



Messages from the Ganges Basin Development Challenge: Unlocking the Production Potential of the Polders of the Coastal Zone of Bangladesh through Water Management Investment and Reform

May 2014



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Report overview

This report is a contribution to the synthesis work of the CGIAR Challenge Program on Water and Food Ganges Basin Development Challenge. It presents seven evidence-based messages about water resources and the production potential of the coastal zone of Bangladesh, and advocates for changes to resource-use technologies, resource management policies, institutional coordination and governance mechanisms.

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Executive Summary

The coastal polders of Bangladesh are characterized by extremes in terms of both challenges and opportunities. The polders are home to about 8 million people, where 85% of rural householders live under the national poverty line. The polders are subjected to flooding during the rainy season; drought and salinity during the dry season, and cyclones. In addition, the impacts of climate change, especially sea level rise, will be most severe in this region. Much of the *poverty* of the region has been *attributed to soil and water salinity and flooding*, which constrain agricultural and aquacultural productivity and cropping system intensification. The CGIAR Challenge Program on Water and Food (CPWF) Ganges Basin Development Challenge (GBDC) *research shows that this need not be the case!* This document draws on the GBDC research findings and discussions over the last decade and presents seven key evidence-based messages. The aims of the messages are to correct misperceptions about water resources^a and the production potential of the coastal zone, and to advocate for changes in resource-use technologies, resource management policies, institutional coordination and governance mechanisms. The seven messages are summarized below; their details with explanatory notes and supporting evidence are included in the main text.

Message 1

Water resources in the coastal zone have largely been misconceived as constraints to production and are therefore, under-utilized. In reality, they are rich and valuable resources, which can be used to support agricultural and aquacultural production and livelihood improvement of farming families and communities.

Message 2

With advances in crop and aquaculture technologies and existing water resources, there is tremendous potential to improve food security and livelihoods. This potential relies on the adoption of improved species, varieties, cropping system intensification (two to three crops per year) and diversification with high-value crops and aquaculture species in all polders and all salinity regimes across the coastal zone.

Message 3

To unlock the potential productivity improvement, it is of utmost importance to invest in water management infrastructure – but with a new paradigm with fundamental changes in thinking about the polders and their roles, and special emphasis on drainage:

- *Each polder must be considered as an integrated water management unit, with due attention given to the infrastructure inside the polder to enable intensified and diversified production systems.*
- *Improving drainage is the key intervention and the entry point for production systems intensification and diversification.*
- *Rural roads and other transport structures inside the polders must be considered an integral part of the water management infrastructure. They can effectively form the boundaries of sub-hydrological units, and also units of community water management.*

^a Water resources include all sources of water that are useful or potentially useful. This document, however, focuses on surface water.

Message 4

Maintenance of infrastructure is the Achilles heel of water management in the polders of the coastal zone. Deferred maintenance can be solved through a three-tier strategy:

- **Community level:** *Improving financial sustainability of the Water Management Organisations;*
 - **Local government level:** *Effective use of local government institutions' social safety-nets funds in maintenance of infrastructure;*
 - **Central government and donor level:** *Creating a Trust Fund.*
-

Message 5

A transparent and accountable water governance framework is needed for the polders, that

- *formalizes and enhances the role of local government institution representatives in all levels of water governance;*
 - *follows the integrated water resources management (IWRM) river-basin governance principles, giving due attention to interactions/inter-dependence across different scales and sectoral users.*
-

Message 6

For future agricultural and aquacultural production, it is vital to enhance trans-boundary cooperation on water to ensure adequate trans-boundary flow in the dry season to prevent further salinity intrusion, and to improve drainage systems for mitigating the aggravation of inundation due to sea level rise in the rainy season.

Message 7

Access to data and modern tools in planning, policy analysis, technology targeting and consensus building is needed. To enhance the effectiveness of data and tools:

- *Models and databases must have the ability to integrate both socioeconomic and biophysical data and have access to multidisciplinary, multiinstitutional datasets;*
 - *A Spatial Data Infrastructure should be in place.*
-

Realizing the tremendous opportunities to improve food security and livelihoods in the polders of the coastal zone would address key priorities for agricultural development for Bangladesh as articulated in the Country Investment Plan (2011) as part of the Food Availability component. Furthermore, given the pressure to increase production further to feed the growing population of Bangladesh, and the already high cropping intensity and productivity in other parts of Bangladesh, the coastal zone may well be the only region where very large gains can still be made to meet the needs of the future.

Introduction

The coastal zone of Bangladesh is characterized by extremes in terms of both challenges and opportunities. The zone is situated on the southwestern portion of the Ganges Delta, a vast and dense network of large rivers and smaller distributaries (channels or *khals*) crisscrossing the landscape ^[1]. The coastal zone broadly comprises that region adjacent to the coast and extending inland in which the rivers are tidal throughout the year, although its inland boundaries are actually defined by administrative boundaries. The water level fluctuation between low and high tide is commonly 2-3 m, and sea water moves further inland during the dry season, progressively increasing river salinity until the river flows start to increase with the onset upstream of the monsoon rains. Prior to protection of the lands through the construction of embankments, much of the coastal zone experienced tidal flooding twice a day. Most of the coastal zone was a marshy wetland, in contrast to the fertile floodplains of the rest of the land that is now Bangladesh. The region suffers from cyclones roughly once every 3 to 4 years, which also cause storm surges with water levels typically rising up to about 3 m, but which can be catastrophic, with extremes up to about 9 m.

