Assessing the Role and Capacity of Water Management Organisations for Ensuring Delta Food Security in Bangladesh

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Abstract

The coastal zone, encompassing one-third of the country's area, is the most climate-vulnerable region of Bangladesh. Over the years, Bangladesh has made substantial investments in the coastal zone by constructing and rehabilitating 139 polders, enclosing approximately 1.2 million hectares of land. However, despite the vast opportunities it presents, the land productivity within these polders remains disappointingly low due to many factors, notably poor water governance and management practices. To improve in-polder water management, the responsibility of operation and maintenance of the polder water infrastructure has been transferred to Water Management Organisations (WMOs) since 2001. Currently, these WMOs operate voluntarily and play an important role in field-level agricultural water management. This study was conducted in 2017–2018 in a medium saline polder (polder 30) to assess the behaviour of WMOs and document their willingness and capability to assume water governance and water management responsibilities in the coastal polder zone. The study examined organisational culture and legitimacy, the hierarchy in decision-making, leadership in infrastructure and conflict management, and communication and coordination skills to effectively operate WMOs. The research methodology involved collecting data through a structured questionnaire from 192 respondents selected from eight randomly selected Water Management Groups (WMGs – the lowest tier of WMOs) out of a total of 40 WMGs in polder 30. Additionally, 18 representatives from key institutions, including the Bangladesh Water Development Board (BWDB), Local Government Institutions (LGI), and WMOs, were chosen randomly for Key Informant Interviews (KIIs).

The findings of this study highlight that WMGs were not fully adhering to participatory principles in their operations. Transparency, financial accountability, leadership qualities, as well as communication and coordination capacities within WMGs were identified as areas needing improvement. These limitations raise concerns about the ability of WMGs to effectively address future challenges in ensuring food security for the climate-vulnerable communities residing in the polders of Bangladesh. The results from one of the component experiments of this study aiming to link water management with agricultural production highlighted that improving drainage through efficient water management could lead to a substantial increase in rice yields, with a gain of at least 1.5 tonnes per hectare during the wet season. Furthermore, this enhanced drainage system would support year-round cropping, promoting high-yielding, high-value, and nutrition-rich crops with two to three times higher productivity than traditional cropping systems.

Investing in water governance, specifically focusing on enhancing the capacity of WMOs and improving drainage infrastructure within the polders, holds the potential to bring about significant positive changes in ensuring the food security of the climate-vulnerable communities in Bangladesh's coastal polders.

Keywords: Water Governance, Participatory water management, Drainage, Rice yield, Tidal rivers

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1. Introduction

Participatory water management for agriculture is a widespread practice across many countries, where local communities and stakeholders actively engage in decision-making, planning, implementation, and monitoring of water management practices (Jaspers, 2003). This approach is particularly vital for enhancing productivity and improving the livelihoods of coastal polder communities, especially in deltaic countries like Bangladesh. The concept of "polderisation" originated in the Nordic countries and the Netherlands (Pranzini et al., 2015).

Polders are low-lying tracts of land enclosed by earthen embankments along the perimeters of islands formed amidst the intricate network of rivers in coastal deltaic regions of Bangladesh (Mondal et al., 2015a). These embankments are equipped with regulators or sluice gates that facilitate drainage and water intake into the polder for agricultural development. By effectively controlling water levels through these sluice gates, polders create arable land, prevent soil salinisation, and safeguard crops from excess water during rainy seasons. This delicate management of water and agriculture significantly contributes to food security and the well-being of vulnerable communities (Morton and Oslon, 2018). The hydrological characteristics of coastal polders in Bangladesh differ considerably from other regions of the country. Managing the substantial inflow of river water into the polder ecosystem through sluice gates is a complex task beyond the capabilities of an individual. Inadequate management of polder infrastructure, including canal networks within the polder ecosystems, has led to unfavourable water environments for adopting improved agricultural production systems year-round. Canal siltation, canal obstruction due to fishing activities, and drainage issues during the monsoon season result in waterlogging, necessitating community coordination and effective participatory water management.

The Bangladesh Water Development Board (BWDB) plays a pivotal role in water resource development, constructing 139 polders encompassing 1.2 million hectares of land during the 1960s and 1970s. These polders aimed to protect coastal lands from tidal flooding and salinity intrusion, while improving the livelihoods of coastal zone communities (Dewan, 2012a). Initially, BWDB staff operated the sluice gates for in-polder water management, but the absence of community involvement in infrastructure maintenance led to the gradual deterioration of water management facilities (Dewan et al., 2014). Consequently, various non-governmental organisations and development agencies advocated participatory water management (Dewan, 2012b). Using the National Water Policy (MoWR, 1999) and the Guidelines for Participatory Water Management (MoWR, 2001), the BWDB formally began establishing water management organisations (WMOs) to transfer the responsibility for sluice gate operation and maintenance to these organisations (Dewan et al., 2014). The BWDB, through various initiatives, formed formal and informal WMOs (including Water Management Groups – WMGs, Water Management Associations – WMAs, Gate Committees, etc.) with different organisational structures. In most cases, the role of the Union Parishad (UP), the lowest tier of the administrative unit, was not recognised other than the advisory role in sluice gate operation. Generally, the project-based WMOs do not focus much on in-polder water management, which is critical for the adoption of year-round cropping in the polder zone (Dewan et al., 2014; Dewan et al., 2015; Mondal et al., 2015b; Yadav et al., 2020). In post-project interventions, WMOs often became inactive, with UP representatives taking over sluice gate operation (WLE, 2014). Multiple actors with conflicting roles in water management further exacerbated the poor operation and maintenance of coastal polders (Naz and Buisson, 2015). The Blue Gold Development Program of BWDB, launched in March 2013, aimed to standardise the organisational structure and roles of WMGs and WMAs as per the Guidelines for Participatory Water Management (GPWM) and Water Act (Dewan et al., 2014).

Farmers in polders predominantly cultivate local rice varieties during the *aman* (wet) season, yielding lower output (1–3 t/ha) compared to the national average of 3.2 t/ha (BBS, 2020). Waterlogging during the monsoon and inadequate drainage delay dry season cultivation, leaving crops vulnerable to damage from pre-monsoon rains and cyclonic storms (Mondal et al., 2015c). Although improved agricultural technologies are available, the polders in the coastal zone have yet to benefit from these advancements. Adoption of High Yielding Varieties

(HYV) of rice in the *aman* season significantly impacts sustainable cropping in the following rabi season (Mondal et al., 2015c; Yared et al., 2021). However, growing HYV rice in *aman* season by individuals is impractical due to the management of large amounts of water entering through sluice gates. Community coordination on a hydrological area-level adoption is required for managing water in such an agro-environment. Empowering WMOs in polder water management and governance is essential to address these challenges and facilitate improved in-polder water management.

Many studies have examined the productivity gains associated with improved water management involving farmers and WMOs (Mondal et al., 2015a; Mondal et al., 2022; Yadav et al., 2020). This paper aims to review the structure, roles, responsibilities, and competencies of WMOs and assesses their capacity and willingness to undertake voluntary water governance and management responsibilities to tackle food security challenges in the 21st century.

2. Materials and Methods

2.1 Study Site

The study was conducted in Polder 30, located in the southwest coastal zone of Bangladesh. The area falls under the agro-ecological zone 13 (AEZ 13) of the Ganges tidal floodplain and lies between latitude 22˚37'59'' and 22˚46'05'' N, and longitude 89˚27'55'' and 89˚31'57'' E (Fig.1). The polder covers an area of 6,455 ha, with a 66% net cultivable area (CEGIS, 2015) and is protected from high tides by an embankment which is about 40 km long, 4.3 m wide at the crest, and 5–7 m high. The peripheral rivers are tidal, with water levels varying by about 3–4 m between low and high tides (Khan et al., 2015). Five rivers flow along the periphery of the polder, of which two are major rivers (Kazibacha and Lower Salta) that flow along the east and west sides of the polder. The polder has 11 sluice gates used for water intake and drainage and 10 flushing gates used only for overland water intake (CEGIS, 2015). There are 53 canals of various lengths (1–7 km), and the total length of the canal networks is about 107 km (Mondal et al., 2010).

