AGWATER SOLUTIONS

Improved livelihoods for smallholder farmers

REGIONAL ANALYSIS OF EX-SITU WATER HARVESTING

Potential for expansion in South Asia

JULY 2012

Introduction

South Asia (SA), including India, Pakistan, Bangladesh, Sri Lanka, Nepal, and Bhutan, is one of the most populous regions in the world. Agriculture is the backbone of the economies of SA nations and is the main source of livelihood for many rural poor households. While parts of SA have experienced considerable agricultural sector growth in the last half-century, other areas, including large parts of eastern India and Bangladesh, have lagged behind. Many farmers face water scarcity due to both physical constraints as well as lack of adequate water storage and management. Inability to access or control water has a direct impact on agricultural productivity and reduces the potential payoff from other productivity-increasing inputs, such as fertilizers and improved seeds. Furthermore, climate variability is one of the most influential factors affecting agricultural production, and long-term climate change raises concerns about the future feasibility of irrigated agriculture in the region.

A number of measures for improved agricultural water management have the potential to increase productivity and improve the well-being of poor agricultural producers in the region. One promising strategy is ex-situ water harvesting. Ex -situ water harvesting involves collecting runoff originating from rainfall over a surface away from the field and storing it in surface storage systems for later use in the field. This type of rainwater harvesting provides supplemental or protective irrigation during dry periods of the cropping season.

Methodology

This brief is based on a study that uses an integrated modeling system that combines geographic (GIS) data analysis and predictive modeling tools to assess the regional potential for smallholder agricultural water management in Sub-Saharan Africa and SA. It focuses on the potential expansion of ex-situ water harvesting throughout SA and includes an assessment of the impacts of climate change on the application potential of the technology.

The assessment process includes two components: ex-ante GIS and predictive modeling analyses. The ex-ante analysis uses a set of suitability criteria to identify areas where the technology could potentially be applied, pixel by pixel, across the region. The formulation of assessment criteria and the scoring scheme were developed through expert consultations and validation and reflect the best available expert knowledge. For ex-situ water harvesting, the environmental suitability criteria for ex-ante GIS analysis are shown in Table 1.

A pixel with a score greater than 42 is considered to have irrigation potential. The application areas derived from the suitability analysis were also compared with the labor-constrained application areas obtained from rural population analysis at the basin level; the minimum of the two application areas in a river basin was selected as the final ex-ante estimates for the areas with irrigation potential in the river basin.

The results derived from the ex-ante GIS analysis are further refined through hydrological and crop simulations using the Soil and Water Assessment Tool (SWAT). SWAT is a hydrological and agricultural model that evaluates the long-term impacts of water and land management practices on water availability, water consumption, and yield of cultivated crops. The agricultural system in SA is already intensively irrigated, and the expansion and intensification of irrigation in SA is primarily constrained by physical scarcity of water. In this assessment, we first use the SWAT model to account for renewable water resources in SA river basins and water consumption over existing irrigated land, which in turn allows for an estimation of the amount of water resources that are still exploitable for irrigation. Based on the estimates of exploitable water resources for irrigation and other information—including irrigation water-use intensity and production costs, the potential for the expansion of ex-situ water harvesting is calculated.

Key assumptions in the predictive modeling assessment include the following:

- *Cultivation of Particular Crops*. Ex-situ water harvesting will be used for the cultivation of a limited set of crops based on evidence from field studies (i.e., wheat and gram during the winter seasons; a cultivation area ratio of 10:1 is assumed).
- *Water Availability*. Exploitable water resources are calculated as the runoff during the winter season, adjusted for existing irrigation water use and environmental needs.
- *Source of Ex-Situ Water Harvesting*. Harvested water is directly abstracted from water storage facilities (not after artificial groundwater recharge).

