Background

The United Nations' Millennium Development Goals and the Bangladesh government's poverty reduction strategy emphasize that "raising land productivity and increasing diversification of agriculture production" are "fundamental to poverty reduction as well as for food security" in the country (IMF 2013). In this context, the positive impacts of the BMDA on agriculture, especially rice production, has been rightly regarded as a success story. This autonomous body under the Ministry of Agriculture, presently working in 16 districts of Bangladesh (map 1), seeks to enhance food security and living standards mainly through agricultural development. Its multipronged resource management model is a rare example of integrated development. In this drought-prone region where rain-fed monocropping was the norm, the BMDA introduced inverted DTWs and a prepaid smart metering system that has transformed agriculture into a "three crop revolution" (Kang 2013). Cropping intensity has risen from 117 percent to 200 percent, higher than the national average of 175 percent (Jahan et al. 2010b). The results have helped reduce poverty in the region from 57 percent in 2000 to 36 percent in 2010 (Jolliffe et al. 2013). The Barind region is characterized by diverse agroecological conditions. Aside from the Padma River, all other rivers are seasonal and dry up during the dry season (Jahan et al. 2010a). Precipitation is diverse, erratic, and low with an average 1,600 millimeters compared to the national average of 2,550 millimeters and sometimes affected single-

MAP 1. Districts Covered by the Barind Multipurpose Development Authority

Source: Barind Multipurpose Development Authority.

crop production before irrigation was available. The Rajshahi district receives low rainfall, whereas Thakurgaon and Rangpur lie in the 1,500- to 2,000-millimeter and 2,000- to 2,500-millimeter belts, respectively. Runoff is high in some areas with limited groundwater storage, which makes it prone to drought (Ahmeduzzaman, Kar, and Asad 2012).

Although this case study profiles the clearly impressive innovations regarding electric-powered DTWs, it also poses the question of whether DTW-driven rice crop intensification is sustainable in parts of the region. A limited number of interviews in communities using STWs, mainly in the Thakurgaon district, suggests that though farmers within DTW command areas are thriving, farmers outside these areas may be struggling with enhanced groundwater drawdown in the dry season because maximum STW depths are typically only 15 to 20 meters (de Silva and Leder 2016). With STW-dependent farming communities constituting most of the region's population, this case study argues that the viability of DTWs must consider the externalities that they may induce.

Framing this discussion on sustainability of DTWs in certain parts of the Barind region is what could be described as the rice-groundwater nexus in Bangladesh, a dominant development paradigm driving investments in the agriculture and irrigation sectors. Bangladesh is now the world's fourth-largest rice producer and nearly self-sufficient in rice (Mainuddin and Kirby 2015). Rice accounts for nearly 80 percent of the country's gross cropped area (Amarasinghe et al. 2014), and rice production has almost tripled since 1976–77 (Mainuddin et al. 2014). Given the scarcity of land, the production increase was driven by yields that rose to almost 4.3 tonnes per hectare from 2.7 tonnes per hectare in 1995. Bangladesh's rice area under irrigation has increased to 77 percent from about 30 percent in 1995 (Amarasinghe et al. 2014), and the country increased use of modern varieties during the same period. The rapid expansion of the dry-season rice crop has especially contributed to enhanced production. Today, 80 percent of boro rice is groundwater irrigated (Mainuddin et al. 2014) and accounts for almost all the irrigation-consumptive water use of rice. These results have improved the livelihoods of millions of rural poor (Qureshi, Ahmed, and Krupnik 2014) and reduced rural poverty (Gautam et al. 2016).

Informing this case study is fieldwork undertaken specifically for this study as well as primary data collected by the International Water Management Institute in 2016 under the project Improving Water Use for Dry Season Agriculture by Marginal and Tenant Farmers in the Eastern Gangetic Plains (de Silva and Leder 2017), funded by the Australian Center for International Agricultural Research. Combined, this research covers six districts (Chapai, Natore, Nowabganj, Rajshahi, Rangpur, and Thakurgaon) and includes discussions with officials from BMDA and the Department of Agriculture, focus group discussions and interviews with farmers from communities with and without a DTW (Rangpur and Thakurgaon), and review of available secondary data and literature on the Barind region.[3]

Innovations around DTWs

DTWs were introduced by the Bangladesh Water Development Board (BWDB) in 1963–66 and were originally diesel-powered. In about 1990, the energy source powering DTWs changed to electricity because of the unreliability of diesel DTWs and resulting crop losses. The BWDB handed over supervision of DTWs in northern Bangladesh to the BMDA in 2001–02.