Human interventions to make the coastal lands more productive began many centuries ago with the localized construction of small earthen embankments to protect the land from saline water intrusion and flooding ^[1]. However, these embankments were often destroyed during the monsoon season. Gaps in the embankments were opened at low tide to enable partial drainage of the land behind them when needed. The embankments enabled the production of a low yielding (*aman*) rice crop during the rainy season, but there was hardly any production of winter (*rabi*) crops or early rainy season rice (*aus*).

Large-scale coordinated development of well-engineered embankments and the creation of polders in the coastal zone only began in the 1960s with the implementation of the Coastal Embankment Project (CEP), driven by the need for land and food for the increasing population. The polders were designed to increase agricultural production by protecting the lands from inundation due to high tides and river flooding, but they also provide protection against typical storm surges. Polders, ranging in size from a few thousand to about fifty thousand hectares were constructed throughout most of the coastal zone, with foreign aid assistance. Sluice gates were installed in the embankments, with most gates connecting some of the larger natural channels within each polder to the surrounding rivers. This provided the ability to drain water from or bring water into the polders as needed, and additional smaller inlet structures



The polders (delineated in black) of the coastal zone of south-west and south-central Bangladesh.



Sluice gate in a polder embankment letting water into the khal for irrigation

Farmer selling shrimp at the local fish depot

(‘flushing’ pipes) were also installed. The CEP was a successful project that established standards and criteria based on the then available knowledge of river, estuarine and coastal processes. The immediate socioeconomic consequences were spectacular and positive. Transport infrastructure was dramatically improved, integrating new roads with navigation facilities, which enabled products to be marketed over long distances. The yield of *aman* rice increased, and its production was much more secure. The polders also enabled the production of crops during the dry season, typically a low input and low yielding legume. Overall, a backward area was transformed for the better, and incomes and living standards improved. In 2008, the polders supported a total population of 8 million people ^[2] living on the 1.2 million hectares of land within 139 polders across the coastal zone.

However, there were also some unintended consequences of the development of the polders. The very act of preventing the high tides from spreading over the land and confining them within the river channels caused sedimentation in the rivers, which was exacerbated in the southwest by reduced river flows from India and by the development of the Ganges-Kobadak Irrigation Scheme in Bangladesh. While sedimentation of the rivers resulted in severe waterlogging problems outside the polder zone, it also led to waterlogging problems within the polders due to the raised elevation of the river beds, which restricted or even prevented drainage. In some locations, the bottoms of the riverbeds adjacent to the polders are now above the land surface inside the polders. Added to this, the polder infrastructure deteriorated due to inadequate maintenance and refurbishment due to inflexible and inefficient funding for operation and maintenance. Sluice gates became damaged or even disappeared, and embankments were occasionally breached as a result of high river flows and cyclones. Inside the polders, the *khals* silted up, diminishing the ability to drain during the rainy season, and to store fresh water for use when the rivers are too saline during the dry season. Because of lack of maintenance and dysfunctional operation, polder function deteriorated to the degree that protection of life, property, and crops was no longer adequate; economic production was less than it might be; and the environment deteriorated. In the meantime, the rest of the country was experiencing the benefits of the ‘Green Revolution’ through the adoption of improved rice varieties, increased input use (especially fertilizer) and the development of irrigation (predominantly from groundwater). This enabled large-scale expansion of high-yielding irrigated *boro* (dry season rice) production; replacement of late maturing traditional tall *aman* varieties with shorter duration high-yielding varieties; and cropping system intensification elsewhere in the country, but not in the polders.

To address the problems of polder deterioration and waterlogging, many investigation and development projects were implemented over the years, with the overall objectives of achieving substantial and sustained reduction in the risk of loss of life and damage to property; effecting equitable improvements from agriculture, fisheries and related activities; and ensuring sustainable restoration of and improvements to the environment. The more recent of these projects include: the ‘System Rehabilitation Project’; the ‘Char Development and Settlement Project’; the ‘Meghna Estuary Study (MES)’; the ‘Coastal Embankment Rehabilitation Project’^[3] (CERP II); the ‘Khulna Jessore Drainage Rehabilitation Project’; the ‘Integrated Planning for Sustainable Water Management (IPSWAM) Project’; the ‘Coastal Embankment Improvement Project’^[4,5] (CEIP); the ‘Small-scale Water Resources Development Sector Project’; and ‘Blue Gold’^[6]. A number of new ideas and approaches were developed under these projects for solving the problems of the coastal zone, in terms of engineering works and in terms of water management and governance requirements. The management of the infrastructure (operation and maintenance) of the polders was initially led by the central government through implementing agencies and field level staff. However, following devolution in the 1990s the responsibility was steadily transferred to the communities. This resulted in the formulation of the Bangladesh National Water Policy^[7] in 1999, which was operationalized in 2001 with the Guidelines for Participatory Water Management^[8]. These guidelines clearly establish that communities are the main stakeholders of water management and that Water Management Organizations (WMOs) have to be formed to lead the operations. These organizations are also responsible for routine and minor maintenance of the water infrastructure, whereas implementing agencies are supposed to support major maintenance requirements.

Yet, despite the huge investment in the coastal zone to date, the poverty of farming families in the polders remains extreme. For example, about 80% of rural households in the polders of the south-west and south-central coastal zone exist on less than the national poverty line (US\$1.25/person/day) compared with the Bangladesh national average of 40%^[9]. More than 50% of rural households are functionally landless, with less than 0.2 ha per household^[9]. Much of the poverty has been attributed to soil and water salinity, and to flooding as a result of rainfall and drainage congestion, that constrain agricultural and aquacultural productivity and cropping system intensification. Only 25% of the cropped land area is irrigated compared with the national average of 68%^[2].



