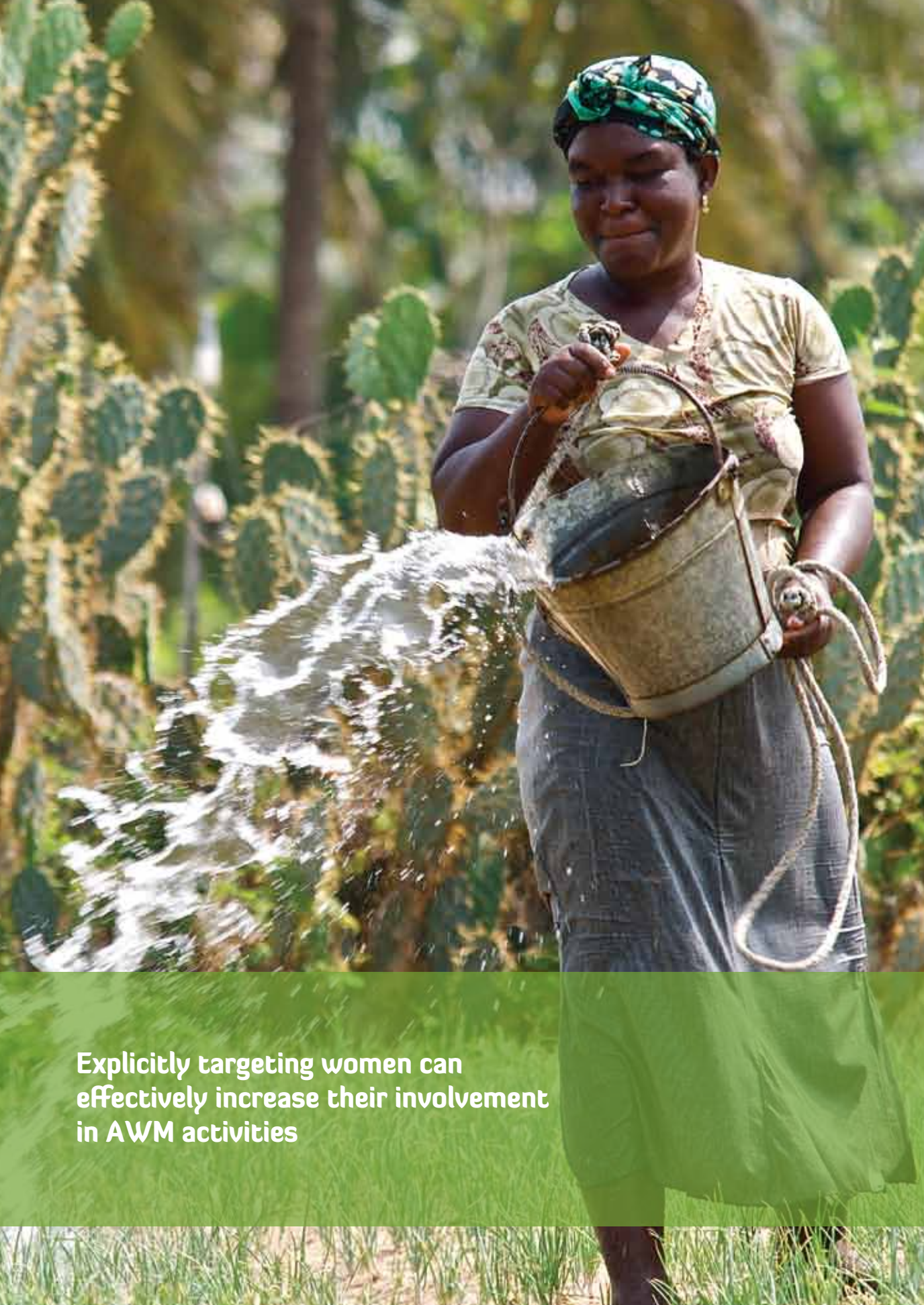
The AgWater Solutions Project has developed a business model around the idea of irrigation service providers. Irrigation service providers go from farm to farm with small motor pumps, offering to irrigate lands of smallholders for a fixed fee per hour, day or season. Poor farmers gain access to motorized pumping while the entrepreneur profits from renting out pumping equipment and providing paid irrigation services to others. Service providers are a known phenomenon in Gujarat, India, and Bangladesh.