Inverted DTWs

The primary aquifer in the Barind region accessed by DTWs and STWs alike is the Dupi Tila formation composed of deltaic sands, silts, and gravels overlain by as much as 30 meters of Barind clay. Recharge to the aquifer is limited by vertical leakage through a low-permeability clay layer (Ahmed and Burgess 1995). The BMDA engineers designed an inverted DTW because the conventional DTW technology was not suitable to lift groundwater in the Barind region. The inverted DTWs, described by Asaduzzaman and Rushton (2006), can extract water from relatively "poor" aquifers with limited saturated thickness that exist at a depth of approximately 30 to 40 meters. Of the 25 upazilas (subdistricts) in the Barind region, 10 have poor aquifers, where normal DTWs cannot function. According to the BMDA, 15,813 DTWs currently irrigate 496,198 hectares of boro paddy in the Barind region. DTW command areas vary in size. In Dhondogaon village, Thakurgaon district, it can reach 24 hectares for rice, though this measurement varies depending on the specific water demand of selected crops.

The Prepaid Metering System

The BMDA initially collected irrigation fees from farmers by issuing paper coupons through dealers. This was a cumbersome process with loopholes for corrupt practices.

There was scope, for instance, for operators to run a pump without receiving any coupon and to illicitly sell water to farmers without the BMDA's knowledge. In 2005–06, prepaid metering was introduced, and by 2010, almost all pumps were managed through the new system, in which each farmer in the command area buys a smart card from the BMDA's upazila office at a nominal cost. The BMDA selects a dealer for each upazila to recharge the smart cards, who is provided a mobile vending unit (MVU) at a cost of Tk 30,000 to 60,000 (US$360 to $720). The BMDA pays the dealer a commission of 2.5 percent on the amount of recharge. Farmers recharge their respective smart cards with a dealer and approach the DTW operators to buy water. When a farmer requires irrigation, the farmer-elected DTW operator enters the farmer's smart card in a prepaid meter attached to the DTW, and water is supplied for irrigation. The pump stops automatically after the scheduled duration requested by the farmer, and the prepaid meter deducts the necessary amount from the farmer's smart card (photo 1). Irrigation charges are fixed depending on the discharge rate of the pumps and vary between Tk 75 and 115 (US$0.9 to US$1.40)

This system collects 100 percent of irrigation charges for the BMDA, making it a surplus-generating, self-sufficient organization. About 60 percent of the money collected from farmers pays for electricity consumption, 10 percent goes to DTW operators, 2.5 percent to the smart card dealers, 15 to 20 percent for maintenance, and the remainder pays for other costs such as BMDA staff salaries. Field operations are overseen by the BMDA's upazila offices, which are managed by Assistant Engineers, who hire mechanics and other staff to maintain the DTWs and collect data from the MVUs. The BMDA is working to introduce telemetering systems that would monitor DTW functioning from BMDA headquarters. In this system, the data from each pump will automatically be uploaded to a server at the BMDA's head office.

Water Savings and Conflict Avoidance Using Underground Pipelines for Distribution

Underground pipelines are being put in place in all DTW command areas to avoid substantial loss of water during distribution as a result of seepage and evaporation and to minimize the need for farmers to have water channels on their land. Maintenance of concrete channels has been costly because of frequent breakage. Construction included overhead water tanks at DTWs for irrigation and supply lines to distribute drinking water when supplies of the latter are scarce in the summer months.

DTW-Enabled Transformation of Agriculture in the Barind Area

Electric-powered DTWs have enabled farmers in the Barind region to largely overcome the risks of crop failure and drought-related crises. DTWs help farmers stabilize crop production during midseason dry spells and carry over groundwater storage during multiyear monsoon failures, ensuring minimum crop losses. Farmers interviewed during the field study confirmed that since construction of DTWs in their area, they have not faced the severity of drought as in earlier years.

DTWs substantially increase cropping intensity and lowered costs for farmers. Purchasing water from private STWs has been expensive, costing between Tk 3,000 and 3,500 (approximately US$36 to $42) for irrigating one bigha (approximately 0.1 hectare) of boro (summer) paddy. Irrigation from electric DTWs costs one-third to one-half less. The changes have boosted farmer income, reducing migration in search of jobs and improving children's education.

PHOTO 1. Components of Prepaid Irrigation Fee Setup

a. Mobile vending unit b. Prepaid smart card c. Prepaid meter

Source: Authors.

