

August 2019



# AgriMAR Bangladesh

Managed Aquifer Recharge to provide irrigation water for agriculture in a saline environment

Project overview



## Executive summary

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Agriculture in the coastal plain of Bangladesh faces a number of serious challenges, among which the issue of seawater intrusion. During the dry season most of the surface water bodies of the vast delta area become saline or brackish, making the water unsuitable for irrigation. Farmers are therefore limited to one or two harvests of rainfed crops per year. This project aims at improving livelihoods and climate-resilient agriculture by making irrigation water available during the dry season, which allows farmers to grow an off-season harvest of high-value crops. AgriMAR systems provide a simple, low-cost solution for safely storing freshwater underground to be used for irrigation when it is needed. A detailed economic assessment shows that there is a positive business case for growing bitter melon or water melon using the AgriMAR system.

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## Colophon

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# Introduction

Acacia Water implemented a managed aquifer recharge (MAR) system for the irrigation of crops with different salt tolerance levels in the district of Bagerhat, in the coastal plain south of Khulna, Bangladesh [1]. Constructed as an aquifer storage and recovery (ASR) system, it provides a low-cost solution for storing freshwater in a saline environment to be used for irrigation during the dry season. This allows for a diversification of agriculture and improves the resilience of farmers to climate change, which causes brackish surface water and groundwater to protrude increasingly land inward. Bangladesh's economic growth is to a large part generated by the development of irrigation agriculture and AgriMAR systems show good potential for changing towards climate-smart irrigation agriculture that can help to improve livelihoods in delta regions, such as in southern Bangladesh.

## Fact sheet AgriMAR system Bangladesh

**Location:** Rampal Agri Farm, Bagerhat District, coastal plain of Bangladesh

**Coordinates:** latitude 22.567130°, longitude 89.730580°

**Climate:** Tropical, monsoon June – October, annual rainfall 75 in (1,900 mm)

**Operator:** Saline Farming (NL) and Lal Teer (BD)

**Implementation:** Acacia Water (NL), Dhaka University (BD)

**Commencement of operation:** 2019

**Purpose:** Provision of irrigation water during dry season

**Design:** ASR well (gravity infiltration, shallow and deep filter), prefiltration through horizontal sand filter

**Source water:** Rainwater collected in a pond (supplemented with river water if good quality available)

**Aquifer:** Fine sand, confined, brackish groundwater (EC 6 – 12 mS/cm)

**Capacity:** Expected infiltration >190,000 ft<sup>3</sup>/year (5,400 m<sup>3</sup>/year), recovery efficiency ca. 50%

**Construction costs** (upscaling): 4,500 €

**Operation & maintenance:** 620 €/year

**Estimated benefit-cost ratio:** bitter melon: 1.13; water melon: 1.97

**Main advantage:** Low-cost freshwater storage in a saline environment for climate-resilient agriculture

## Project concept and implementation

In large parts of Bangladesh's rural coastal region the population has limited access to safe drinking water due to salinity in both shallow and deep groundwater. During the dry season, many of the delta's rivers and canals turn saline [4]. The abundant monsoon rains provide large amounts of freshwater and applying ASR has proven to be a suitable solution for bridging the water availability-demand gap: available freshwater from the rainy season can be stored in

brackish aquifers to be used during the dry season [5]. The rainwater is captured in ponds, filtered, and pumped into a surface reservoir from where it can infiltrate into the aquifer via one or multiple recharge wells. The water is stored in the underground, safe from contamination and evaporation. During the dry season, when the demand is high, it can be pumped to the surface.