Polder embankment protecting the lands inside the polder (right) from flooding by the river at high tide (left).



Farmers at Bazar Khali in polder 43/2F.

The CGIAR Challenge Program on Water and Food (CPWF) Ganges Basin Development Challenge (GBDC)^b [10] research shows that with existing advances [11] in crop and aquaculture technologies and available water resources [12], there are tremendous opportunities [13] to improve food security and livelihoods in the coastal zone. Furthermore, given the pressure to increase production further to meet the needs of the growing population of Bangladesh, and the already high cropping intensity and production in other parts of the country, the coastal zone may well be the only region where significant gains can still be made. This opportunity for the polders is also an opportunity and priority for Bangladesh.

The Ganges Basin Development Challenge (GBDC) findings have been disseminated and discussed in various platforms, ranging from on-site discussions with farmers and local stakeholders [11, 14, 15] to presentations to partner institutions and donors [16]. Policy briefs and dialogues have also been initiated with policymakers and donors at national [17] and local levels [15].

This document draws on the GBDC research findings and learnings from discussions with stakeholders, and presents the evidence-based key messages from the multidisciplinary research program. The primary target audience of these messages includes senior policymakers, planners, leaders of implementation agencies, leaders of local government institutions and donors. The aims of the messages are to provide new information and influence investment priorities for the polders of the coastal zone, through: (a) correcting misperceptions about the production potential of the coastal zone; and (b) advocating for the changes in resource use technologies, resource management policies, institutional coordination and governance mechanisms needed to realize the production potential of the polders.

The document also presents explanatory notes, evidence from GBDC research findings and other references to substantiate the key messages.

^b The CPWF Ganges Basin Development Challenge (GBDC) is a research for development program seeking “to increase the resilience of agriculture and aquaculture systems in the coastal areas of the Ganges Delta.” Its partners include international institutes, Bangladesh institutes, universities, NGOs etc.

Message 1:

Water resources in the coastal zone are rich, but under utilized

Water resources in the coastal zone have largely been misconceived and under-utilized. In reality, they are a rich and valuable resource to support agricultural and aquacultural production and livelihood improvement of farming families and communities.

Explanatory notes and evidence:

- Due to salinity intrusion during the dry season, water resources in the coastal zone have been described as a constraint to agricultural production. The CPWF - GBDC findings have identified the richness of the water resources and their huge potential to support agri- and aqua-cultural production across all salinity regimes of the coastal zone
 - In low salinity areas^c such as much of Barisal Division, there is adequate fresh water in the rivers for irrigation throughout the dry season. This would be true even in the climate change (CC) scenario with a 22 cm mean sea level rise (SLR) and a moderate precipitation change^[12]. Case in point: it has been demonstrated that rain and surface water can be managed to grow three high-yielding rice crops in a year, or two high-yielding rice and one high-yielding and/or high-value winter (*rabi*) crop in polder 43/2F in Barisal^[11].
 - In moderately saline areas^d, such as parts of Khulna Division, there is fresh river water from mid-June to mid-February. During part of the dry season, river water could be brought into these polders from locations where the water is still fresh for: (a) distribution, via the internal canal networks, to other parts of the polders where the adjacent river water is already too saline; or (b) storage in the internal canal networks by filling them with river water before it becomes too saline (> 2 mg/L or ~ 4 dS/m) for irrigation of *boro* rice or *rabi* crops once the water in the rivers becomes too saline^[11, 18, 19]. For example, detailed investigations in polder 30 suggest that storage of freshwater in the internal canal networks could meet the irrigation demand of 1,200 ha (20% of the polder) of *boro* rice in Polder 30^[12], and that this area could be doubled if the canals were dredged^[18]. (Of course, how the benefits of this water might be shared equitably is a governance issue)^[12].
In the above areas, the soil may become saline if left fallow during the dry season. Irrigation with fresh water to grow a dry season crop not only increases farmers' income but also helps leach salinity from the soil profile^[19].
 - In much of Khulna Division, brackish water is often perceived merely as a constraint to agricultural production. In reality, it should be considered as a resource that can be effectively managed for aquaculture without jeopardizing *aman* rice production^[11, 20]. The need for brackish water resources is evidenced by the large number of unauthorized pipes/structures that farmers install for supplying brackish water for shrimp culture^[21].
- Large tidal fluctuations (amplitude up to 2-3 m) in the rivers of the coastal zone^[12] offer huge potential for low-cost water management in the forms of: (a) gravity drainage throughout the *aman* (*kharif*2) season; and (b) gravity irrigation during the *kharif*1 season or aus rice establishment, as well as during dry spells during the *aman* crop.
- There are indications that there is plenty of untapped good-quality (low salinity and other chemical content) groundwater in some locations that can be used for agricultural production^[22]. For example, farmers are using shallow tubewells for irrigation of dry season crops in Polder 30 and Tala Upazilla, Khulna District^[23], and in the coastal zone of West Bengal, India^[11]. However, the use of groundwater has to be exercised with prudence to avoid salinization of aquifers^[11]. There is a need for a groundwater resource assessment to determine sustainable levels of extraction across the coastal zone.