Emerging Concerns over Sustainability

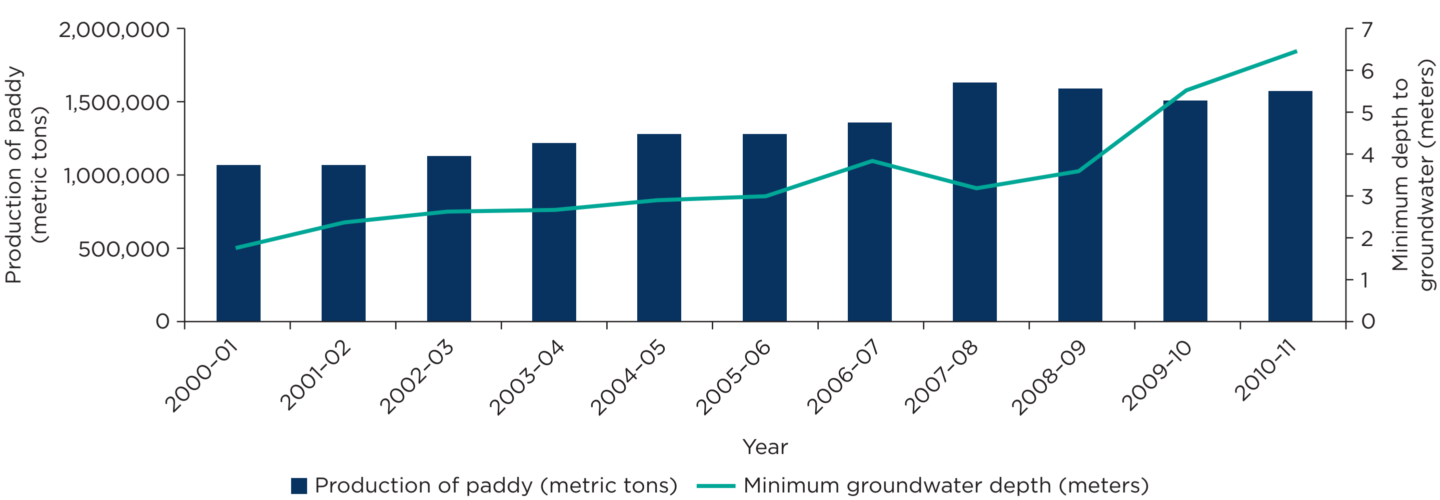
Recent studies have expressed apprehension about overutilization of groundwater resources (Adhikary et al. 2013; Ahmeduzzaman, Kar, and Asad 2012; Islam et al. 2010; Rahamatulla et al. 2013). According to Dey et al. (2013), some parts of the Barind region reveal a declining trend in groundwater levels between 1981 and 2011. Aziz et al. (2015) show a direct relationship between the increase in boro paddy production and groundwater depletion in the Rajshahi district (figure 1).

Farmer observations in Rajshahi and Thakurgoan reflect this concern (de Silva and Leder 2017). Farmers in the Tanore upazila of the Rajshahi district reported that the water table in late February had declined from about 9 meters in the mid 2000s to about 23 meters now, whereas monsoonal recharge now causes it to rise to about 15 meters, compared to 5 or 6 meters in the past. Similarly, interviews with DTW operators in Rajshahi indicate DTW depths had to be increased from time to time as groundwater levels drop well beyond 30 meters in the boro season. DTW operators in some locations in Rajshahi also noted DTW pump breakage in the early boro season as a result of intensive use (de Silva and Leder 2017).

Although farming communities served by DTWs have clearly benefited, communities without access to DTWs report conditions have become more challenging, and this has potentially significant developmental implications (de Silva and Leder 2017). In some parts of the Thakurgaon district, STW users can no longer provide timely supplementary irrigation for aman rice. The same issue arises in the case of dry-season boro rice when STW functionality is particularly impacted, with a lack of irrigation also for rabi crops such as potato, wheat, and maize. The overall impact is lower yields across these crops and seasons and increased irrigation costs that now constitute more than 50 percent of total production costs. Farmers in these areas estimate that they therefore earn Tk 30,000 to 40,000 (US$360 – US$480) a year less than farmers serviced by a DTW. They expect this gap to grow, believing production costs will increase, particularly as a result of rising fuel costs. Domestic hand pumps in such villages also struggle during March and April each year. The division between STW- and DTW-dependent farmers in Thakurgaon is captured in their differing perceptions of water security. Farmers in DTW command areas expect another 15 to 20 years of good irrigation and feel it less imperative to change their crop choices and cultivation practices. STW users are, not surprisingly, more anxious. In Rajshahi, the need to deepen DTWs and pump failure early in the boro season suggests there, too, groundwater-based irrigation is becoming more challenging.