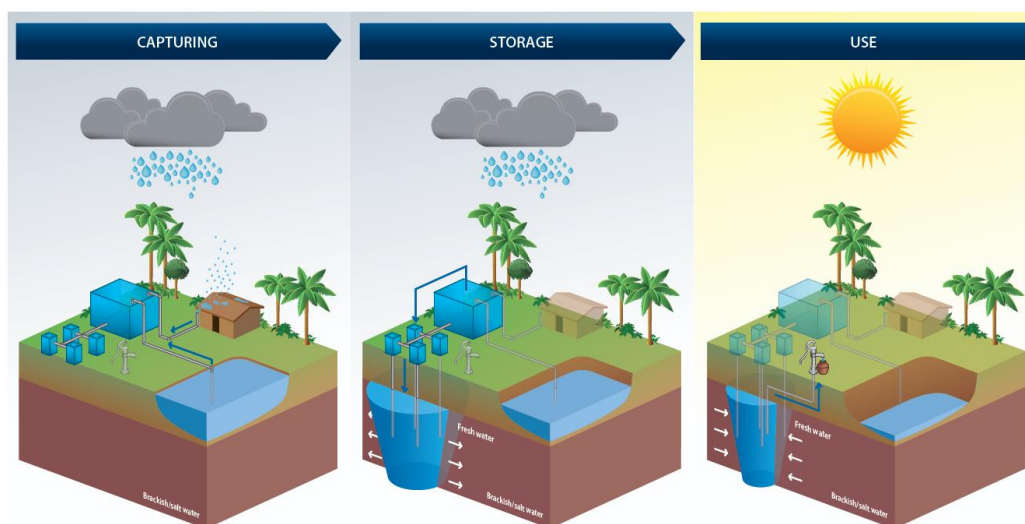


Figure 1: Managed Aquifer Recharge: rainwater is captured, stored in the subsurface, and recovered for use during the dry season

Together with Dhaka University, UNICEF, and the Department for Public Health Engineering (DPHE) Acacia Water designed and piloted a MAR system for the provision of drinking water to rural communities in 2009 [2]. In several stages 95 MAR systems had been implemented by 2017, with the design being optimized throughout the project. Infiltration water is collected in a pond, pre-filtered in a sand filter and infiltrated in the shallow confined sand aquifer via four to six infiltration wells that are placed around a central abstraction well. The drinking water MAR systems have provided important knowledge on the technical functioning and – more importantly – on the socio-economic sustainability of MAR systems in the coastal zone of Bangladesh. It became apparent that operation and maintenance of the systems require considerable resources that make a robust financing scheme necessary. Upscaling of the technology, dissemination of knowledge, and general oversight should lie in the hands of a governmental body [2].

Drawing on the experience of implementing the drinking water MAR systems, the concept was adapted for irrigation water. In 2017, Acacia Water was approached by the Netherlands-based organization Saline Farming [6], partnering with the Bangladeshi seed company Lal Teer, to design a sustainable system for providing freshwater at a pilot site for salt-tolerant crops. The project is funded by the Dutch Postcode Lottery with the Dutch NGO ICCO as lead partner [7] and is implemented by Acacia Water together with Dhaka University.



At the pilot site, rainwater is collected in shallow ponds. The developed AgriMAR system features a horizontal drain that is installed parallel to a pond over a length of 50 ft (Fig. 2). For filtration, water flows from the pond to the horizontal drain through a jute-lined chamber with filter sand that can be removed for cleaning. In a test, the turbidity of river water collected in the pond was reduced from 100 NTU to 50 NTU by this simple filtration technique [1]. A much lower turbidity is expected if rainwater is used for infiltration. Using a motor pump, a 175 ft<sup>3</sup> (5 m<sup>3</sup>) reservoir is filled with water from the drain. The water then infiltrates under gravity in the shallow and deep 4" filters of the well. The infiltration capacity is around 300 ft<sup>3</sup>/h (9 m<sup>3</sup>/h) with an overhead pressure of 4.5 – 9 ft (1.5 – 3.0 m), depending on the water level in the reservoir.