Table 1. Ex-ante GIS analysis criteria for ex-situ harvesting in SA

Criteria for ex-situ harvesting	Scoring scheme
Topography	0 - 4% = 0, 4 - 20% = 33, 20 - 30% = 17, 30% < = 0
Runoff	0 - 25 mm/m = 0, 25 - 45 mm/m = 8, 45 - 75 mm/m = 17, 75 – 110 mm/m = 25, > 110 mm/m = 34
Soil moisture	0 - 60 mm/m = 0, 60 - 120 mm/m = 17, > 120 mm/m = 33

Note: mm/m=millimeters per month

Table 2. Irrigation and production costs

Irrigation costs-capital (US$/ha/yr)	Irrigation costs-other (US$/ha/yr)	Production costs (US$/ha/yr)
94	78 (wheat), 38 (green gram)	274 (wheat), 250 (green gram)

- *Production and Irrigation Costs*. Costs assumed for the estimation of costs and benefits of the expansion of ex-situ water harvesting are shown in Table 2.

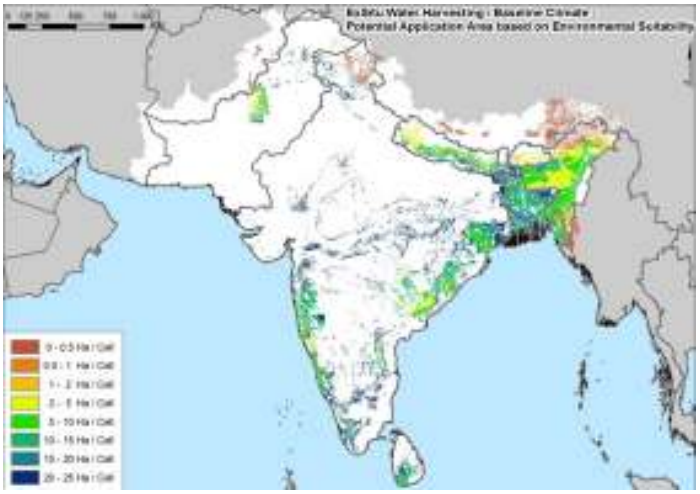

Figure 1. Suitable area for expansion of ex-situ harvesting, ex-ante results
Source: IFPRI Team

Potential for expansion of ex-situ water harvesting in SA

The ex-ante results show that electric pump–based irrigation has the potential to be expanded to 7.7 million ha in the region and reach 52 million people, with the largest potential in Pakistan and southern and western India. The results are shown in Figure 1 and Table 3.

Taking river basin hydrology, environmental constraints, yield improvements, and costs of the investment into account results in a 31-percent lower potential for adoption of ex-situ water harvesting in the region compared to the ex-ante assessment.

The results of the SWAT assessment for ex-situ water harvesting are summarized in Table 4 and Figure 2 for the baseline scenario. The results indicate a potential area expansion of 21 million ha, 9 million ha less than under the ex-ante GIS analysis. The total number of people reached is reduced to 205 million, compared to 298 million in the ex-ante assessment.

Total net revenues as a result of the expansion of ex-situ water harvesting throughout the region would be $6 billion per year, with revenues highest in southern India, far-eastern India, and western India.

Table 3. Ex-ante potential for ex-situ harvesting in SA, assuming 100 percent adoption

	Area (thousand ha)	Population reached (thousand)
Bangladesh	5,099	47,930
Bhutan	105	1,111
India-Central	3,057	29,956
India-Eastern	6,557	64,256
India-Far-East	3,134	30,711
India-Northern	1,651	16,181
India-Southern	5,195	50,910
Indian-Western	2,785	27,297
Nepal	1,296	12,964
Pakistan	726	10,603
Sri Lanka	630	6,049
South Asia Total	30,235	297,968

Source: IFPRI Team

This expansion would be accompanied by a significant increase in water consumption. The total increase in water consumption as a result of the expansion of ex-situ water harvesting in SA is estimated at 20 billion m^3/yr. Given the already high water consumption levels in the region, this would, however, only constitute a 4 percent increase in overall consumption.