4) Link specialist financing for AWM technologies to existing programmes

Financing for AWM technologies may also be possible by linking with relevant rural development programs, such as India's MGNREGS.

5) Encourage women to own AWM equipment

Explicitly targeting women can effectively increase their involvement in AWM activities. Targeting female or mixed groups with free or subsidized pumps, for example, can be an effective way to reach women farmers.



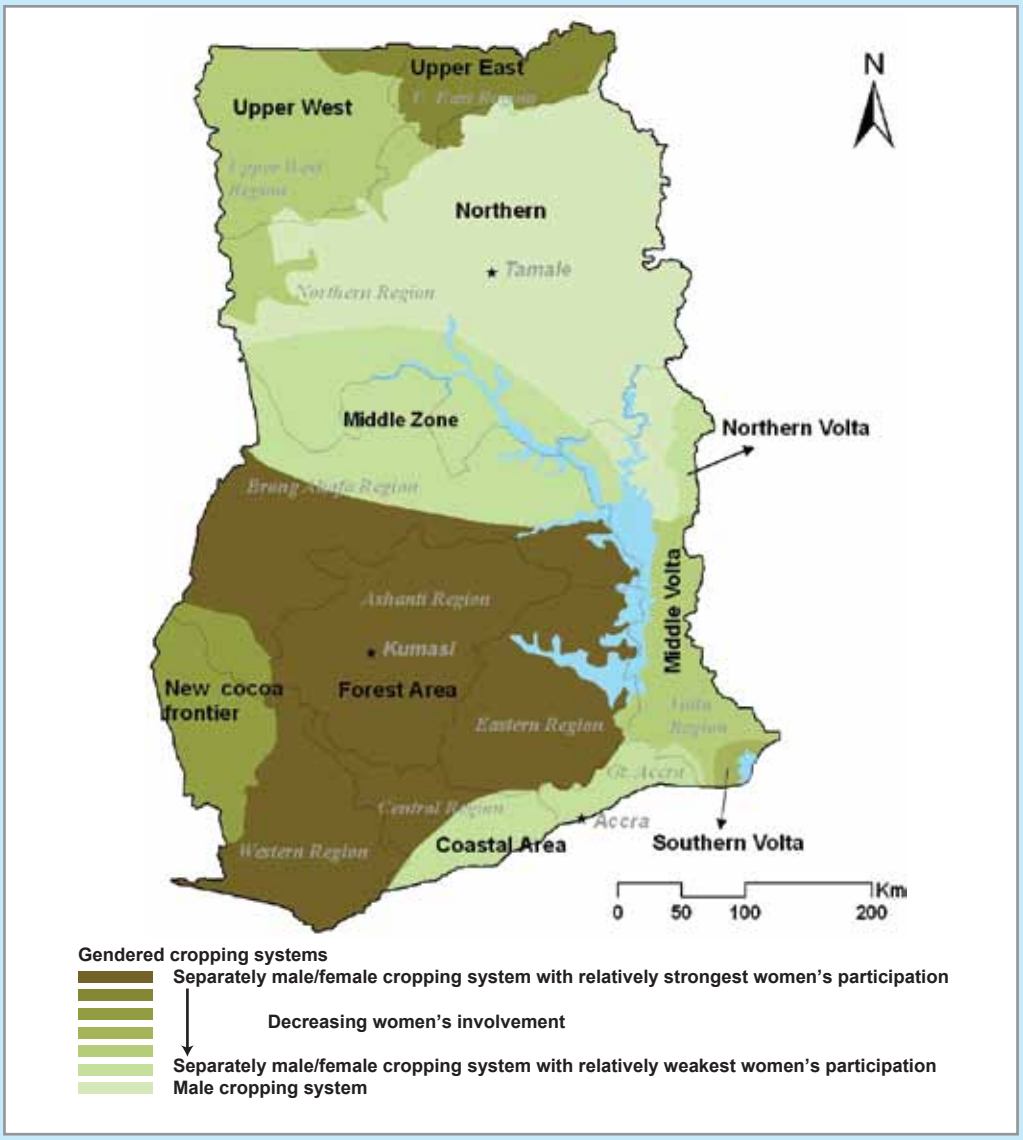
Explicitly targeting women can effectively increase their involvement in AWM activities