The infiltrated freshwater displaces the brackish groundwater and forms a lens at the top of the aquifer. EC values of the ambient groundwater of 6.7 mS/cm and 12.2 mS/cm were measured in the shallow and deep filter respectively [1]. As a considerable amount of infiltrated freshwater is lost to mixing at the boundary of the lens, only the shallow filter is used for recovery. The simple, low-cost AgriMAR system was constructed with locally available materials and unskilled labour (with the exception of the borehole which was drilled by a local contractor using a low-tech straight-flush manual rotary drilling technique). At the pilot site the recovered freshwater is mixed with brackish surface water to irrigate salt tolerant crops with water of constant low salinity. The AgriMAR system shows great potential for improving off-season irrigation agriculture in Bangladesh by allowing for an extra harvest of high-value crops during the dry season.

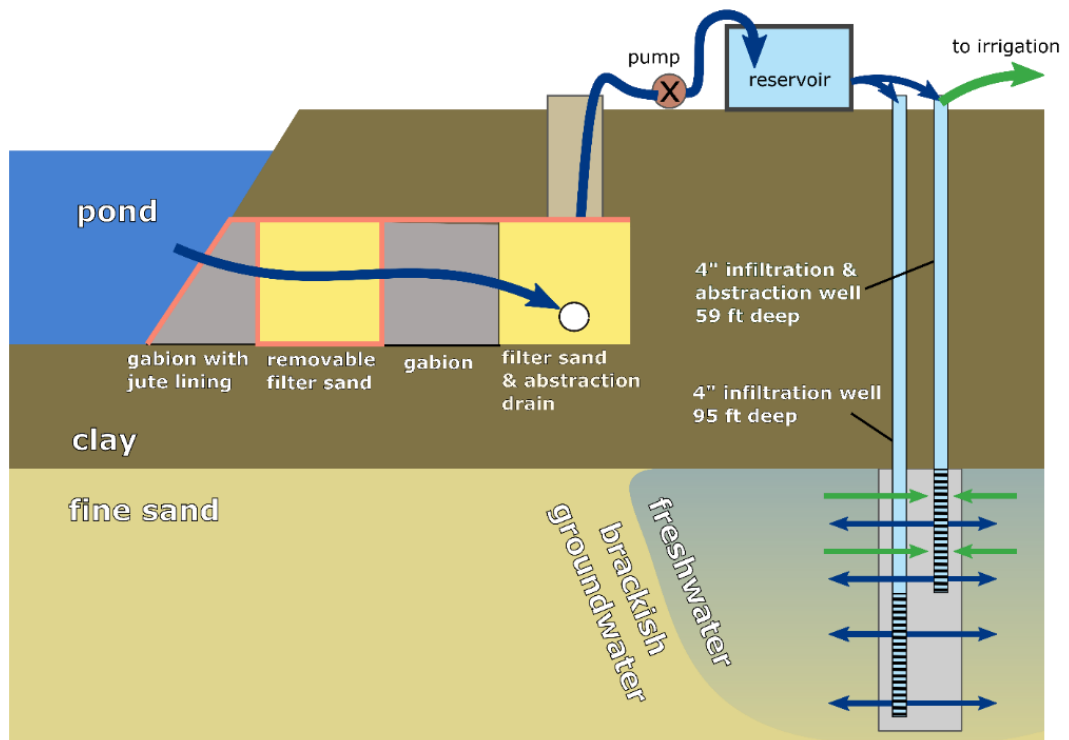


Figure 2: Cross-sectional view of the AgriMAR system

## Environmental sustainability of the AgriMAR system

Salinization of agricultural lands in the coastal zone of Bangladesh is increasingly caused by inundation from cyclonic storm surges and seawater intrusion due to reduced river discharge and rising sea level [4]. Some rice farmers have converted their field to brackish water aquaculture ponds (shrimp farming) because salinity levels reduced their crop yields. As a consequence, however, surrounding fields become salinized too – a change that is difficult to reverse.

