AGWATER SOLUTIONS

Improved livelihoods for smallholder farmers

# REGIONAL ANALYSIS OF ELECTRIFICATION

## 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, many other regions, 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 seed varieties. 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 subsidized rural electrification, which would enable the expansion of electric-powered pumps for groundwater extraction and an increase in irrigated surface areas.

Compared to diesel-powered pumps, which are used throughout much of the region where electricity is not available, electric pumps are cheaper to operate and cleaner. Like diesel pumps, they have considerable capacity relative to traditional water-lifting means (lifting from an average depth of 30 meters) and have flexibility to move among different water sources and many farmers.

## 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 for the expansion of electric pump –based irrigation 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 electric pumps, the environmental suitability criteria for ex-ante GIS analysis are shown in Table 1.

A pixel with a score greater than 61 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 we consider that the expansion and intensification of irrigation in SA is primarily constrained by the 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.

**Table 1. Ex-ante GIS analysis criteria for electric pumps in SA**

| Criteria for electric pumps | Scoring scheme |
|---|---|
| Groundwater | Safe = 0, Semi-Critical = 0, Critical = Excluded, Over-exploited = Excluded, Restricted = Excluded, Saline = Excluded |
| Electrification | False = 0, 5 km Buffer = 17, True = 33 |
| Market access | 5 km = 10 minutes = 34, 10 km = 20 minutes = 22, 20 km = 40 minutes = 11, 30 km = 60 minutes = 0, 60 km = 120 minutes = 0 |
| Distance to surface water | < 0.5 km = 33, > 0.5 km = 0 |

Based on the estimates of exploitable water resources for irrigation and other information—including irrigation water-use intensity, rural population, and production costs—the potential for the expansion of electric pump–based irrigation is calculated.

Key assumptions in the predictive modeling assessment include the following:

- *Cultivation of Particular Crops*. Electric pump–based irrigation will be used for the cultivation of a limited set of crops based on evidence from field studies (rice, tomatoes, and onions in winter seasons; a cultivation area ratio of 100:1:1 is assumed).
- *Water Availability*. The water balance is accounted for at a river basin scale. Exploitable water resources in a river basin are calculated as the safe yields of groundwater ($m^3H_2O$/yr) (average rate of groundwater recharge, $m^3H_2O$/ha-yr × basin area, ha), adjusted for existing irrigation water use.
- *Production and Irrigation Costs*. Costs assumed for the estimation of costs and benefits of the expansion of electric pump–based irrigation are shown in Table 2.

**Table 2. Irrigation and production costs**

| Irrigation costs-capital (US$/ha/yr) | Irrigation costs-other (US$/ha/yr) | Production costs (US$/ha/yr) |
|---|---|---|
| 246 | 80 | 180 (rice), 1,000 (tomatoes and onions) |

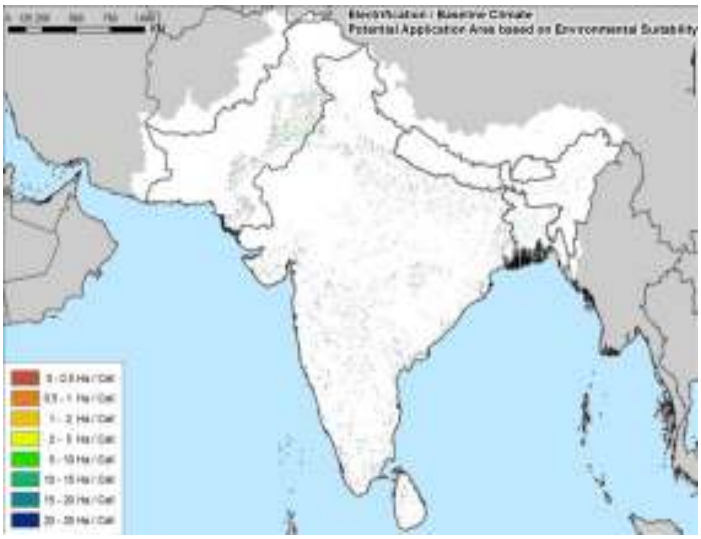

*Figure 1. Suitable area for expansion of electric pump-based irrigation, ex-ante results*
*Source: IFPRI Team*

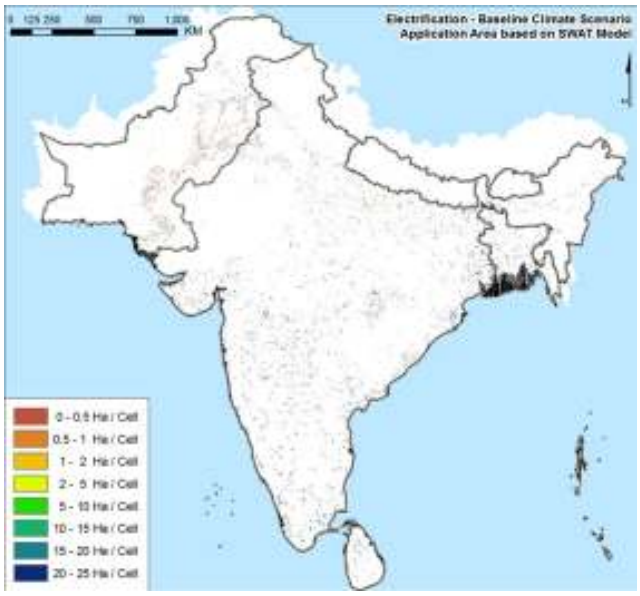

*Figure 2. Suitable area for expansion of electric pump-based irrigation, SWAT results*
*Source: IFPRI Team*