2.2. Water Governance and organisational competencies

Water governance encompasses a broad spectrum of elements, including political, social, economic, and administrative systems, which directly or indirectly influence the use, development, and overall management of water resources (Dewan, 2012b). To gain a comprehensive understanding of water governance, it is imperative to understand the organisational theory of WMOs. It encompasses two pivotal facets: organisational structure and behavioural competencies (Fujita 2011). Organisational structure primarily addresses the division of labour and coordination mechanisms, while behavioural competencies highlight the actions and conduct of employees, both as individuals and as part of groups. Organisational behaviour encompasses aspects such as organisational culture, leadership, internal communication, hierarchical structure, decision-making processes, motivational incentives, and performance (Fujita, 2011; Dewan, 2012a).

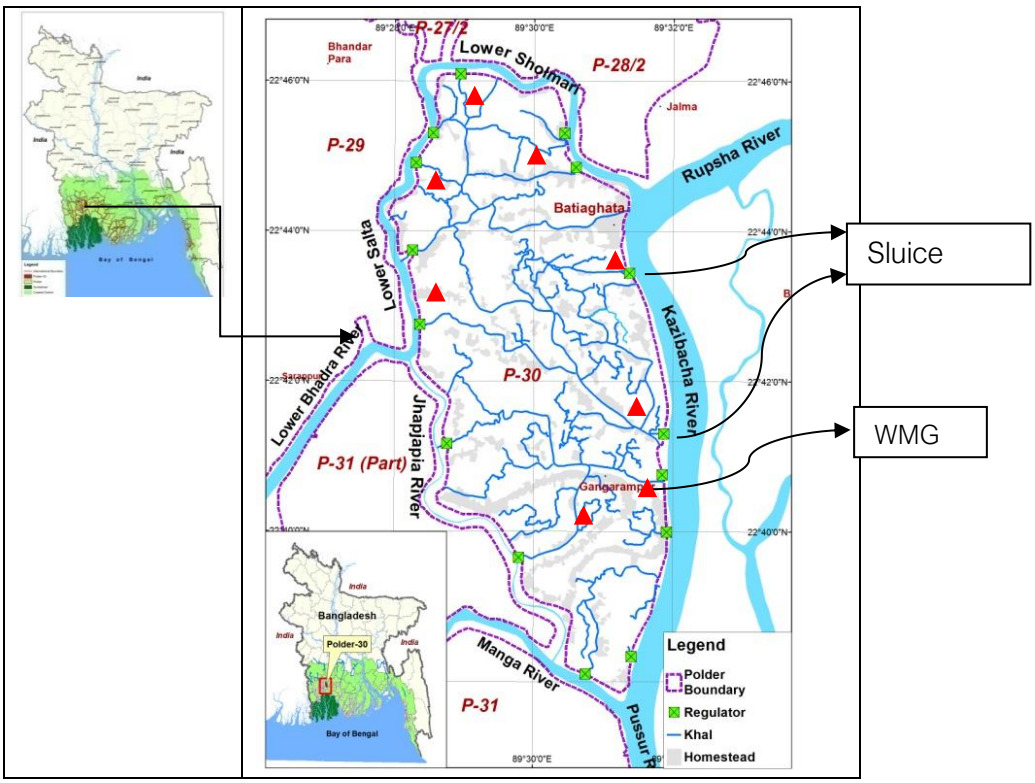

Figure 1. Map of polder 30 showing the selected water management groups (WMGs, in red triangles).

There are many published frameworks for categorising the essential competencies required to evaluate WMOs (Alaerts and Kaspersma, 2009; Kaspersma, 2013; Alaerts and Kaspersma, 2022). These competencies are categorised based on different levels, including individual, organisational, and institutional tiers, as well as their inherent nature, spanning technical, managerial, and governance competencies, and their capacity for continuous learning (Alaerts and Kaspersma, 2022). In this study, we adapted the organisational theory framework (Table 1) which encompasses organisational structure and various competencies at the organisational level (Fujita, 2011; Dewan, 2012a; Alaerts and Kaspersma, 2022) to evaluate the performance of WMOs with respect to water governance and water management.

Researchers in the field of organisational behaviour across the globe have extensively delved into the concept of transparency within the context of various crucial organisational aspects, including the development of trust, the formation of organisational identity, perceptions of leadership, and the cultivation of organisational culture (Pirson and Malhotra, 2011; Walumbwa et al., 2011). The high legitimacy and acceptability of an organisation are linked significantly to the presence of transparent behaviour and accountable financial management within its culture. Transparency is a critical element of knowledge-sharing, which brings increased awareness, coherence, and comprehensibility to information exchanged between WMOs and the community (Pagano and Roell, 1996; Schnackenberg, 2014). Effective leaders, armed with a clear vision and strong communication skills, play an indispensable role in steering WMOs toward success and achieving their goals (Khan and Gerrard, 2005).

2.3. In-polder water management and crop production

In the southwest coastal zone, the operational status of sluice gates in the polder ecosystems follows a seasonal pattern. Typically, these gates remain open from July to mid-December, facilitating water intake and drainage

Table 1. Organisational theory framework of different indicative competencies at the organisational level for assessing the performance of WMOs in polder 30 (adapted from Fujita, 2011; Dewan, 2012; Alaerts and Kaspersma, 2022).

Organisational Theory	Structure/competence type	Components of competence level
Organisational structure	Organisational structure	Division of labourers into specific task Coordination and standardisation
Organisational behaviour/competence	Management competence	Financial management Leadership in operational and infrastructure management Conflict resolution
	Governance competence	Organisational culture, rules regulations, legitimacy, transparency, ethics Organisational hierarchy in decision-making Internal communication and coordination
	Economic competence	Motivational incentive in joining WMG activities. In-polder water management and crop production

to support rice cultivation during the wet season. The management of these sluice gates is a collaborative effort between the Sluice Catchment Sub-Committee (SCSC) and WMOs. Their coordinated actions involve opening the sluice gates during high tides to intake water for irrigation during dry spells. Conversely, during low tides, the gates are opened to drain excess water, thereby mitigating flooding caused by high rainfall. The sluice gates are normally closed from the second half of December to the end of June to prevent saline water intrusion into the polder zone (Yadav et al., 2020; Mondal et al. 2022).

The farmers in this region cultivate tall traditional varieties of rice without the use of fertilisers, minimising the need for extensive drainage. However, it becomes evident that efficient fertiliser management, particularly for High-Yielding Varieties (HYV) of rice, requires improved water management practices within the polder zone to attain high yields (Yared et al., 2021; Mondal et al., 2022). Therefore, HYV rice cultivation with improved water management, focusing on drainage for efficient fertiliser management, was evaluated in the aman seasons of 2015 and 2018 (Mondal et al., 2015a, 2022), in collaboration with the WMGs and farmers in Fultala and Bayerbhanga villages situated within the catchment of two sluice gates (Katakhali and Khoria).

Good-quality seeds of BRRI dhan52 (HYV rice) were provided to the farmers to cultivate in *aman* season. The farmers adopted the recommended crop and water management practices for HYV rice cultivation, including drainage of the ponded water prior to the topdressing of nitrogen fertiliser by systematically opening the sluice gate during low tides and closing it at high tide (Mondal et al., 2015a, 2022). The performance of HYV rice with improved water management was compared with the neighbouring farmers' crop and water management practices at both sites. The neighbouring farmers cultivated traditional rice varieties without fertiliser, and the field was not purposefully drained during the cropping season.

2.4. Data collection

A questionnaire, finalised after pre-testing, was used to collect data from the selected WMGs with a major focus on organisational behaviour related to organisational culture, hierarchy, and transparency in decision-

making, financial accountability, leadership, internal communication, and motivational incentive-related issues of WMGs. Most of the questions were designed to capture the respondents' perceptions on a Likert scale to assess human attitude. Researchers and statisticians consider the Likert scale as an ordinal scale and argue that choices or responses are arranged in some ranking order (Joshi et al., 2015). In the questionnaire, the Likert scale, having scores of 1 to 5 for a response, was used for data collection, where 1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree, and 5=Strongly Agree.