Climate change affects agriculture in Bangladesh threefold: Firstly, average temperatures are projected to increase by ca. 4 °C by the end of this century, which results in a larger demand for irrigation water. Secondly, rainfall patterns are projected to become more variable with a likely increase during the monsoon months, further exacerbating the problem of flooding. Thirdly, sea level rise is likely to displace more than 35 million people from coastal districts and salt water intrusion will lead to a further loss of arable land. Already 42% of arable land in the coastal area is affected by varying degrees of soil salinity, and a continuation of this trend is projected to reduce rice and wheat production by 8% and 32% respectively by 2050 [3]. AgriMAR can help to maintain crop-based agriculture by providing more freshwater to counteract salinization.

Earlier studies came to the conclusion that the feasibility of MAR in the coastal area of Bangladesh is governed predominantly by the salinity of the ambient groundwater [1, 2, 4]. Close to the ocean groundwater salinity is too high (>15 mS/cm, red zone in Fig. 3) to make MAR technically feasible, but a broad zone of brackish groundwater shows good potential for MAR (light green and green areas in Fig. 3). The operation of the drinking water MAR systems in this zone revealed an average recovery efficiency of 33% over a 5-10 year period for the initial system design [2]. The loss can be attributed mainly to mixing and groundwater flow (including tidal movement). It is expected that the new AgriMAR system has a recovery efficiency of 50% or more because of improved well design.



Figure 3: Drilling of the MAR well (left), installed well and infiltration reservoir (middle), construction of drain intake (right)

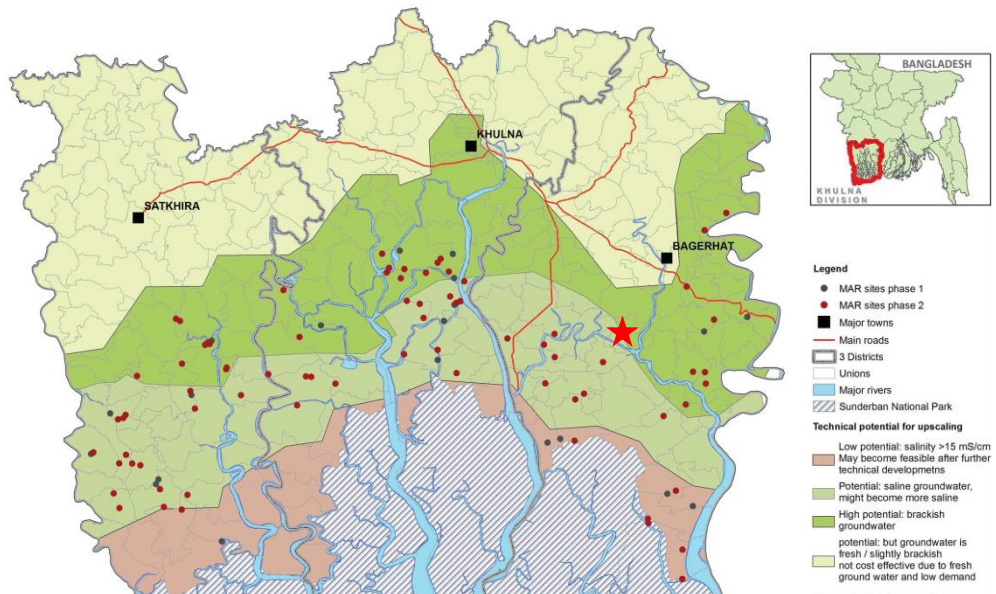


Figure 4: Potential for MAR in the coastal plain of Bangladesh, operational drinking water MAR systems (dots) and new agricultural MAR system (star)

Compared with MAR for drinking water, higher salinity levels are acceptable for irrigation water so that more of the infiltrated water can be used. The two infiltration wells have a combined infiltration capacity of 300 ft<sup>3</sup>/h (9 m<sup>3</sup>/h). Assuming conservatively that infiltration is operated for 8 hours per day and for 75 days per year a total volume of at least 190,000 ft<sup>3</sup> (5,400 m<sup>3</sup>) is infiltrated annually.