Fishing in a rice-fish system in a low salinity region

Aman rice (high yielding variety, HYV) in polder 30.



Message 2: There is huge potential for greatly increasing productivity through cropping system intensification and diversification

With advances in crop and aquaculture technologies and available water resources, there is tremendous potential to improve food security and livelihoods via the adoption of improved species, varieties, cropping system intensification and diversification on all lands exposed to all salinity regimes across the coastal zone.

- *Three crops/year in low salinity areas, (e.g., much of Barisal Division)*
- *Two to three crops/year in moderately saline areas, (e.g., parts of Khulna District)*
- *Shrimp-rice system or year round poly-aquaculture in high salinity areas, (e.g., Southern Khulna/Satkhira districts)*

Explanatory notes and evidence:

- Many well-tested, short-duration, stress-tolerant rice varieties (preferred by many farmers) are now available ^[11], (e.g., BRRI dhan54 for stagnant flooding; BRRI dhan52 for flash flood submergence; BINA dhan8 and BRRI dhan47 for salt-affected areas).
- New aquaculture species that can be raised separately or together with shrimp enable more productive and less risky year round polyculture ^[11].



Crop diversification can greatly improve food security and livelihoods.

Above: Farmers with sunflower oil and watermelon. Right hand page: A field of sunflowers



- New species, new varieties, timely crop establishment and improved crop, nutrient and water management have enabled high productivity in areas/seasons where this was not previously possible. Hence, the increase in cropping system intensity, diversification and productivity of the coastal lands. The GBDC and other projects have successfully validated the following:
 - Three crops of rice (yielding ~ 16 t ha⁻¹ rice) or two crops of rice (10 t ha⁻¹) and one *rabi* crop (8 t ha⁻¹ maize or 3 t ha⁻¹ sunflower) for low-salinity zones, (e.g., Polder 43/2F, Barguna District) ^[11]. These outputs are substantially higher than those from the predominant present land use of one *aman* rice crop with traditional varieties (< 3 t ha⁻¹) - sometimes (~30% of land area) followed by grass pea (0.5-0.75 t ha⁻¹), and sometimes preceded by one transplanted aus rice on about 50% of land area (~ 3 t ha⁻¹) ^[24].
 - *Aus – aman* rice (8 t ha⁻¹), *aman – boro* rice (10 t ha⁻¹) or *aman – high-yielding and high-value rabi* for medium-salinity zones, (e.g., Polder 30, Khulna District) ^[19, 25, 11]. At present, the predominant cropping practice is traditional *aman* rice (< 3 t ha⁻¹), followed by sesame in the early *kharif* season (on about 80% of land area), which is often damaged and sometimes completely destroyed by early rainfall in March – April and by cyclonic events in May.
 - Aquaculture – rice system in high-salinity areas with brackish water shrimp and fish in the dry season and rice and fresh water fish and prawn in the wet season, for the high-salinity zones, (e.g., Polder 3, Satkhira District) ^[23, 11] .
 - Aquaculture system with brackish water shrimp and fish in the dry season and fish polyculture in the rainy season for high-salinity zones, (e.g., Polder 3, Satkhira District) ^[11].
- Spatial analyses and land use assessments have identified large areas of land which may be suitable for various innovative production systems ^[13].

^c High-salinity = River water salinity > 2 mg/L for more than 5 months per year.

Message 3: It is of utmost importance to invest in water management infrastructure – but with a new paradigm and special emphasis on drainage

Achieving large-scale adoption of innovative production systems and unlocking the potential of the water resources require proper investment in water management infrastructure. This should be guided by a new paradigm, with fundamental changes in thinking about the polders and their roles.

3a. Each polder must be considered as an integrated water management unit, with due attention given to infrastructure inside the polder to enable intensified and diversified production systems

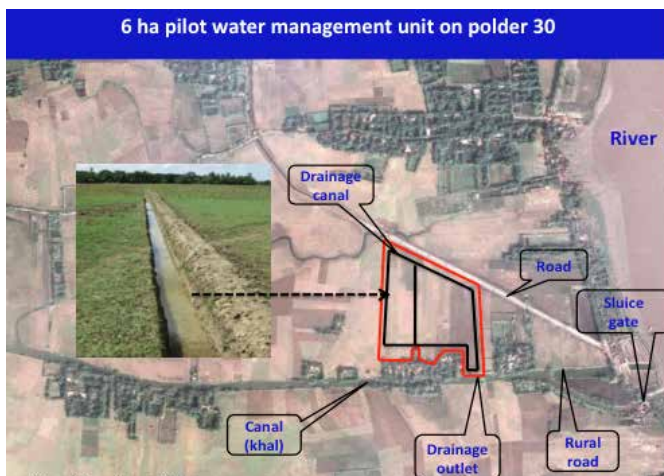
Explanatory notes and evidence:

- Most of the polders were built during the 1960s and 1970s. Their original primary function was the prevention of tidal flooding and salinity intrusion. Their agricultural support role was to enable and protect the traditional *aman* rice crop, using the traditional low-yielding, tall-statured, long-duration and photoperiod-sensitive varieties.
- To realize the opportunities from improved crop technologies and innovative production systems, the roles of the polders *must change and include 'enabling intensified and diversified production systems'*. New cropping systems, new crops, new varieties and species will require specific water conditions. As the optimal production systems may change from one location to another, across and within polders, polder design and water resource management must be polder- and production system-specific. To achieve their new role of enabling cropping system intensification and diversification, the polders must include the following functions, singly or in combination:
 - Timely and adequate intake of fresh water for irrigation of dry season (*aus, boro* rice and *rabi*) crops ^[19, 26,11]
 - Storage of fresh water for irrigation of dry season crops when surrounding rivers become saline ^[18].
 - Intake of brackish water for dry season aquaculture ^[11]. This contradicts completely the original role of 'salinity intrusion control'.
 - Conveyance and distribution of fresh/brackish water to the fields.
 - Drainage during and at the end of the rainy season, as elaborated in section 3b below.
- To many engineers (in charge of designing and building polders), a polder comprises the embankment surrounding the land protected by the embankment, and the peripheral sluice gates connecting the internal canal network with the surrounding rivers. This definition is grossly inadequate. To fulfill the additional functions described above, *each polder must be considered as an integrated water management unit, with due attention given to the existing infrastructure inside the polder. Investment in polders must include investment in internal water management infrastructure, especially secondary, tertiary and field canals for irrigation as well as for drainage.*

3b. Improving drainage is the key intervention and the entry point for cropping intensification and diversification

Explanatory notes and evidence:

- In the original design, the polders enabled the cultivation of traditional *aman* rice, which could withstand an inundation depth up to 80 cm. Drainage was not a critical issue.
- For cropping system intensification and diversification, improved drainage is critical:
 - Improved drainage reduces prolonged deep inundation, enabling farmers to achieve timely establishment,



Above left: Local government and village roads bind three sides of this six hectare water management unit.

Above: Waterlogging in a low lying area with impeded drainage in polder 30 - water too deep for rice.

Left: Water draining out of a polder through a sluice gate

good fertilizer management, and grow high- yielding, short-duration aus and *aman* rice in the rainy season ^[26, 11].

- Drainage at the end of *aman* rice hastens soil drying, and facilitates land preparation and timely establishment of *rabi* crops, meaning that higher yielding and/or higher value *rabi* crops can be introduced. It also increases yield and yield stability of *rabi* crops by preventing waterlogging caused by unwanted early season rains (in March and April) ^[25].
- Drainage is critical for water depth and water quality management in shrimp ghers. In the shrimp rice system, intensive drainage at the end of the shrimp phase prior to establishment of the *aman* crop allows adequate leaching of salt prior to transplanting the *aman* crop; and the ability to drain is also needed during the *aman* crop to prevent prolonged deep inundation ^[11].
- Internal drainage canals can be used to store freshwater for irrigation of *boro* rice, *rabi* crops or *aman* rice during dry spells.

3c. Rural transport structures must be considered as an integral part of the water management infrastructure. They can effectively form the boundaries of sub-hydrological units, and also units of community water management

Explanatory notes and evidence:

- Rural transport structures such as roads, bridges and culverts can strongly influence water flow and distribution. They are often not under the jurisdiction of water sector organizations and there is little coordination among different ministries/organizations. In many cases, due to poor design (as a result of not taking drainage into account) and inadequate capacity of cross-drainage structures, internal roads obstruct the flow of water and exacerbate waterlogging problems ^[12].

- If properly planned/designed and considered as an integral part of the water management system, the rural structures can help reduce many conflicts in water management that are related to high/low land elevation, and to divergent demands for opening/closing the sluice gates for different land uses. The rural road network lends itself well to defining sub-hydrological units (mini-water sheds), each having its coherent hydrology, with commonality of interest among the land and water users, and where the community can implement enhanced water governance and management, enabling implementation of improved production systems. Without uniform and common community water management at a mini-watershed level, individual farmers cannot practise improved production systems^[25,11]. Examples of such sub-hydrological units are:
 - Farmers in waterlogged areas in polder 30 proposed an embankment to separate their low lying zone from higher surrounding lands^[27].
 - Creating sub-hydrological units (mini-watersheds) is a critical step in ‘cracking the productivity code’^[25].

Message 4: Maintenance of infrastructure is the Achilles heel of water management in the polders of the coastal zone.

Maintenance is often deferred due to lack of incentives and funds

- Polders or sub-polders differ in many aspects but they have one thing in common: poor or lack of maintenance, resulting in malfunctioning and deteriorating infrastructure and water management systems^[14,21].
- In principle, WMOs are responsible for infrastructure maintenance, but
 - they lack incentive (public goods dilemma, if communities don’t fix it in time, the government or a donor will come with a new project in a few years);
 - their current financial positions are very poor, even so-called minor repairs and maintenance may be beyond the capacity of the community^[14]. Though, in theory, these are not beyond the capacity of a functioning WMO.

However, deferred maintenance can be solved through a three-tier strategy.

4a. Community level: Improving financial sustainability of the Water Management Organisations (WMOs) via increasing contributions from the community and sources of income

Explanatory notes and evidence:

At the community level, funding and incentives for maintenance can be increased via:^[28]:

- Increasing members’ contributions together. This can be helped by improved rules for the collection and expenditure of maintenance fees;
- Giving WMOs access to income generating assets such as lease of common land and water bodies or micro credit;
- Creating strong local institutions with ownership over the infrastructure from the start of the projects; and
- Creating homogenous WMO’s so that members have shared interest (see ‘sub-hydrological units’, message 3c).
- WMOs already have the right to raise funds and they are already declared as cooperatives, but further training and empowerment are needed to make their fund raising efficient.
- There are some good examples that suggest that if WMOs are well-managed, they are able to collect maintenance fees.