A multi-stage sampling technique was used to finalise the sample size for information collection. Out of the 40 WMGs in polder 30, eight WMGs were selected for this study. The polder was divided into four segments from North to South, and two WMGs were randomly selected from each segment. The lists of general members (farmers) from the selected eight WMGs were collected from the membership registers and validated with WMA. For the in-depth interview, the sample size was calculated using Yamane's formula (Yamane, 1967). The total number of farmers of the polder was 5,326. Considering 7% desired level of precision (margin of error), the sample size of the respondents was 192 calculated using the formula:

$$n = \frac{N}{1 + N(e)^2}$$

where *n* is sample size of the survey, *N* is the population size, and *e* is the desired level of precision/margin of error.

Therefore, data were collected from 192 respondents equally divided and randomly selected from eight WMGs. The respondents were divided into three management levels (M1, M2 and M3) of the WMGs. The Chairman, Vice-Chairman, Secretary, Joint-Secretary, and Cashier of WMGs were categorised as the management level, M1; while seven EC members were considered as the management level, M2; and the farmers/general members of WMGs were included in the M3 level. In total, four respondents, each from M1 and M2, and 16 persons from the M3 level, were randomly selected for the interview. In addition, 18 informants were taken: two persons from BWDB, four from the Blue Gold Program, four from Union Parishad (2 Chairman and 2 Members), four from WMA (Chairman, Vice-Chairman, Treasurer, and Destitute Woman), and four from WMGs (Chairman of four WMGs) were selected for KII. A set of KII questionnaires, which were mostly open-ended, was used for an in-depth interview.

2.5. Data analysis

The data analysis was conducted using SPSS 24.0 and MS Microsoft Excel. For the ordinal data, the median was calculated to interpret the respondents' scores. The Kruskal-Wallis test, a nonparametric test performed on data with ordinal numbers that indicates the presence or absence of significant differences among compared groups (Dinno, 2015), was used to determine the statistical differences among the medians of three management levels (M1, M2 and M3). After the Kruskal-Wallis test, the *post hoc* test (Dunn's test) was done to compare the pairwise significance. Dunn's test is the appropriate nonparametric pairwise multiple-comparison procedure when a Kruskal-Wallis test is rejected (Dinno, 2015). The levels of statistical significance were tested at $p<0.05$.

3. Results

Organisational structure and organisational behaviour/competence are an integral part of organisational theory. Due to several project interventions by the BWDB, the organisational structures of WMOs in the coastal polder zone are shaped almost similar. But there are differences in perception and participation regarding the organisational competencies of WMOs.

3.1. Organisational Structure

In polder 30, the WMO is two-tiered including the Water Management Group and Water Management Association who are responsible for water governance and water management. In this polder, there are 40 WMGs and one WMA registered under BWDB. In addition, 10 Sluice Catchment Sub-Committees (SCSC) were also created by the WMGs to operate sluice gates for water management and agricultural development. The organisational structure of the WMOs in polder 30 is shown in Table 2.

3.2 Organisational Competence

Organisational competence of WMOs in the study polder was assessed focusing on its management competence (financial management, leadership in operational and infrastructure management, and conflict management), governance competence (transparency, hierarchy in decision-making, internal communication, and coordination among different stakeholders done by the EC members), and economic competence (the incentive requirements to join WMO activities and benefit of water management in crop production).

3.2.1. Management competence

Management competence of WMOs in polder 30 was assessed, focusing on financial management, leadership in operational and infrastructure management, and conflict management among different stakeholders done by the EC members.

Table 2. Structure of the water management organisations (WMOs) in polder 30 (source: GoB, 2006 and KII survey data in 2017).

WMOs	**Structure of WMOs and category of respondent level (M1-M3)**	
WMG (n=40)	General Committee (GC)	GC consisted of all farmers of a village or WMG area (M3)
	Executive Committee (EC)	Consisting of 12 members elected by GC. EC Officials: Chairman, Vice Chairman, Secretary, Joint Secretary, Cashier (M1) EC Members: Seven members from Farmers, Fishers, Landless, Destitute Women (M2)
WMA (n=1)	General Committee (GC) Executive Committee (EC)	Formed taking 3–4 representatives from each WMG Consisting of 12 members elected from GC. EC Officials: Chairman, Vice Chairman, Secretary, Joint Secretary, Cashier EC Members: Seven members from Farmers, Fishers, Landless, Destitute Women
SCSC (n=10)	General Member (GM)	Consists of 1–2 representatives from each WMG within the catchment area of a sluice gate
	Coordinator	One Coordinator per sluice gate selected from GMs

3.2.1.1. Financial management

The financial management was assessed by examining expenditures, audits, savings of the members, and investments made by the EC of WMGs. Most of the respondents of M1 (94%) and M2 (84%) indicated that EC prepared an annual budget and shared information with the community. In comparison, most M3 respondents (63%) disagreed of existing of this practice, making them significantly different from the other two layers (Fig. 2 and Table 3). However, there was a consensus among respondents across all three management levels (97–

100%) that the WMGs maintained active bank accounts with the required signatories. Regarding the issuance of well-documented receipts for monthly member savings, most M1 (88%) and M2 (78%) respondents expressed satisfaction, although 12–22% of M1 and M2 respondents remained neutral. Notably, the perception of M3 significantly diverged from that of M1 and M2 respondents (Table 3). The study also revealed that only approximately half of the M1 (score 4) and M2 (score 3) respondents agreed to the sharing of savings-related information with individuals during the Annual General Meeting (AGM). Conversely, most of the farmers (M3) disagreed that this practice is followed. Given that a significant number of respondents from all three management levels either opposed or remained neutral on this issue, it suggests challenges in organising the AGM. It is plausible that the community, including many members of the EC, might be unaware of or not participating in the AGM. The responses of the M3 level (55%, score 2) significantly differed from the other two management levels (M1 and M2) regarding AGM practices.

Similar responses were observed across the management levels for savings and investment-related activities of WMGs. A substantial number of participants from all management levels expressed dissatisfaction with the way their group savings were invested. Only 17–59% of the respondents agreed that WMGs invested the group's savings for income generation with proper consultation (Fig. 2). Surprisingly, a remarkable number of respondents of M2 (40%) maintained neutrality on this issue (scored 3). Among all the management levels, M3 had the highest number of unsatisfied respondents (61–73%) regarding investments from savings and were significantly different from M1 and M2. However, M1 and M2 scored well with record keeping on income-expenditure for audit (94%); the M3 level respondents differed significantly with them as they disagreed (50%) or were unaware (16%) of the practice.

3.2.1.2. Leadership in operational and infrastructure management

Leadership skills of the EC were analysed on the basis of operational and infrastructure management and conflict resolution among the WMG members and within WMGs in the study polder. The leadership qualities of WMGs in relation to the operation of sluice gates and the management of polder infrastructure were primarily assessed in terms of their ability to navigate socio-political influences on water management, secure funding, and lead voluntary efforts for the maintenance of water infrastructure within the polder ecosystems. The study exhibited that the majority of respondents in M1 (76–81%) and M2 (50–59%) categories were satisfied with the WMGs' efforts in operating sluice gates for irrigation and drainage during the *aman* season (Fig. 3). Consequently, there was no significant difference in perception between M1 (scoring 4) and M2 (scoring 3.5–4). However, a notable proportion of farmers (76–85%) belonging to the M3 group disagreed with this assessment, indicating that they found sluice gate operations for enhancing water governance and management in the polder unsatisfactory. A significant disparity in opinions on water management was evident between M1 and M3, as well as between M2 and M3 (Table 4). Furthermore, when it came to handling social and political influences affecting sluice gate operations for effective in-polder water management, 63% of M1 (scoring 4) and 50% of M2 (scoring 3.5) respondents reported that they could successfully manage these influences. Conversely, only 29% of M3-level respondents agreed with this perspective, while 49% disagreed with the opinions of M1 and M2 and these differences in opinion were statistically different (Table 4).