The full implications of the divergence in water security views are still emerging, and villages dependent on STWs significantly outnumber those served by a DTW (table 1). STWs, in fact, still account for most farmers' served and cultivated areas. Although this is not an immediate concern in Rangpur, where water tables appear more stable, in Thakurgaon, DTWs irrigate only an estimated 30 percent of cultivable land (de Silva and Leder 2017). With STW

FIGURE 1. Production of Paddy in Metric Tons Shown Together with Minimum Groundwater Depth



Source: Aziz et al. 2015.

TABLE 1. Deep Tubewells and Shallow Tubewells in Rajshahi and Rangpur Districts

	DTWs (electric and diesel)			STWs (electric and diesel)		
District	Wells	Area irrigated	Farmers served	Wells	Area irrigated	Farmers served
Rajshahi	16,495	553,095	1,339,311	328,101	706,905	2,168,594
Rangpur	7,445	212,979	365,335	396,938	779,339	2,519,088

Source: Minor Irrigation Survey 2015–16, Ministry of Agriculture, Government of Bangladesh.
Note: DTWs = deep tubewells; STWs = shallow tubewells.

irrigation (fuel) costs rising and rainfall and temperature fluctuations likely to increase irrigation demand, the plight of STW-dependent farmers is a fundamental policy question. For these communities, the absence of DTWs is a dual problem because hand pumps used to supply domestic water also cease to function. The development conditions where STWs no longer work may further regress if households become mainly reliant on rain-fed cultivation. In other words, they risk returning to a pre-irrigation era.

In addition to lower earnings and food security, a scenario where STWs become wholly or seasonally redundant also means fewer crop combination options to respond to climate change and other stresses. The capacity for greater agrarian diversification was in fact highlighted by Gautam et al. (2016) as a key condition if multiple developmental goals are to be met, including reducing rural poverty and malnourishment. The emerging concerns over future groundwater irrigation as a key means of production must be taken seriously as a driver of developmental inequity that may potentially reverse hard-won gains fighting poverty.

Conclusions

The Barind approach augmenting groundwater-driven irrigation with about 16,000 DTWs has been an example of adaptive resource management in the face of adverse agroecological conditions. But field interviews suggest that changing groundwater conditions are driving an increasing heterogeneity in the outcomes arising from this irrigation-based rice-intensification model of rural development in the Barind region. At the center of this emerging policy issue is an apparent divergence in farmers' developmental trajectories based on their geographical location and whether they are served by DTWs or STWs. In Rangpur, farmers linked to both DTWs and STWs appear to remain water secure. But in Thakurgaon, farmers in DTW command areas gain better crop yields, saving time and money, whereas villages relying on STWs are already facing water security issues. The future of STW users appears less certain across the board, though even some DTWs appear to struggle to deliver adequate water due to depletion, as in Rajshahi.

The negative impacts associated with DTWs, namely those of declining groundwater tables, speak to the policy question of what should constitute "success" or "sustainability" with respect to this groundwater-based rice production model. Are changes in groundwater conditions bringing to the surface an overdependence on irrigated agriculture and the need to consider supply-side measures? Is there a need to reimagine what sustainable and equitable rural development means and what indicators should be used to track future progress? The solution does not seem to be to add more DTWs, and the government's precaution of suspending further investments in DTWs in this region should be applauded. Although this study, based on data from limited case studies, cannot make conclusions on the overall groundwater situation in the study districts, nor the prevalence of STW failure, the differing farmer irrigation experiences suggest future DTW investments should be based on a more nuanced consideration of localized groundwater conditions and other users.

The current suspension of new DTW installations also provides a pause to reflect on the important emerging trade-offs between food security policy defined through rice production and water security and crop diversification. This break may present an opportunity to promote more crop diversification that could reduce pressure on groundwater resources while addressing the need for agrarian diversification, as emphasized by Gautam et al. (2016). Farmer interviews suggest that the innovations around DTWs may, ironically, have stifled crop diversification as they attempt to maintain water security in areas where groundwater levels may be in decline. Such scenarios provide little incentive for farmers to shift from their comfort zone of rice cultivation. In other words, diversification to less-water-demanding crops and other water-saving methods is unlikely to occur voluntarily until a water insecurity threshold is experienced, by which time diversification would be reactive rather than a proactive adaptive strategy.

The analysis in this case study purposefully ends on cautionary footing. Although not seeking to detract from the significant positive gains made through investments in DTW technology to date, it does seek to make the point that a resource base cannot sustain long-term overextraction, so the balance between benefits and externalities is likely to shift. The evidence presented here suggests a need for more-comprehensive research to verify groundwater conditions, risks to STW users, and developmental implications to inform future policy on farm development driven by DTWs in the Barind region.

NOTES

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2. International Water Management Institute (IWMI), Colombo, Sri Lanka.
3. A. H. Chowdhury, personal communication, November 5, 2018.

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