Understanding the roles men and women play in farming

Mapping gender-related farming systems is a useful way to understand and classify the complex and diverse ways in which men and women participate in agricultural activities. In Zambia, ethnicity often determines the roles men and women play in farming. Our surveys showed that matrilineal systems predominate in over half of the country. In Ghana, we found gender-related cropping systems were more closely tied to agroecological zones. Women play a significant role in agricultural production in many parts of the country. Further studies in this field could help better target investments and the dissemination of agricultural information, technologies and financial products.

How gender relates to crop cultivation in Ghana

(Source: Meinzen-Dick et al. 2012)



Helping farmers buy suitable equipment

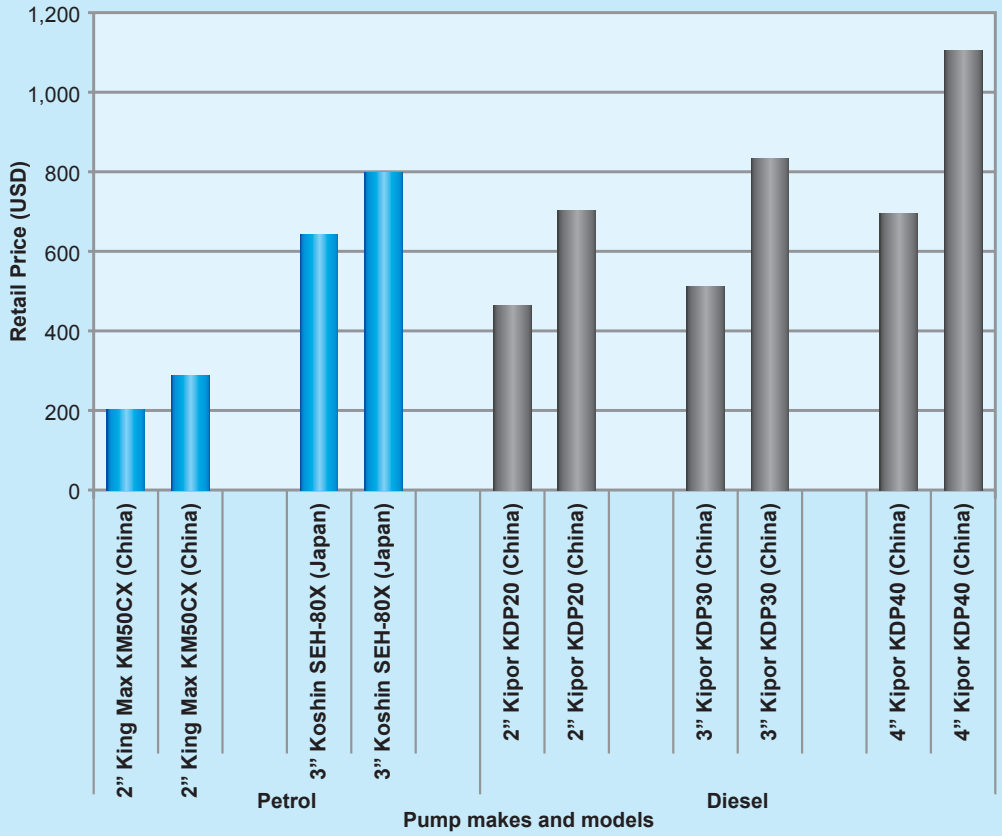
Farmers often do not have information about which technology to buy, how to operate equipment and what maintenance support they should receive. This is particularly true in sub-Saharan Africa, where dealers often have only one or two types of pumps and sell what they have, rather than what suits farmers. Pump markets tend to be poorly developed and immature, so there are no restrictions on the type of pumps imported and little quality control.