Results from water quality monitoring (2012-2014) of the first drinking water MAR systems show that the salinity decreased to acceptable limits at most sites, the iron concentration reduced significantly at all sites, the presence of arsenic reduced at most sites, and the microbiological quality of the groundwater was improved compared to pond water [2]. A comprehensive monitoring plan was set up for the AgriMAR pilot system and seven piezometers are in place to monitor groundwater quality around the AgriMAR well.



Figure 5: Construction of gabions (left), jute lining and filter gravel (middle), abstraction drain (right)

The AgriMAR system performs well regarding externalities: Energy requirements are low, freshwater for infiltration is abundant during the monsoon season so that there is no competition for it, and a positive groundwater balance is guaranteed by the fact that the aquifer is brackish – abstracting more water than previously infiltrated is not possible because the brackish groundwater cannot be used for irrigation. By providing a low-cost source for irrigation water throughout the year the AgriMAR system can greatly improve the climate resilience of farmers in the delta of Bangladesh, one of the most vulnerable regions regarding climate change impacts.

## Economic costs and benefits

Agriculture in the zone of brackish groundwater with good potential for MAR (light green and green areas in Fig. 1) is currently restricted to one harvest per year, due to limited freshwater availability. AgriMAR enables farmers to gain an extra harvest per year and to diversify their agricultural activity: Most farmers can grow one harvest of rainfed rice during the monsoon season while their fields lay fallow during the dry season. Using irrigation water from the AgriMAR system farmers get the opportunity to grow high value crops during the dry season, for example water melons, bitter gourd, or potatoes. The additional income has to cover the investment and operational costs of the AgriMAR system and farmers indicated that they are willing to spend 12-20% of their turnover on irrigation water [11].

Considering the investing capacity of the average Bangladeshi farmers, implementation of AgriMAR in the coastal area of Bangladesh requires a simple, low-cost design based on local materials and expertise. Crucial factors for successful implementation of AgriMAR with a positive rate of return include the crop type, farm gate prices, the plot size, the number of farmers potentially willing to collaborate in a cooperation and the interest rate. Based on the experience gained during the implementation of the pilot project it was estimated that one AgriMAR system could be constructed for as little as EUR 4,500 while annual operation and maintenance costs are around EUR 620 (assuming that an electrical pump is used). Considering local interest rates for a loan, a 10-year life span, and other factors business case analyses were carried out for the popular high-value crops water melons and bitter gourd [9].

The business case is positive for both bitter gourd and water melon (see Table 1). Currently, water melons seem to be the better choice because the expected yield is higher and the agricultural input costs are lower than that of bitter gourd. This results in a benefit-cost ratio of 1.97 for water melons and 1.13 for bitter gourd. The latter is projected to further increase since the demand for bitter gourd is growing exponentially as national demand is high and access to the export market in the Middle East is improving [9].

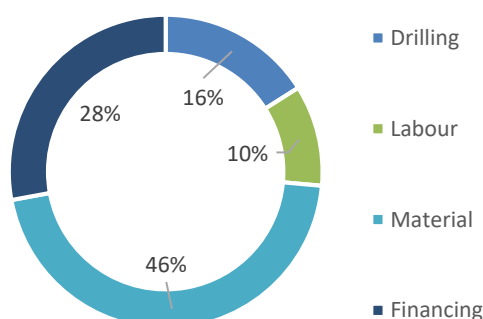




Figure 6: Distribution of fixed costs for constructing an AgriMAR system



Table 1: Cost-benefit analysis for an AgriMAR system for growing bitter gourd vs. water melon [9]