Regarding their ability to lead voluntary efforts and raise funds for emergency infrastructure repairs, most respondents in the M1 and M2 categories (78–88%) agreed (scoring 4) that they could satisfactorily oversee such activities except for maintenance of water infrastructure within the polders (Fig. 4 and Table 4). While 56% of M3 respondents (scoring 4) acknowledged that WMGs (M1 and M2) possessed the capacity to secure funds for emergency repairs, a significant 88% of them disagreed (scoring 2) regarding the ability of M1 and M2 to effectively organise and lead voluntary efforts for water infrastructure management within the polder zone.

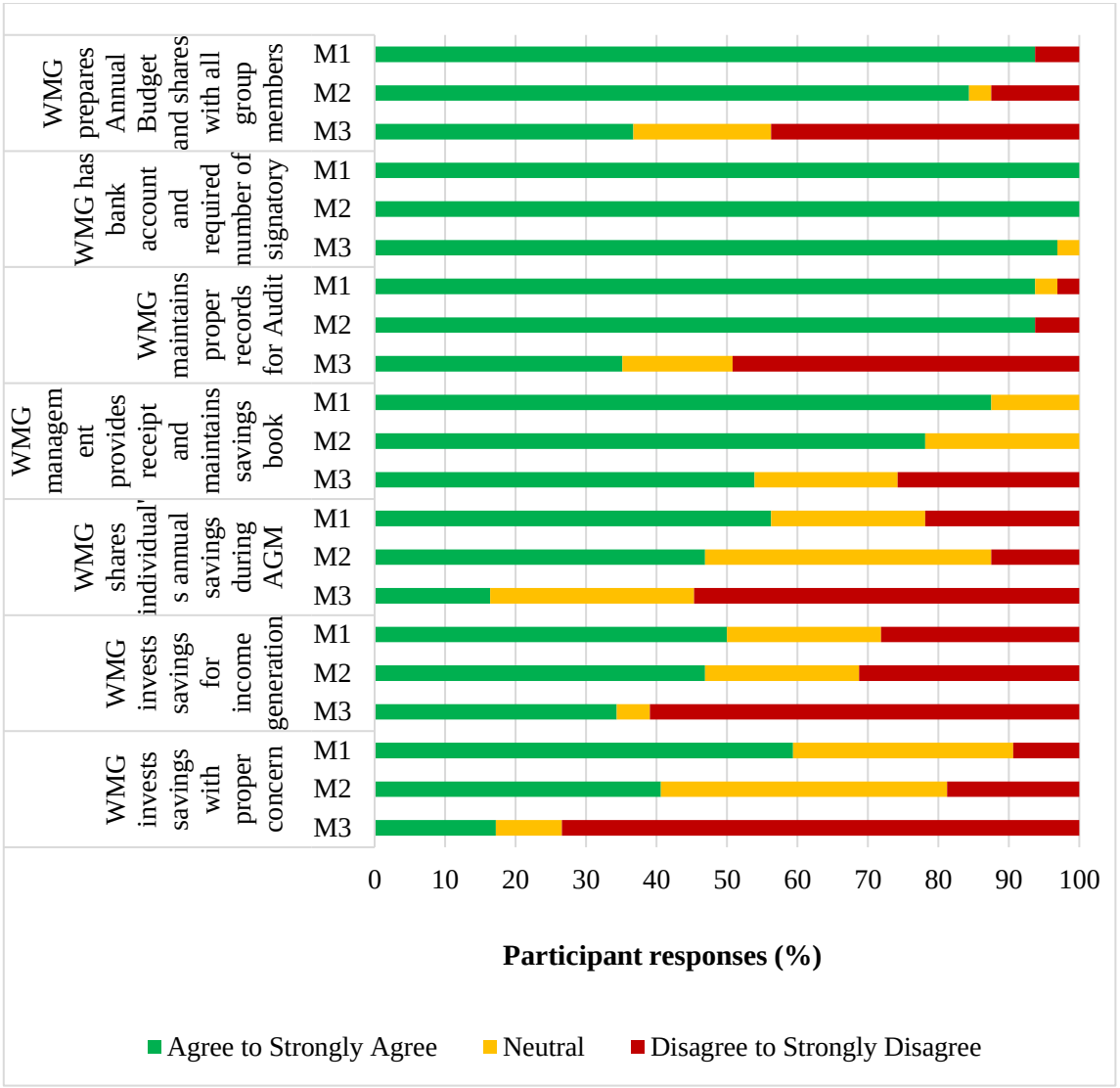

Figure 2. Opinions on the financial management and accountability by different management levels (M1, M2, and M3) of WMGs.

Table 3. Financial management and accountability of WMG members (Likert Scale: 1= Strongly Disagree, 2= Disagree, 3=Neutral, 4=Agree, and 5=Strongly Agree).

Financial management and accountably of WMG	Median			*P* value of overall sample with KW test	*P* values for management level pairs comparison using post hoc test (Dunn's test)		
	M1	M2	M3		M1-M2	M1-M3	M2-M3
WMG Annual Budget preparation and sharing with all group members on a regular basis	4	4	3	0.000	0.891	0.000	0.000
Having a bank account and the required number of signatories	5	5	5	0.000	0.391	0.000	0.014
WMG maintains proper records for Audit (income and expenditures)	5	4	3	0.000	0.089	0.000	0.000

WMG management provides receipts for monthly savings and maintains a record book	4.5	4	4	0.000	1.000	0.000	0.000
WMG shares annual savings with each individual during AGM	4	3	2	0.000	1.000	0.000	0.000
WMG invests the group's savings for income generation	3.5	3	2	0.003	1.000	0.010	0.063
WMG invests the group's savings with proper concern, and the return is satisfactory	4	3	2	0.000	0.787	0.000	0.000