Consequently, farmers either do not invest or when they do they often pay purchase prices or maintenance fees exceeding the market value, or buy equipment that is ill-suited to the size or use of their land, the crops produced or to locally available maintenance services. In Zambia, our surveys showed that pump prices varied between dealers and locations without obvious reasons (Figure 7). Without a straightforward connection between the price and quality of pumps, un-knowledgeable farmers may end up with low-quality but expensive products. In Tanzania and Ghana, several farmers we surveyed complained that they had bought pumps that broke down within one season.

Figure 7: Variation in the retail price of pumps in Zambia

(Source: Adapted from Colenbrander 2011)

Note: The cost of pumps varies from USD 200-1,000 depending on the make and model. There are retail price differences of up to 50% between different companies for exactly the same make and type of pump.



Enabling farmers to grow crops profitably

Extension workers, whose role is to disseminate technical knowledge within rural areas, only reach a small portion of communities, and seldom have a background in water management, irrigation equipment, horticulture or dry-season cultivation. In Ghana, only 10% of males surveyed said they had received a visit from an extension worker in the past year. For female farmers, this figure was less than 1%. In Tanzania, some farmers surveyed claimed they had never seen extension workers in all their years of farming. Farmers said they need information on what crops to grow, how to treat diseases, the proper doses of fertilizers and pesticides to use, as well as information on a range of quality seeds.

Without this information, their choice of crops is limited and farmers are not able to fully exploit market opportunities that are opened up by irrigated farming. Lack of information on marketing and produce prices places farmers in a vulnerable position. In Ghana, more than 90% of vegetables are sold in local markets. In remote areas where infrastructure and transport are limited, smallholders depend on middlemen or market women for credit and seeds, and also to market their crops. These brokers, known locally as 'tomato queens' or 'Mercedes mamas', often collude to set prices limiting farmers' ability to negotiate crop prices.

These brokers dominate and, as a result, many smallholder farmers in Lusaka's Soweto Fresh Produce Market (the largest vegetable retail market in Zambia) sell their produce below the market prices. The lack of a legal framework facilitates this practice. Smallholders lose out or choose not to participate at all. Our surveys found that, in Ghana and Tanzania, farmers often rely on traders to provide loans at the beginning of the season, on the condition that they sell their produce at the end of the season at a fixed (low) price. Even outside these arrangements, farmers tend to sell at the same time as everyone else when prices are lowest. Few try to manipulate cropping dates to beat the market glut.

How and where to invest wisely

1) Improve the information farmers receive on market-oriented farming

Extension service providers in many countries are often trained to support farmers in staple crop production, and often lack the skills and experience required to support irrigated market-oriented crop production and sales. Both government extension services and farmers require support to improve their skills in selecting, growing and marketing suitable and profitable crops.

2) Make more information available to farmers on marketing

Farmers and local dealers need training on how to operate and maintain equipment, the brands that represent best value and acceptable price ranges. Dealers also need to learn about marketing and providing good after-sales service, and farmers would benefit from knowing how best to market their crops. Well-informed dealers can earn a good reputation and attract more customers. Brands with a good price-quality ratio and instruction manuals in local languages may prove to be more attractive to smallholders and gain a larger market share. Farmers also need information on crop prices. Well-informed farmers can gain larger profit margins and keep a higher proportion of the incomes from their crops, instead of handing that money to powerful traders.

3) Provide storage facilities to farmers

Having access to storage facilities can help farmers keep their produce until prices in the marketplace are higher. Without proper storage they are forced to sell directly after the harvest when prices are low. Building cold storage units would keep crops fresh for longer and increase the time-frame farmers have to sell their produce.

4) Promote 'try-before-you-buy' schemes

Dealers would benefit from help in setting up demonstration plots, where farmers could try out equipment before making a purchase. Providing credit to dealers, which is sometimes available from wholesalers and manufacturers, could incentivize them to keep a wider, more varied stock.