4b. Local government level (Union Parishad): Effective use of local government institutions' social safety-nets funds in maintenance of infrastructure

Explanatory notes and evidence:

- The Union Parishads' (UP) social safety nets funds (40 day work, KABIKHA) are already available and are at UP's disposal. They can use these for water management maintenance.
- This will also create more employment opportunities for the landless, and the poor of the community.
- Contributions from local government may encourage the community to contribute.
- Formalizing UP's involvement in the water governance framework will facilitate this process, see message 5a.

4c. Central government and donor: Creating a Trust Fund

Explanatory notes and evidence:

- Deferred maintenance often leads to the requirement of new projects and building of new infrastructure, which in turn will be neglected and deteriorate. Instead of investing in new projects, Government of Bangladesh and donors should create a Trust Fund to solve the problem of 'deferred maintenance' on a long-term basis.
- All polders would receive allocations for repair and maintenance every year from interest accrued by the Trust Fund.
- Proper use of the Trust Fund requires a clear polder water governance framework and coordination among different actors ^[28].



Poor maintenance and informal water intake pipes result in damaged embankments, roads and severe flooding.



Message 5: A transparent and accountable water governance framework is needed for the polders

The present institutional coordination is too fragmented and disjointed. There is a need for a transparent and accountable water governance framework for the polders that:

Sa. Formalizes and enhances the role of local government institution (LGI) representatives in all levels of water governance

Explanatory notes and evidence:

- Many institutions and actors (WMOs, UP, LGED, BWDB, different ministries, NGOs etc.,) are involved in water management, but there is no institution that is responsible for coordinating their actions ^[29].
- The Union Parishad (UP) Act allows UPs to work on water management ^[30], but the roles of UP in water governance have not been formalized. Qualitative and quantitative data have shown that the UP chairman, secretary and its members are de-facto decision makers but do not necessarily have a formal role, both for operation and management ^[14].
- The 'Guidelines for Participatory Water Management' ^[8] recognize the 'advising role' of LGIs. In reality, the line agencies often bypass LGIs, marginalizing their roles. We propose that the guidelines elevate the roles of LGIs to take the lead for coordination and play a central role in organizing the different actors in water management for several reasons as explained below:
 - LGIs, as institutions, are in a better position to give long-term perspectives than the project-dependent WMOs, which are registered as cooperatives and supposedly project-independent, yet they are often project-funded and collapse (or at least become dysfunctional) at the end of projects.
 - UPs and other LGIs are already involved in conflict resolution.
 - Community members have trust in UPs and other LGIs as elected bodies.
 - Having a formal and central role in water management coordination would encourage UPs and LGIs to use Social Safety Net Funds for water infrastructure maintenance (see 4b). Formalizing the role of LGIs in water management would also reduce the conflicts between LGIs and project-based WMOs ^[14], thereby encouraging the cooperation among the line agencies, LGIs and WMOs.
- Admittedly, if the LGIs are to take this new and important role, they will need much support from water management institutions and further training to enhance their capacity in coordinating participatory water management.

Sb. Follows the IWRM river-basin governance principles, giving due attention to interactions/inter-dependence across different scales and sectoral users

Explanatory notes and evidence:

- The roles of the different actors in water management are not clearly defined, leading to overlaps in operation of the water management infrastructure.
- Most projects have focused on water management at the community level; conflicts among communities and different users are widespread. There is no clear water governance framework in place to manage water resources and to deliver water services at different scales within the polders.
- From a management perspective, a polder can be compared to a river basin, having a well-defined hydrological boundary. Just as a river basin can be divided into subbasins and water management systems, a polder can

be divided into subunits at different scales, each with well-defined hydrological boundaries. We propose a three-tier governance framework, and that the principles of river-basin IWRM ^[32, 33] be used to guide the water governance of the polders.

Scale/ Hierarchy	Boundary	Members	Management/Coordination
1. Sub-hydrological (sHU) units ¹	Local rural roads/levees	Women and men living in, and landowner in the sHU	Committee Gate committee, Water Management Group (WMG) (reps. of women/men living/ farming in the sHU with coordination led by reps. of the Village/Union Parishad)
2. Sub-polder (SP)	Provincial/ district roads/ embankments	sHUs within the SP	SP WM Committee (reps. of WMGs with coordination led by reps. of the Union Parishad)
3. Polder	The peripheral embankment	SPs within the polder	Polder WM Committee (reps. of SP WM Committees with coordination led by reps. of the Union/Upazilla Parishad)

¹ See Message 3c



Aman rice growing in a gher used for brackish water shrimp in the dry season

Message 6. Enhancing trans-boundary (TB) cooperation on water to ensure adequate trans-boundary flow during the dry season and to mitigate climate change (CC) + sea level rise (SLR)-induced aggravation of inundation during rainy season are vital for future agriculture and aquaculture production

Explanatory notes and evidence:

- The change in trans-boundary (TB) flow in the last 40 years has shaped the dry season water availability in the southwest coastal zone of Bangladesh. The annual minimum flow in the Ganges monitored at Harding Bridge decreased from 1,920m³/s in 1974 to 730m³/s in 2013^[12]. Over the same period, salinity increased from 0.5 to 9.3 g L⁻¹^[12] in the Bhairab River (*Khulna*) of southwest coastal zone.
- Among the external drivers of change, TB flows and CC+SLR will have the strongest direct impacts on the future hydrology of the coastal zone in Bangladesh. Salinity intrusion in the dry season is more sensitive to TB flows than to SLR. Under the moderate scenario of SLR, the area that can be irrigated with suitable water quality (salinity < 2 g L⁻¹) is reduced by 3% compared with the present area. The same area is reduced by 7% if the TB flow equals the minimum trans-boundary flow under the Ganges Treaty^[12]. *Ensuring adequate TB flows during the dry season is more important than SLR adaptation for sustaining agriculture and aquaculture production in the dry season.*
- Because of uncertainties due to CC, SLR and TB flows, it is important to develop crop varieties with increased tolerance to salinity to facilitate cropping system intensification in the 'worst' case scenarios of low TB flows and high SLR.
- During the rainy season, the TB flow is not controlled and is the 'natural flow'. The major external drivers of change will be CC + SLR, and they will exacerbate drainage congestion in the coastal polders. For example, under the moderate scenario of CC + SLR, the area inundated with water depth 30 – 90 cm for 3 days in Polder 30 will increase from 20% (present) to 43% (in 2050)^[12]. Climate resilient crops and aquatic species and CC+SLR adaptive drainage systems are vital for intensification of agriculture productions.



From above clockwise:
Women store seed for the next rice crop;
empowerment of women to lead in
homestead aquaculture; school children in
polder 43/2; farmer standing on sluice gate,
the river behind him at high tide.



Message 7. Access to data and modern tools in planning, policy analysis, technology targeting and consensus building is needed

The effectiveness of planning, technology targeting, open dialogues and consensus building among multiple stakeholders can be increased by access to modeling and spatial analysis at different scales for scenario-based planning and target domain identification. To enhance their effectiveness:

7a. Models and databases must have the ability to integrate both socioeconomic and biophysical data and have access to multidisciplinary, multiinstitutional datasets

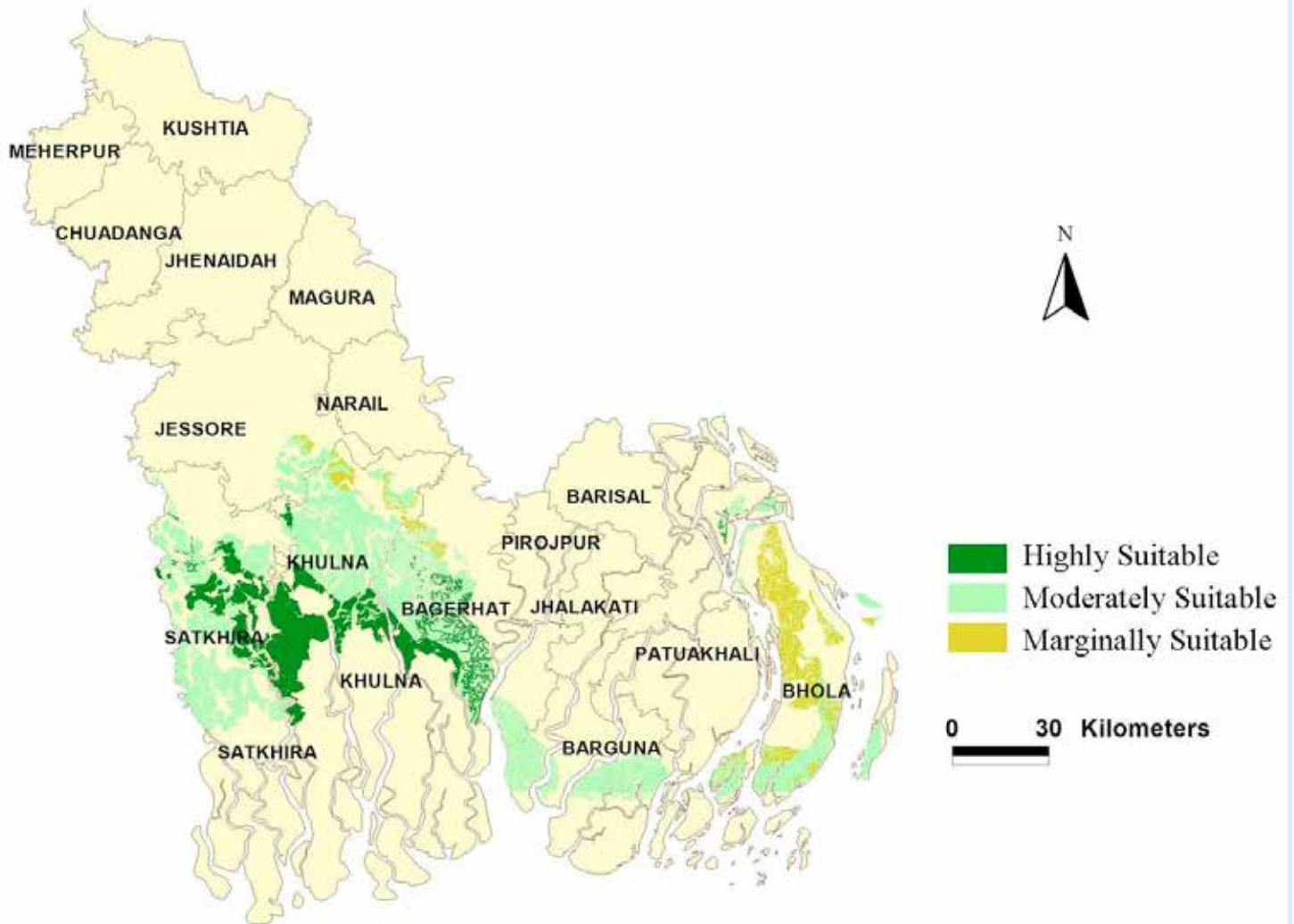
Explanatory notes and evidence:

- Models and tools used in the GBDC include:
 - Hydraulic models to quantify the environmental properties of the coastal zone under present and future scenarios of external drivers; and
 - GIS-based, spatial analysis for extrapolation domains and land use proposals.
- CPWF GBDC has demonstrated that no single partner has all the data needed for spatial analyses of extrapolation domain ^[13]. The models utilized significant amounts of secondary data provided by partner institutes (Bangladesh and International), notably BWDB, LGED, SRDI, IWM, IWMI and IRRI.
- This could not have happened without a transparent data sharing mechanism, based on mutual trust and understanding ^[33]. The role of IRRI – through CPWF-GBDC – as an independent agency with no national agenda has been to facilitate and lead this process. Continued progress towards more open access data would greatly benefit from the leadership of agency operating at the highest levels of government.
- In the longer term, accessibility to multidisciplinary, multiinstitutional datasets can only take place if there are effective and sustainable data-sharing mechanisms in place. Again, an open-access policy data developed by government agencies would facilitate this. The data could be provided through a data portal maintained by the above agency. Services that are developed based on this data could generate sustained revenue, but the underlying data should be open-access.

7b. A spatial data infrastructure (SDI) should be in place

Explanatory notes and evidence:

- Most of the data in Bangladesh have been generated by, and are products of projects. As projects end, the jurisdiction over the data becomes less clear. There has been no central data repository.
- Tracking down and accessing data is both costly and time consuming.
- The proposed SDI is a policy and infrastructure framework to:
 - Encourage Bangladeshi institutes/organizations to openly share GIS data;
 - Include a sustainable and transparent data sharing mechanism, based on mutual trust and understanding; and
 - Greatly enhance the ability of all concerned to respond to policymakers' needs.
- An example of a potential benefit of an SDI: All GBDC partners acknowledged they benefit from data sharing in GBDC. They all agreed that the development of a common repository with data in globally accepted formats and projections would facilitate accelerated use of data for research purposes ^[34].



Spatial data infrastructure can be used to identify regions most suitable for shrimp-rice systems in the coastal zone.



It's mid-February on polder 30, and most of the land is still fallow; women collecting last year's rice straw for fuel, ploughing for sesame beginning

Conclusion

The seven messages can be summarized in the following take-home message:

The adoption of improved species/varieties, together with cropping system intensification and diversification across the polders of the coastal zone, offers the potential to make a quantum leap in meeting future food security requirements. Unlocking this potential requires effective investment in water management, but with fundamental changes in thinking about the roles of the polders and their water management infrastructure, and major reforms in institutional coordination and water governance mechanisms. More emphasis should be given to drainage, integration of the internal rural transport infrastructure into the water management system, and treating the whole polder as an integrated water management unit with due attention to interactions and coordination across different scales and sectoral users. Looking to the near future, it is vital to ensure adequate trans-boundary flow in the dry season and to implement measures to provide resilience against the CC- and SLR-induced increased inundation in the rainy season. To realize the seven messages requires scenario-based planning, technology targeting, policy change, open dialogues and consensus building among multiple stakeholders. Investment in a spatial data infrastructure (SDI), together with modern planning tools, will greatly increase the effectiveness of these activities

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The following GBDC partners contributed to the research underpinning these messages:

- Bangladesh Agriculture University (BAU)
- Bangladesh Fisheries Research Institute (BFRI)
- BRAC
- Bangladesh Rice Research Institute (BRRI)
- Bangladesh University of Engineering and Technology--Institute of Water and Flood Management (BUET)
- Bangladesh Water Development Board (BWDB)
- Indian Council of Agricultural Research--Central Institute for Brackish-Water Aquaculture--Kakdwip Research Centre (ICAR-CIBA)
- Indian Council of Agricultural Research--Central Soil Salinity Research Institute--Regional Research Station Canning Town (ICAR-CSSRI)
- Institute of Water Modelling (IWM)
- International Center for Living Aquatic Resources (WorldFish)
- International Rice Research Institute (IRRI)
- International Water Management Institute (IWMI)
- Jahangir Alam, Bangabandu Sheikh Mujibar Rahman Agricultural University
- Local Government Engineering Department (LGED)
- Patuakhali Science and Technology University (PSTU)
- Shushilan
- SocioConsult Ltd
- Soil Resource Development Institute (SRDI)



Above: Shrimp ghers during the dry season in polder 3

Front cover photo: A typical scene in the rainy season - farmers transplanting old seedlings of traditional rice varieties, with water level above their knees

About CPWF

The CGIAR Challenge Program on Water and Food (CPWF) was a comprehensive, global research program that ran from 2002 to 2013. CPWF's goal was to increase the resilience of social and ecological systems through better water management for food production (crops, fisheries and livestock). In order to do so, the program carried out an innovative research and development approach that brought together a broad range of scientists, development specialists, policy makers and communities, in six river basins, to address the challenges of food security, poverty and water scarcity.

CPWF was integrated into the CGIAR Research Program on Water, Land and Ecosystems (WLE). WLE combines the resources of 11 CGIAR centers and numerous international, regional and national partners to provide a cohesive approach to natural resource management research. The program goal is to reduce poverty and improve food security through the development of agriculture within nature. This program is led by the International Water Management Institute (IWMI).

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