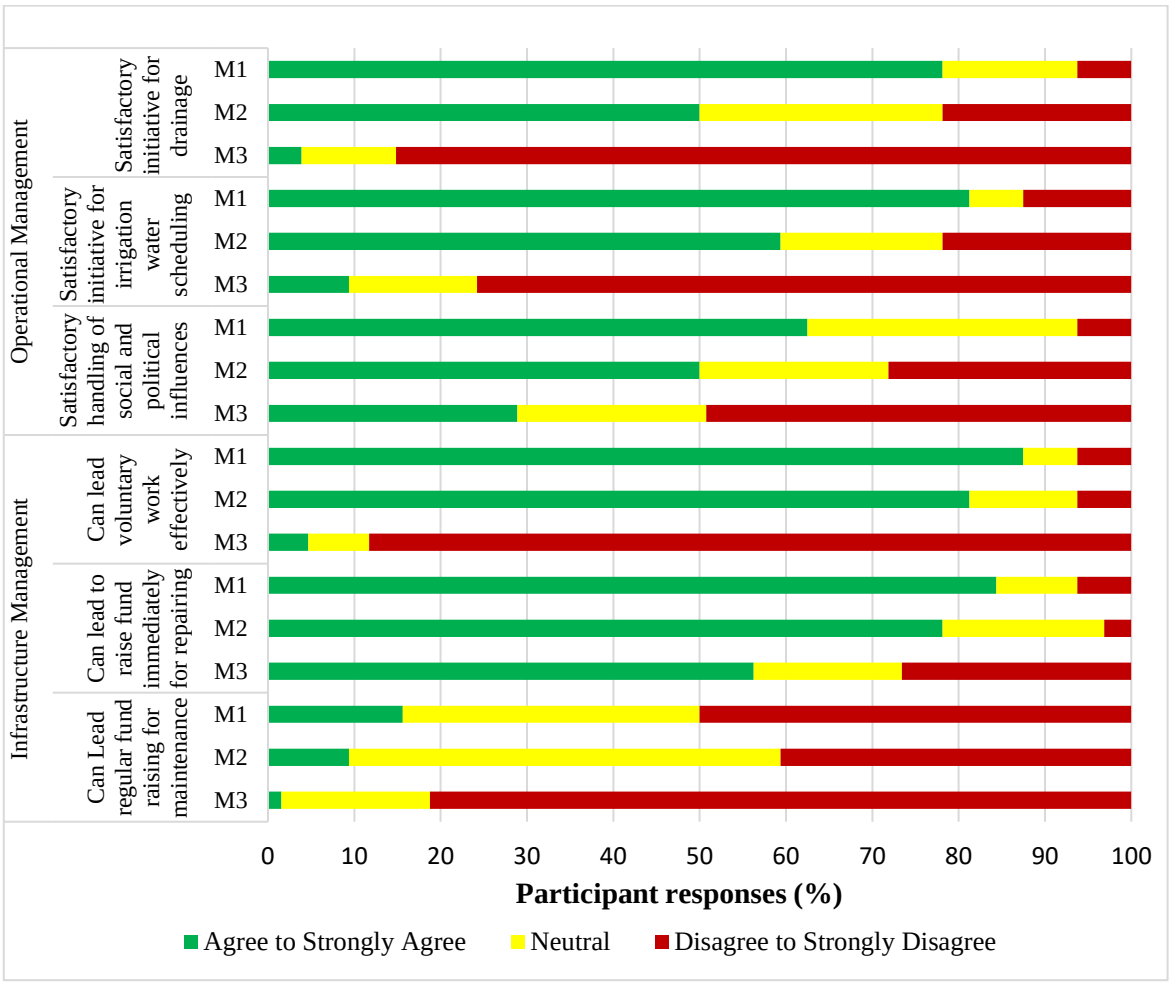

Figure 3. Opinion of different management levels (M1, M2, and M3) on operation and maintenance of polder water infrastructure.

3.2.1.3 Conflict resolution

Overall conflict management capability or institutional performance of the WMGs was evaluated in the context of conflict resolution among their members or other agencies for sluice gate operations for water management

or water infrastructure development. According to the results, 66–75% of respondents from M2 and 78–97% from M1 were effective in resolving conflicts among WMG members, in sluice gate operations for irrigation and drainage, and among national and local agencies involved in agricultural and livelihood improvement within the polder community (Fig. 4). In contrast, the farming community (M3) held differing opinions from WMG management (M1 and M2) on all aspects of conflict resolution except those concerning agency personnel. Among these conflicts, a significant disagreement arose in sluice gate operation, with 72–93% of M3 respondents expressing dissatisfaction with the performance of EC members (M1 and M2) in operating the sluice gates to ensure timely water supply and drainage for sustainable cropping in the polder zone. The farming community (93% of M3) also indicated a lack of knowledge regarding water management, particularly regarding the timing of drainage for fertiliser application in High-Yield Variety (HYV) rice and periodic drainage during the dry season in case of heavy rainfall to protect crops.

Table 4. Opinion of different management levels (M1, M2 and M3) on operational and infrastructure management of WMG members (Likert Scale: 1= Strongly Disagree, 2= Disagree, 3=Neutral, 4=Agree, and 5=Strongly Agree).

Operational and infrastructure management of WMG	Median			*P* value of overall sample with KW test	*P* values for management level pairs comparison using *post hoc* test (Dunn's test)		
	M1	M2	M3		M1-M2	M1-M3	M2-M3
Operational management							
Satisfactory initiative for drainage	4	3.5	2	0.000	0.158	0.000	0.000
Satisfactory initiative for irrigation scheduling	4	4	2	0.000	0.453	0.000	0.000
Satisfactory handling of social and political influences for effective water management	4	3.5	3	0.000	0.146	0.000	0.028
Infrastructure management							
Can lead voluntary work effectively	4	4	2	0.000	1.000	0.000	0.000
Can lead to raising funds immediately for repair and other purposes	4	4	4	0.000	0.833	0.000	0.024
Can lead regular fundraising for maintenance	2.5	3	2	0.000	1.000	0.000	0.000

The study further revealed that 75% (M2) to 97% (M1) of respondents effectively managed conflicts among WMG members, indicating a high level of performance by the Executive Committee (EC) in conflict management within the WMGs. In contrast, the majority of farmers (63% of M3) did not share this view, leading to a significant discrepancy in perception between M1 and M2, and M1 and M3 (Fig. 4 and Table 5). The research also showed that respondents at the M1 level (scoring 4) were successful in managing conflicts related

to scheduling sluice gate operations for irrigation (100%) and drainage (84%), a view endorsed by the majority (66–72%) of M2 respondents. However, approximately two-thirds of M3 respondents strongly disagreed (scoring 2) with M1 and M2 on this matter. In contrast, most M1 (78–91%) and M2 (65–82%) respondents rated their ability to manage conflicts of WMG with other WMGs, BWDB, UP, and local administration regarding sluice gate operations in the polder zone as effective (scoring 4), with no significant differences in

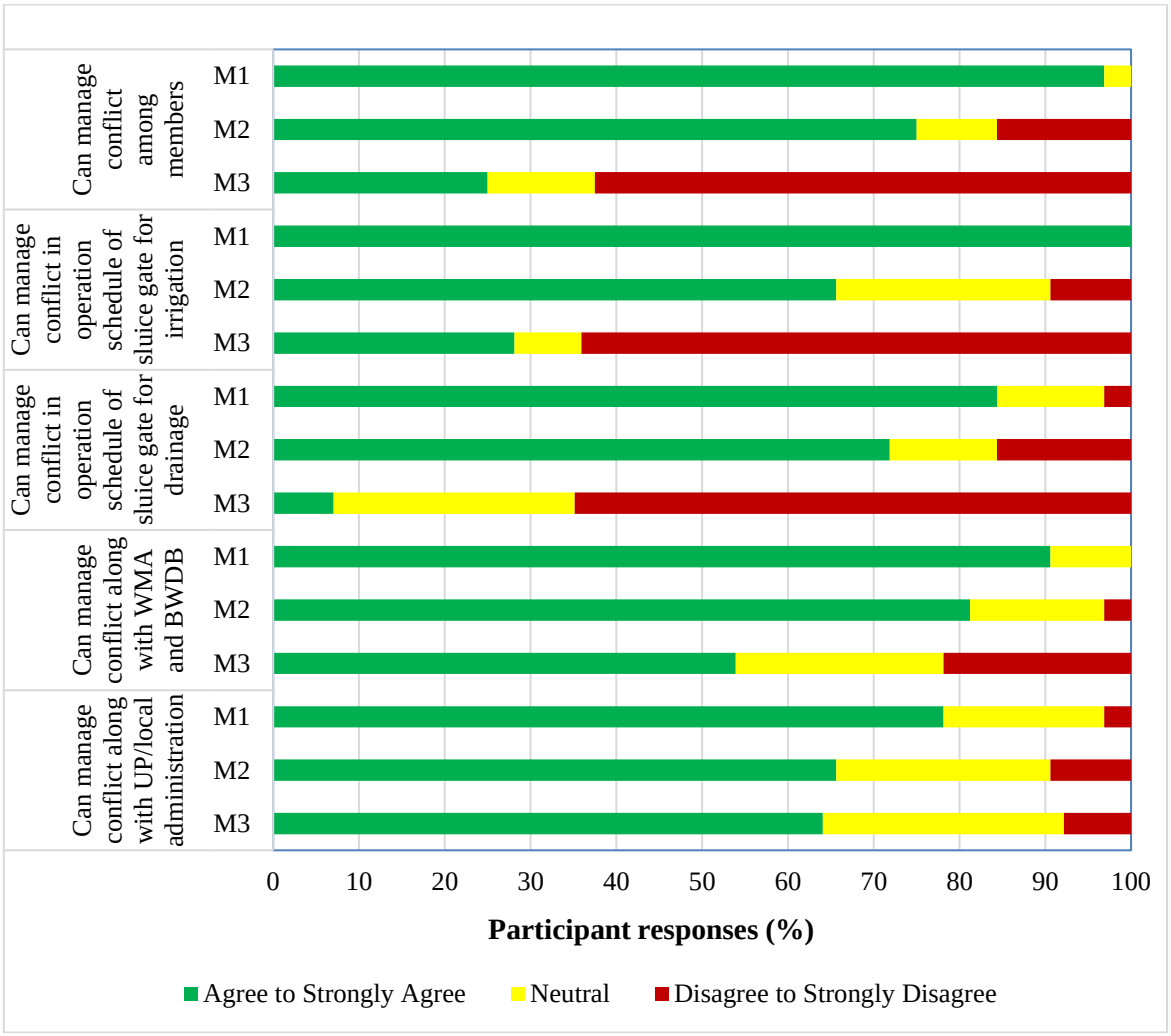

Figure 4. Opinion of different management levels (M1, M2, and M3) on conflict management capability of WMG members.