5) Use existing networks to disseminate information

Expanding existing mobile phone and radio networks can help dealers market a broader range of technologies to a wide audience. In Ghana, the International Fertilizer Development Center mapped all known fertilizer dealers in the country and linked their mobile phones to a single network. This meant that marketing messages and other information could be sent via short message service (SMS). Data from networks can also be useful for starting a registry of equipment dealers, so that farmers can find out more about their local vendors.

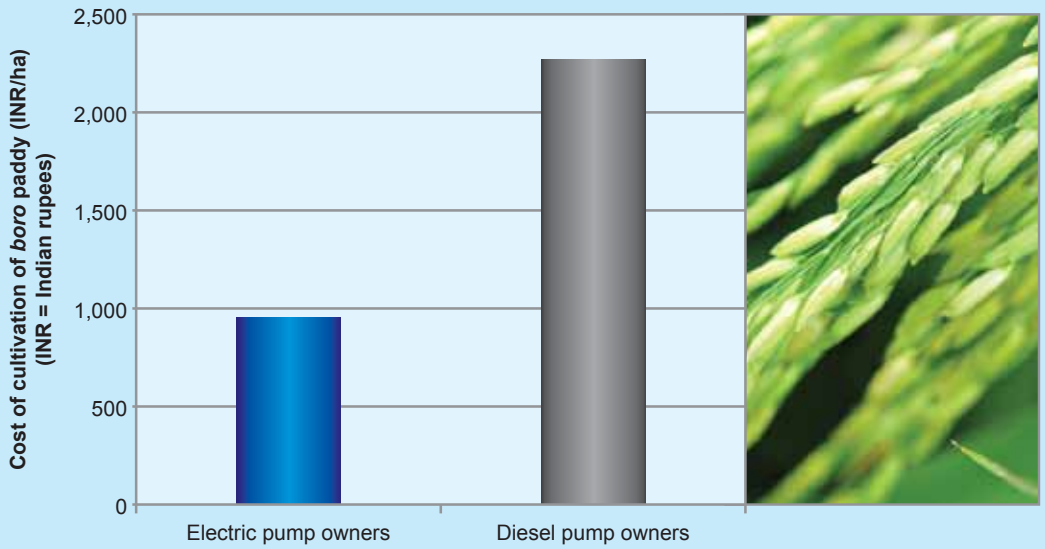
Investments to create policy synergies between sectors

Energy policies affect water use

Policies outside the water realm can hinder farmers' adoption of AWM technologies. For example, energy policies influence whether or not farmers adopt AWM technologies, because lifting water for irrigation requires a considerable amount of power and small motor pumps tend to be energy-inefficient. Developing energy-efficient pumps suitable for smallholdings is, therefore, a possible investment option. Greenhouse gas emissions from motorized pumps are negligible at present, but this could change if the number of pumps in use increases dramatically. So, longer-term solutions may lie in seeking alternative sources of energy. Solar power could be one option, but its cost is currently too high for rural farmers.

Electricity is more attainable, at least in the short run. It costs less than diesel or petrol, and can be combined with general rural electrification plans to reduce poverty on a wider scale. For example, investments made in Gujarat, India, to separate electricity feeder lines for agricultural and non-agricultural users, and to ration power supply to farmers, also improved electricity supplies to local industries and schools. It significantly cut the energy subsidies paid out to agriculture and reduced the amount of groundwater being pumped out. However, water markets also contracted, negatively affecting marginal farmers in the region who relied on those markets to access irrigation. Our case studies from West Bengal suggest that, a program of rural electrification combined with rainwater-harvesting investments could help revive the state's waning agricultural sector (Figure 8), while reducing environmental risks and avoiding the negative impacts on water markets experienced in Gujarat. In Ghana, awareness is growing among policymakers that the adoption of AWM technologies and electricity policies are linked.