	Bitter gourd 	Water melon 
Infiltration volume (75 days/year, 8 h/d, 300 ft <sup>3</sup> /h (9 m <sup>3</sup> /h))	190,000 ft <sup>3</sup> (5,400 m <sup>3</sup> )	190,000 ft <sup>3</sup> (5,400 m <sup>3</sup> )
Recovery efficiency	50%	50%
Crop water demand	16.8 in/year (428 mm/year)	15.7 in/year (400 mm/year)
Irrigation efficiency	50%	50%
Average lifetime for AgriMAR systems	10 years	10 years
<b>Costs</b>		
Construction costs of AgriMAR system	€ 4,500	€ 4,500
Operation & maintenance costs	€ 620 /year	€ 620 /year
Financing costs (12% interest rate, 5 year repayment)	€ 1,740	€ 1,740
Costs of agricultural input & labor	€ 455 /year	€ 322 /year
Total annual costs (incl. discounted construction costs, O&M, financing)	€ 1,699 /year	€ 1,567 /year
<b>Benefits</b>		
Average yield	20 metric ton/ha	29 metric ton/ha
Average marketing price (farm gate)	€ 0.30 /kg	€ 0.32 /kg
Irrigated surface	0.32 ha	0.34 ha
Gross return	€ 1,920 /year	€ 3,094 /year
Net return (overall gain)	€ 221 /year	€ 1,527 /year
Benefit-cost ratio	1.13	1.97

It should be noted that the benefit-cost ratios are average values, based on average parameters for yield, market prices, and irrigation efficiency. Taking into account a broad range of plausible parameters results in benefit-cost ratios of 0.57 – 1.95 for bitter gourd and 0.57 – 4.39 for water melons.

Although the above business cases are promising, subsidized credit, strategic business collaborations and alternative ownership models remain key to implementation. The farmers generally do not have the capital at hand to invest themselves in AgriMAR systems and – as elsewhere in the world – it is almost impossible for them to get a loan because smallholder agriculture comes with a high risk which credit providers are not willing to take at a reasonable interest rate. To take AgriMAR a step further the business case is being discussed with private sector affiliated to agriculture, such as seed companies, the Ministry of Agriculture, and farmer associations. Investing with loans from international development banks, national banks or microfinance schemes could all be an option. In the meantime a crucial action to take is investing in raising awareness among the farmers to the possibility of fresh irrigation water in the coastal area of Bangladesh. By establishing an AgriMAR pilot site near Bagerhat this project is taking a first step in this direction.

## Social sustainability

During the operation of the drinking water MAR systems in Bangladesh it was learned that a clear communication and involvement of the local community from the start of the project is pivotal for the full acceptance of MAR systems as a safe water source.

Proposed ownership models for AgriMAR systems are: farmer cooperation, NGO-supported schemes, or a private ownership, as is the case with the pilot system. All forms of ownership have their strengths and weaknesses, and it depends on the stakeholder dynamics of each specific site which ownership model is most appropriate. The farmer cooperation is desirable because active involvement and ownership of a cooperation of farmers leads to full support for operation and maintenance. But there is also a risk of corruption within the governance structure of the cooperation. A NGO owning the AgriMAR system or advising a farmer association can help to implement sound operation and financing schemes. Local involvement of the stakeholders is an important prerequisite for the successful involvement of a NGO. The strength of private ownership is full commitment as well as clear responsibility (self-reliance) and therefore no risk of a free-rider effect by less invested users. However, commercial interest of private entrepreneurship is a risk as well, since the system might be abandoned as soon as its sole user is not invested in its operation any longer – possibly due to short-term profit considerations [8].

It is recommended that future upscaling plans include the support of farmers in installing AgriMAR systems by providing loans or grants to finance the construction. It is advised that technical assistance and knowledge transfer between different AgriMAR users be facilitated by a suitable party within the governance scheme. Some guidance during the siting and constructing of the systems is recommended, especially during drilling and well construction. Special attention should be paid to proper sealing of the borehole, selection of the appropriate filter depth, and installation of a filter pack. Furthermore, testing of the target aquifer regarding arsenic concentration is important. It is good practice to carry out a pumping test prior to commencement of the operation to determine the aquifer properties and well performance. This will later help to evaluate the clogging rate of the infiltration well, so that clogging management plan can be developed.

With adequate ownership and community engagement, AgriMAR has the potential to sustainably improve the livelihoods of small- and medium-scale farmers in Bangladesh's coastal region by increasing yields and making irrigation schemes more climate resilient.

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