opinion observed between M1 and M2 respondents. Although many farmers (54–64%) agreed (scoring 4) with the opinions of M1 and M2, significant differences were only noted between M1 and M3 in terms of conflict management within the concerned organisations. Overall, 78–100% of executive officials (M1) stated that they were capable of conflict management across all aspects of water governance and management, and these views were supported by the majority (65–81%) of EC members and farmers.

3.2.2. Governance competence

Governance competency of the WMOs was assessed focusing on transparency, hierarchy in decision-making, internal communication, and coordination among different stakeholders by the EC members.

3.2.2.1. Transparency of WMG

The questions related to information-sharing, member selection, sluice gate operation and maintenance, agro-input, and microcredit distribution were asked to three management levels of the WMGs. Overall, the responses from M1 were significantly different from those from M2 and M3 in four test hypotheses out of eight (Table 6).

Table 5. Opinion of different management levels (M1, M2, and M3) on conflict management capability of WMG members (Likert Scale: 1= Strongly Disagree, 2= Disagree, 3=Neutral, 4=Agree, and 5=Strongly Agree).

Conflict management capabilities of WMG	Median			*P* value of overall sample with KW test	*P* values for management level pairs comparison using *post hoc* test (Dunn's test)		
	M1	M2	M3		M1-M2	M1-M3	M2-M3
Can manage conflicts among members	4	4	2	0.000	0.073	0.000	0.000
Can manage conflicts in operation schedules of sluice gate for irrigation	4	4	2	0.000	0.049	0.000	0.000
Can manage conflicts in operation schedule of sluice gate for drainage	4	4	2	0.000	0.685	0.000	0.000
Can manage conflicts along with WMA and BWBD	4	4	4	0.000	0.089	0.000	0.000
WMG can manage conflicts along with UP and local administration	4	4	4	0.029	0.133	0.026	1.000

The study reveals that >94% of EC officials (M1) disclosed all necessary information to the EC members (M2) and farmers (M3). However, the majority of M2 and M3 disagreed with the M1 respondents (Fig. 5). Only 38% of M2 and 13% of M3 agreed with M1 that information related to WMG activities is shared with the community. The median value of M1 level respondents was >3, while M2 scored 3, and M3 scored <3, indicating poor information-sharing and the perception differed significantly among different management levels (Table 6). However, all the respondents (M1, M2, and M3) indicated fair selection of WMG members from special groups (landless, fishermen, and destitute women) by the key officials (M1) of WMGs (Fig. 2). While most respondents of M1 (94–97%) and M2 (59–84%) mentioned that WMG and their advisors (score >4) did not take advantage from the fishing net setters, it was disagreed by the majority of M3 respondents (>50%, score <3). Although there was no significant difference in perceptions between M1 and M2, it differed significantly between M1-M3 and M2-M3 (Table 6), demonstrating poor transparency and mistrust among the WMG members regarding fishing in the polder canals. Information sharing by M2 and M1 on sluice gate operation (63–75%) and

infrastructure maintenance (50–63%) with the advisors and selection of members for agro-input (78–94%) and microcredit (75–88%) distribution were satisfactory (score >3). There was no significant difference in perception on information sharing on sluice operation and input distribution between M1 and M2, but it differed significantly between M1-M3 and M2-M3 (Fig. 5 and Table 6). The majority of M3 respondents either disagreed or remained neutral about the responses of M1 and M2, except for agro-input distribution. It is most likely the issues of sluice gate operation and maintenance were not considered important to share instantly with the farmers (M3), as the EC of WMGs can share those in annual general meetings.

Table 6. Opinion of different management level respondents on the transparency of WMG activities in the polder zone (Likert Scale: 1= Strongly Disagree, 2= Disagree, 3=Neutral, 4=Agree, and 5=Strongly Agree).

Transparency of WMG	Median			*P* value of overall sample with KW test	*P* values for management level pairs comparison using *post hoc* test (Dunn's test)		
	M1	M2	M3		M1-M2	M1-M3	M2-M3
WMG discloses all necessary information to its group members	4	3	2	0.000	0.000	0.000	0.001
Fair selection occurs for landless, fisher and destitute women in WMG	5	4	4	0.000	0.003	0.000	0.008
WMG management does not take any advantage of fishing net setters/fisher	5	4	2	0.000	0.038	0.000	0.000
WMG advisors (UP member, Chairman) do not take advantage of fishing net setters across the canal	4	4	2	0.000	0.092	0.000	0.000
WMG shares information on sluice gate operation with advisors	4	4	3	0.000	0.100	0.000	0.000
WMG shares information on the maintenance of sluice gates, canals, etc., with advisors	4	3.5	3	0.000	1.000	0.000	0.001
Appropriate members selection for agro-input support provided by BG	5	4	4	0.000	0.058	0.000	0.001
No nepotism in providing micro-credit from group savings	4	4	3	0.000	0.515	0.000	0.000