Figure 8: Rural electrification in West Bengal could help revive the state's waning agricultural sector *(Source: This Study)*



Import policies raise prices

In sub-Saharan Africa, all motorized pumps used in agriculture are imported. No local manufacturing capacity exists, except for treadle pumps and manual pumps. High transaction costs, including import restrictions, duty and taxes, along with cumbersome procedures, stop new importers from entering the market and increasing the availability of pumps. The high prices keep these technologies out of reach of smallholder farmers. In Ethiopia, taxes and duty make up an estimated 37% of pump costs for those private importers who work independently from government projects. In Ghana, pumps are exempt from import duty, but the cumbersome exemption process involves many procedural steps and fees.

The Zambian Government instituted a duty waiver and zero value-added tax (VAT) rating for agricultural equipment in 2002 and 2009, respectively. However, our surveys and interviews showed that importers and dealers lack information on procedures. The measure was intended to reduce the cost of pumps to smallholder farmers and boost agricultural production but, in practice, few importers are taking advantage of their entitlements and, if they are, the benefits are not always passed on to the farmers.

How and where to invest wisely

1) Align energy- and water-related policies

Providing farmers with greater access to electricity encourages them to invest in lower-cost, more energy-efficient electric pumps. However, care must be taken to prevent over-pumping of water. This can be achieved by targeting interventions in water-abundant regions, monitoring use and investing in complementary AWM technologies, such as rainwater harvesting, to promote groundwater recharge.

2) Develop alternative energy sources

Investment opportunities exist to evaluate the technical and financial feasibility of solar voltaic and solar thermal systems in farmers' fields, as well as supporting competition among local inventors or universities.

3) Privatize the procurement and marketing of irrigation equipment

This can: mobilize private savings for irrigation investments; eliminate delays in installing, repairing and maintaining equipment caused by bureaucratic procedures and rent-seeking in the public sector; increase competition in the water market, so that water charges fall; and expand the use of pumps.

4) Review tax policies and import duties

Review import duties, exempt small pumps from sales taxes and simplify exemption procedures. Actions should be supported by information campaigns to make tax exemptions known. Farmers' organizations and cooperative societies are in a good position to help.

Investments that take a watershed perspective

While our studies showed that improving access to small-scale private irrigation can have positive impacts and that there is substantial room for increasing the scale and use of AWM technologies, taking water from its natural course for irrigation nearly always has impacts on downstream users and the environment. Further, many watersheds already suffer from poor water quality resulting from agricultural intensification. Dispersed extraction by many small farmers is especially difficult to monitor and regulate, because individuals take varied volumes of water from many places at different times. Future unplanned investments in small-scale private irrigation technologies, together with the increased use of agrochemical inputs, could further degrade water and soil quality.

Successfully scaling-up the benefits and effectively managing the risks posed by AWM requires planning at a watershed scale to balance trade-offs and issues of environmental sustainability. However, planning effective actions at watershed level is challenging due to the individualistic and unplanned nature of how small-scale private irrigation spreads. For example, our research findings showed that there are often multiple actors involved in catchment-scale water governance from the national to local scale, including formal institutions without a specific water management mandate as well as informal (non-codified) institutions. In Burkina Faso, Tanzania and Zambia, for example, there is rarely one formal organization that coordinates all water-related activities or management decisions in a catchment. Usually, a few players make key decisions about the use of local resources, but these tend to represent NGOs, local governments or traditional authorities rather than water management institutions.

How and where to invest wisely

1) Consider multiple, versus single, AWM investments

Combining water-management measures with changes in cropping patterns, appropriate nutrients and other crop-management strategies, together with marketing and infrastructural support, could help minimize the negative environmental consequences and maximize benefits to farmers from AWM expansion or intensification.

2) Develop systems and platforms to mitigate conflicts and promote coordination

Supporting stakeholder-management forums to ensure that national policies and private-enterprise developments work in harmony, can safeguard against trade-offs between users or inequities in the use of resources. Our research in the Narialé Basin, Burkina Faso, suggests that local informal actors are fragmented, preventing collective bargaining, and that an institutional gap exists between agriculture and water resources management. Introducing Water Users Associations (WUAs) could enhance coordination and efficiency

at the watershed scale. Improving relations between villages and national institutions would improve negotiation and planning.