## Potential for expansion of electric pumps 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 lower potential for adoption of electric pump-based irrigation in the region compared to the ex-ante assessment.

**Table 3. Ex-ante potential for electric pimp-based irrigation in SA, assuming 100 percent adoption**

| | Area (thousand ha) | Population reached (thousand) |
|---|---|---|
| Bangladesh | 304 | 1,787 |
| Bhutan | <1 | 1 |
| India-Central | 1,078 | 6,604 |
| India-Eastern | 1,080 | 6,613 |
| India-Far-East | 138 | 845 |
| India-Northern | 448 | 2,745 |
| India-Southern | 1,632 | 9,997 |
| Indian-Western | 1,174 | 7,193 |
| Nepal | 47 | 291 |
| Pakistan | 1,649 | 15,047 |
| Sri Lanka | 149 | 894 |
| South Asia Total | 7,700 | 52,018 |

*Source: IFPRI Team*

**Table 4—Predictive modeling results for the potential expansion of electric pump–based irrigation, 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 | 334 | 1,965 | 0.1 | 1.6 | 15.1 |
| Bhutan | 0.23 | 1.50 | 0.0003 | 0.0009 | 3.3 |
| India-Central | 680 | 4,163 | 0.5 | 4.5 | 3.3 |
| India-Eastern | 1,083 | 6,631 | 0.9 | 6.1 | 9.2 |
| India-Far-East | 135 | 827 | 0.1 | 0.7 | 20.4 |
| India-Northern | 78 | 478 | 0.05 | 0.5 | 0.4 |
| India-Southern | 1,581 | 9,682 | 1.5 | 10.1 | 12.4 |
| Indian-Western | 1,174 | 7,190 | 1.0 | 7.8 | 14.3 |
| Nepal | 45 | 283 | 0.03 | 0.3 | 5.4 |
| Pakistan | 212 | 1,930 | 0.1 | 1.4 | 2.2 |
| Sri Lanka | 159 | 954 | 0.1 | 0.7 | 10.0 |
| South Asia Total | 5,480 | 34,103 | 4.4 | 33.7 | 6.2 |

*Source: IFPRI Team*

The results of the SWAT assessment for electric pump–based irrigation are summarized in Table 4 and Figure 2 for the baseline scenario. The results indicate a potential area expansion of 5.5 million ha, compared to 7.7 million ha in the ex-ante analysis. The total number of people reached is reduced to 34 million compared to 52 million in the ex-ante assessment. Total net revenues as a result of the expansion of electric pump–based irrigation throughout the region would be $4 billion per year. 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 electric pump–based irrigation in SA is estimated at 34 billion $m^3$/yr or 6 percent over current consumption levels.

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

| | Baseline | Csia | Mira |
|---|---|---|---|
| Area (thousand ha) | 5,480 | 4,980 | 5,669 |
| Population reached ('000s) | 34,103 | 30,843 | 35,153 |
| Net revenue (US$ billion) | 4.4 | 3.2 | 3.5 |
| Water use (billion $m^3$) | 33.7 | 31.0 | 33.8 |
| Water consumption increase (%) | 6.2 | 5.7 | 6.2 |

*Note: Results shown are for all of SA. Climate factors were not part of the ex-ante analysis criteria for regional electrification.*
*Source: IFPRI Team*

To investigate the impact of climate change on the potential application of motor pump–based irrigation across SA, 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.

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 changes in the estimated application area due to the climate change are not substantial. Under the dry scenario, there is a slight decrease in the potential of electric pump-based irrigation; while under the wet scenario, there is a slight increase.

## Conclusions

This assessment combines geographic (GIS) data analysis and predictive modeling tools to assess the regional potential for the expansion of electric pump–based irrigation in SA. The estimated expansion area could reach more than 5 million hectares, reach 34 million rural people, and generate net revenues of $4 billion per year. Much of the expansion of this intervention hinges on the lack of rural electrification in significant parts of South Asia; and on the relative cost of diesel versus electric pumps.

A constraint on groundwater availability, assuming "no overdraft," was assumed for this intervention. Unregulated adoption of electric pumps is likely to result in much larger expansion but would undermine the sustainability of aquatic environments. To address concerns associated with electric pump expansion, regulations and policies that help to internalize externalities of irrigation development should be developed hand in hand with investments in this area.