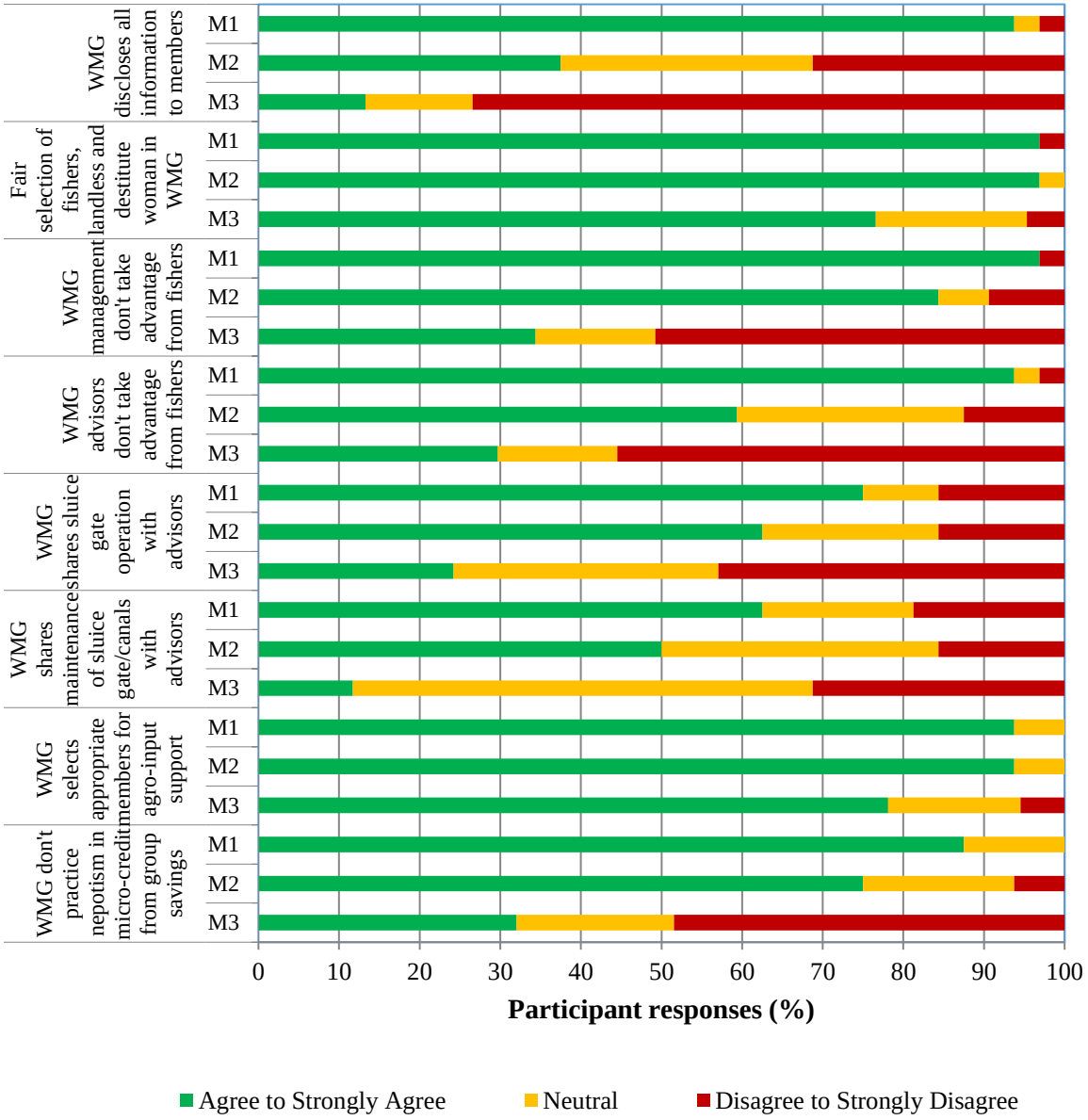

Figure 5. Opinions of the respondents at different management levels (M1, M2, and M3) on transparency of WMG activities in polder 30.

3.2.2.2 Organisational hierarchy in decision-making

Participation in decision-making processes in various events of WMGs such as capacity building of the members, operation, and maintenance of sluice gates to create favourable water environment for agricultural development, timing of terminal drainage and use of budget by the WMGs for different activities are shown in Fig. 6 below.

The decisions on organising and conducting important events like training, selection of members for the training events and distribution of input among the members were taken mainly by the key EC officials (53.6%), followed by the EC team (24.5%) and some cases, only by the Chairman and Secretary (21.9%) of WMGs (Fig. 6). Similarly, the operation (87.0%) and maintenance (65.5%) of sluice gates, the timing of terminal drainage (57.3%) were also done by the Chairman and Secretary involving the SCSC.

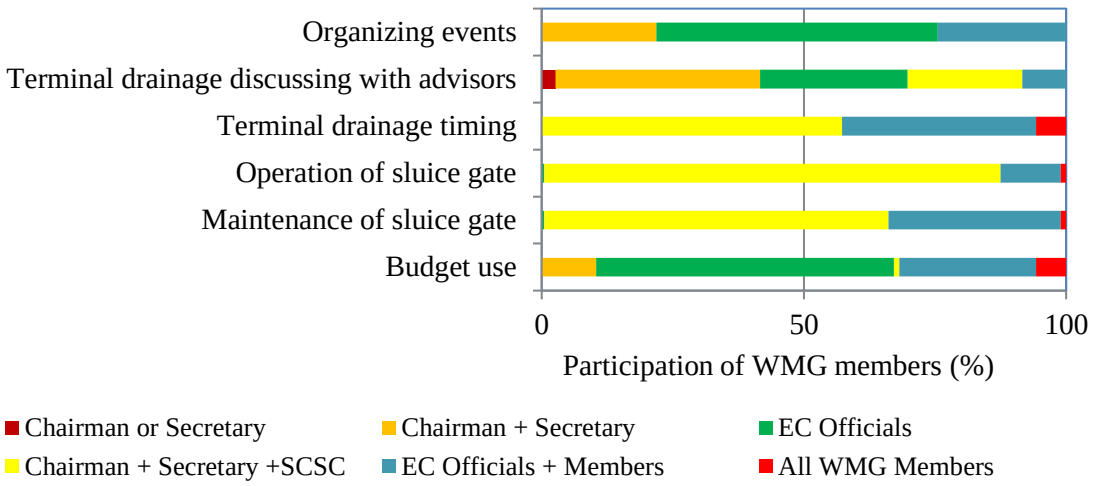

Figure 6. Participation of WMG members in the decision-making process.

Likewise, a decision on the use of the allocated budget was mainly made by the key EC officials (56.8%), followed by the entire EC (26%) and only the Chairman and Secretary (10.4%) of WMGs. In only 26-37% of cases, the entire EC was involved in the decision-making on terminal drainage to facilitate rice harvest, maintenance of sluice gates and budget use for different activities. Interestingly, discussion with the WMG advisors on the timing of terminal drainage is mainly done by the Chairman and Secretary (39.1%), followed by the key officials (28.1%) and SCSC (21.9%); the entire EC was not extensively involved in communicating with the LGI representatives (WMG advisor). The involvement of farmers or general members in the decision-making processes of various WMG activities was not significant.

3.2.2.3. Internal Communication and Coordination

The analysis of internal communication and coordination aimed to assess the WMGs' capacity to communicate and maintain relationships with various stakeholders for utilising polder water resources. The internal communication and coordination issues were analysed to document the capacity of WMGs in communicating and maintaining liaison with different stakeholders using polder water resources. The study showed that most of the respondents at M1 (96.9%), M2 (75.0%) and M3 (87.5%) management levels agreed (score 4) that good to excellent communication and coordination exists between the EC officials (M1) and members (M2) of WMGs, and no significant differences in responses in all three levels were observed (Fig.7 and Table 7). Although the perception of M1 was very positive (score 4), the respondents from M2 and M3 scored slightly less (3) on communication and coordination between EC and the general members. The differences in perceptions were significant between M1 and M2, and M1 and M3, but non-significant between M2 and M3 level respondents. The respondents of all three management levels expressed satisfaction (56–100%) over WMGs communication and coordination with other WMGs, the WMA, and BWDB. Only significant differences in opinion were observed between M1 and M2 regarding communication among the WMGs in polder 30, and that of M2 and M3 between WMG and BWDB. However, issues in communication were prominent between the EC and general members (M3) of WMGs, and between WMGs and Union Parishads (UPs, advisors of WMGs), even though more than two-thirds of EC respondents were satisfied with how they communicated with general members and UPs representatives in the study polder (Fig. 7).

Table 7. Opinion of different management levels (M1, M2, and M3) on communication and coordination between different groups of water management stakeholders (Likert Scale:1= Very bad, 2= Bad, 3=Good, 4=Very good, and 5=Excellent).

Water management stakeholder pairs	Median			P value of overall sample with KW test	P values for management level pairs comparison using *post hoc* test (Dunn's test)		
	M1	M2	M3		M1-M2	M1-M3	M2-M3
M1 vs M2 level of EC	4	4	4	0.000	0.001	0.000	0.000
EC vs General Member	4	3	3	0.000	0.002	0.000	0.582
WMG vs WMG	4	4	3	0.000	1.000	0.000	0.000
WMG vs WMA	4	4	4	0.000	0.526	0.000	0.000
WMG vs BWDB	4	4	4	0.000	0.034	0.000	0.173
WMG vs UP	4	3	2	0.000	0.765	0.000	0.009