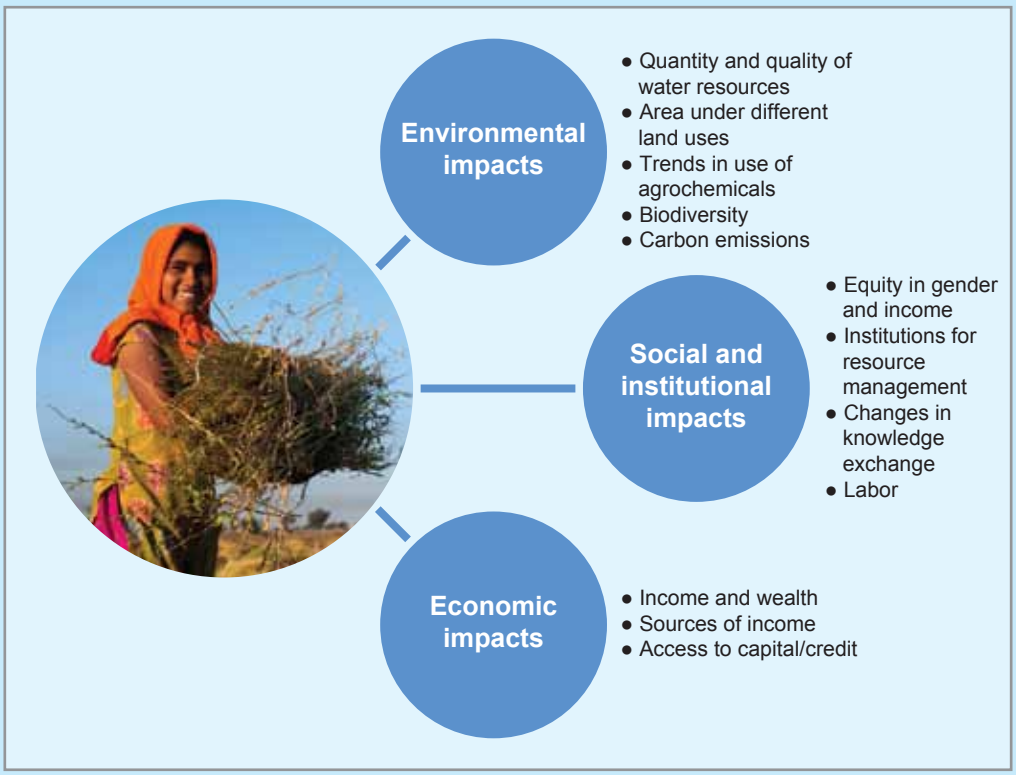
3) Improve monitoring and evaluation of AWM investments

To ensure that the actions taken are both environmentally sustainable and socially acceptable, investors must incorporate monitoring and evaluation systems. The indicators should be designed in consultation with a wide range of communities and local experts. This ensures that those implementing projects gain a holistic view of the socio-ecological contexts in which they operate. Such consultations can help determine which changes are desired and which are not welcome, and prioritize trade-offs between negative and positive impacts (Figure 9).

4) Ensure impacts are viewed in a broader context

AWM interventions take place in complex social and environmental contexts; they lie within a physical watershed but are influenced by political and social networks that are delineated differently. Combining local and external expertize is essential to ensure that local stakeholders are sufficiently knowledgeable to address issues that emerge as a result of AWM interventions, both beyond the immediate watershed threshold and over longer timescales.

Figure 9. Sample indicators to assess AWM impacts
(Source: This study)



The way forward

With sustainable food production and food security back on the international agenda, it is an opportune time to reconsider investments in AWM for sub-Saharan Africa and South Asia. In sub-Saharan Africa, governments and the development partners they work with are well aware that making better use of underutilized water resources on the continent could not only increase production but improve the livelihoods of rural populations.