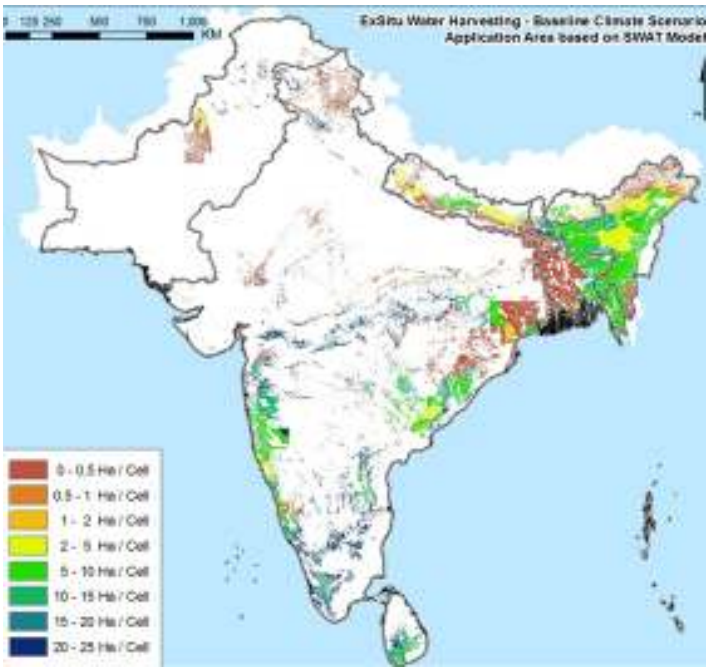

Figure 2. Suitable area for expansion of ex-situ harvesting, SWAT results
Source: IFPRI Team

Table 4. Predictive modeling results for the potential expansion of ex-situ harvesting, baseline results (no climate change)

	Area (thousand ha)	Population reached (thousand)	Net revenue (US$ billion/yr)	Water consumption (billion m3/yr)	Water consumption increase (%)
Bangladesh	1,855	17,439	0.7	1.1	10.4
Bhutan	265	2,807	0.1	0.1	257.5
India-Central	2,539	24,885	0.7	2.8	2.0
India-Eastern	1,808	17,714	0.6	1.9	2.9
India-Far-East	3,676	36,020	1.2	2.0	57.0
India-Northern	627	6,149	0.2	0.4	0.3
India-Southern	5,471	53,616	1.3	7.0	8.7
Indian-Western	3,158	30,952	0.9	3.7	6.7
Nepal	400	3,999	0.1	0.2	2.9
Pakistan	249	3,641	0.05	0.2	0.4
Sri Lanka	806	7,738	0.2	0.5	7.0
South Asia Total	20,854	204,958	6.0	19.8	3.6

Source: IFPRI Team

To investigate the impacts of climate change on the application potential of ex-situ water harvesting across SA, the results were also estimated under two climate scenarios projected by the CSIRO-Mk3.0 model (Csia), using the SRES A2 emission scenario; and the MIROC 3.2 medium resolution model (Mira), using the SRES A1B emission scenario (Table 5).

In a preliminary analysis, the two scenarios were identified as the "driest" and "wettest" scenarios, respectively, among 12 future climate change scenarios projected by general circulation models for SA. The results (Table 5) show that the climate change leads to a slightly reduced application potential in terms of area and population reached under the dry scenario; but increased potential under the wet scenario.

Conclusions

This assessment combines geographic (GIS) data analysis and predictive modeling tools to assess the regional potential of expanding ex-situ water harvesting in SA. The estimated expansion area could reach almost 21 million hectares, reaching 205 million people in rural areas, and generate $6 billion net revenues per year. The potential is by far largest in southern India. The assessment results thus show that ex-situ water harvesting has significant expansion potential in SA. Climate change has limited impacts on the investment potential, with small declines under the dry scenario and small increases under the wet scenario.

Of note, this assessment did not incorporate costs of extracting water from the ex-situ water harvesting structures.

Table 5. Predictive modeling (SWAT) results for the potential expansion of electric pump-based irrigation under climate change

	Ex-ante			SWAT+DREAM		
	Baseline	Csia	Mira	Baseline	Csia	Mira
Area (thousand ha)	30,235	29,707	32,416	20,854	20,119	22,134
Population reached (thousand)	297,968	292,629	318,342	204,958	197,957	217,402
Net revenue (US$ billion)	-	-	-	6.0	5.3	5.9
Water use (billion m^3)	-	-	-	19.8	19.7	20.5
Water consumpion increase (%)	-	-	-	3.6	3.6	3.7

Source: IFPRI Team
Note: Results shown are for all of SA.