Our studies suggest that potential investors should consider a range of options that go beyond formal irrigation to acknowledge and support smallholder farmers who are solving their water problems. In South Asia, where large-scale irrigation has already reached its potential in many places, opportunities lie in revitalizing existing irrigation. Targeted investments can catalyze and improve the scale, benefits and sustainability of farmers' own innovative initiatives.

The scale of current trends is astonishing, but the potential is even greater if strategic support can be provided to overcome key challenges. The key, in all these cases, is to take into consideration the specific requirements of the context in which farmers operate and to accompany, encourage and support smallholder-driven initiatives.

A framework for successfully strengthening smallholder AWM initiatives includes supporting:

- **access to a water source** that gives farmers sufficient and reliable water for their requirements in a way that is sustainable and equitable with other water users and uses in the watershed;
- **access to technologies** that enable smallholder producers to make the most efficient and effective use of the water available to them. These include technologies for lifting, storing and using water;
- **access to information** that empowers smallholder producers to maximize their productivity and profitability using the resources and technologies available to them; and
- **effective mechanisms** for equitable and sustainable community-level management of land and water resources through wise investments that address knowledge gaps and manage trade-offs.

Developing this framework requires a change in the following three preconditions:

- **An enabling policy and institutional environment** that recognizes the specific needs of smallholders, removes constraints to effective water management and provides incentives to maximize the productivity and profitability gains as a result of farmers choosing to adopt and use AWM technologies.
- **Effective service delivery** through public and private channels to provide smallholders with the information, technology, finance and technical advice they require to make informed choices on AWM, growing crops and accessing markets.
- **Strategic investments** by the public and private sectors that will support smallholder farmers' investments and allow them to participate in viable value chains to enhance their productivity, income and profitability.

To move forward, we propose the following:

- **Catalyze water investments** for food by applying the tools presented here and engaging with investors to inform international, national and local-level investment strategies.
- **Align water, energy and agricultural strategies** to support and complement efforts already being made to enhance food value chains. This will involve close collaboration between policymakers, researchers and implementers.
- **Conduct inclusive surveys to monitor and evaluate** agricultural productivity, livelihoods, gender and environmental impacts of AWM solutions practiced by smallholder farmers.
- **Document results and lessons learned** to guide future research and investment.

To help organizations implement our recommendations, we developed targeted decision-making tools (available at http://awm-solutions.iwmi.org), which include the following:

- **Business models** to present costs, benefits and potential impacts of enhancing smallholder access to affordable AWM technologies.
- **National livelihood maps** to target and prioritize investments in specific AWM solutions.
- **Regional suitability maps** to show areas that are geographically, economically and environmentally suitable for investment, and the implications of supporting regional private small-scale irrigation in sub-Saharan Africa and South Asia.
- **Interactive gender map for Africa** illustrating gender-related farming systems to inform investments.
- **Interactive AgWater Solutions scenario tool** to assess and monitor sustainable agricultural intensification in sub-Saharan Africa and South Asia.

Regular discussions with key stakeholders, including researchers, representatives from the government, the private sector, NGOs, donor organizations and farmers' associations are also essential. The project team created an iterative engagement model that informed the research findings and ensured that the project went beyond generating knowledge. The process encouraged decision- making and change at sub-national and national levels. We recommend that further investments are made using a similar model to ensure key individuals and institutions actively participate. Promoting cooperation and communication between local and national actors will ensure investors continually learn and adapt to priorities voiced by all stakeholders. This approach could help investors identify, implement and monitor AWM investments, so that their efforts ultimately have positive impacts in the lives of smallholder farmers.

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AgWater Solutions materials

For each country and region studied under the AgWater Solutions project, we produced materials to assist governments, organizations, donors and the private sector invest wisely to support small-scale agricultural water management. These materials can be found at: awm-solutions.iwmi.org. Available materials include assessments of water-management technologies; national and regional suitability maps and business models for disseminating the most promising technologies; studies of the possible social, environmental and institutional implications of scaling-up the most promising water management technologies; and summaries of stakeholder consultation meetings held in every country.

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