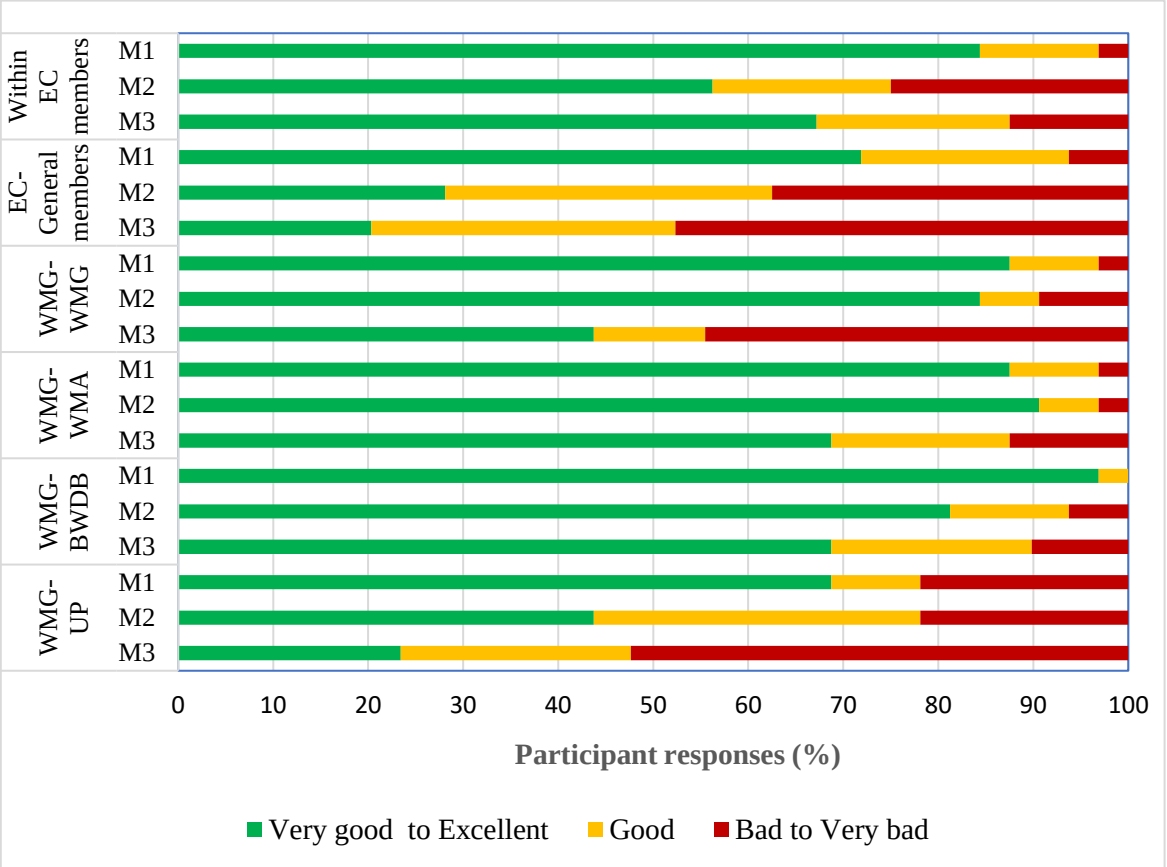

Figure 7. Opinion of different management levels (M1, M2, and M3) on communication and coordination between different pairs of the water management stakeholders

3.2.3. Economic Competence

In this study, two vital issues such as motivational incentives in joining WMG activities and water management for crop production, were assessed.

3.2.3.1. Motivational incentives for joining WMG activities

Two vital issues were solicited to understand the community's interest in being a member of a WMG and what triggered them to do that. Approximately 57% of the respondents, primarily at the M3 level, expressed their willingness to join a WMG. In contrast, 36.5% remained undecided, and around 7% mentioned no interest in

WMG membership (Fig. 8a). The primary motivation (81% response) for the community to take WMG membership was the prospect of participating in capacity-building programs. These programs held the promise of enhancing their knowledge and agricultural skills, providing input support for crop production, and opening avenues for savings. A minority (18%) of respondents shared a similar motivation, but displayed reluctance to engage in WMG's micro-finance initiatives. They were not inclined toward savings-related activities. Only a small fraction of respondents expressed a purely self-centred interest; they were not enthusiastic about contributing to voluntary community work (Fig. 8b).

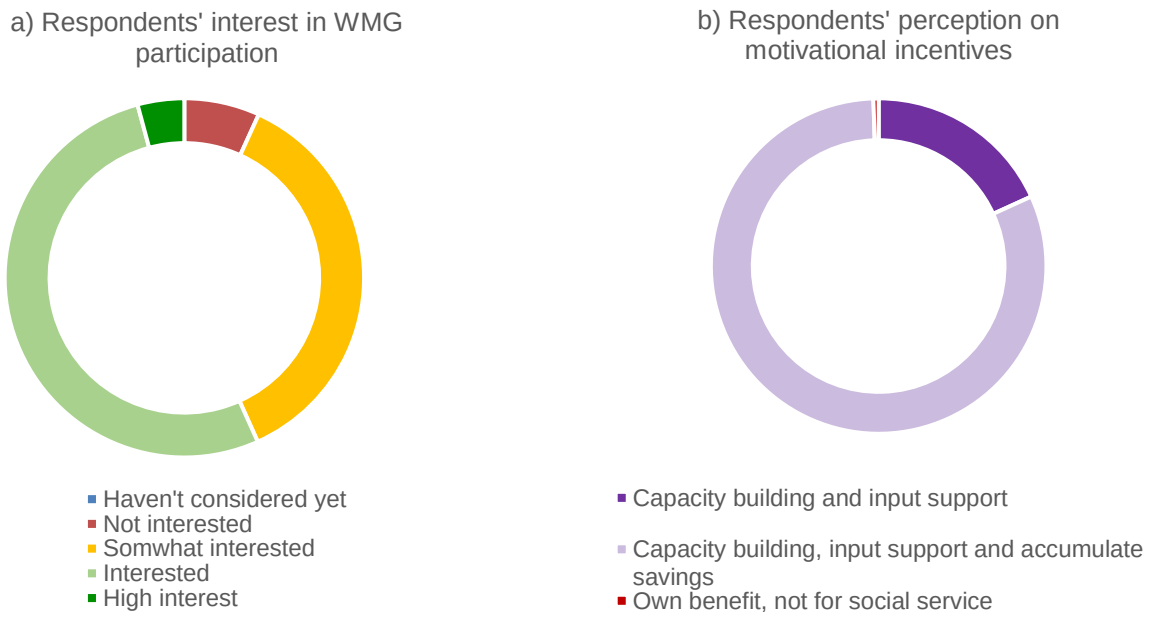

Figure 8. Responses of the community on their interest and motivational incentives to join in a water management organisation.

3.2.3.2. In polder water management for higher productivity

Emphasising the significance of sluice gate operations in managing in-polder water effectively and thereby facilitating the adoption of improved agricultural technologies in the polder zone, a component study was conducted in two mini-watersheds situated in Fultala and Bayerbhanga villages within the study polder.

During the 2015 *aman* season, the yield of HYV rice at Fultala varied from 3.73 to 6.73 t/ha. In contrast, traditional rice varieties cultivated in the adjacent watershed yielded between 2.85 to 3.63 t/ha. This difference was attributed to the improved water environment created through effective sluice gate operations by the WMG (Fig. 8). On average, the yield of HYV rice, with improved drainage, stood at 4.83 t/ha, which was about 1.5 t/ha higher than traditional rice cultivated under conventional water management practices.

In 2018, similar results were observed in Bayerbhanga. The average yield of HYV rice (5.23 t/ha) with improved drainage was 2.3 t/ha higher than that of traditional rice (2.93 t/ha) in a nearby watershed that followed traditional water management practices. Here, the yield of HYV rice ranged from 4.25 to 5.90 t/ha, while traditional rice yielded between 2.24 to 3.30 t/ha. Therefore, it becomes evident that water management, particularly the systematic operation of sluice gates synchronised with the tidal patterns of peripheral rivers in the polder ecosystems, exerts a significant influence on the adoption of improved agricultural technologies and, consequently, enhances productivity in the polder zone. This study highlights that cultivating HYV rice during the *aman* season can increase productivity by 1.5 t/ha to 2.3 t/ha compared to traditional rice by adopting improved drainage through the effective operation of sluice gates. Yadav et al. (2020) reported similar yields of HYV and traditional rice varieties at other locations in polder 30.

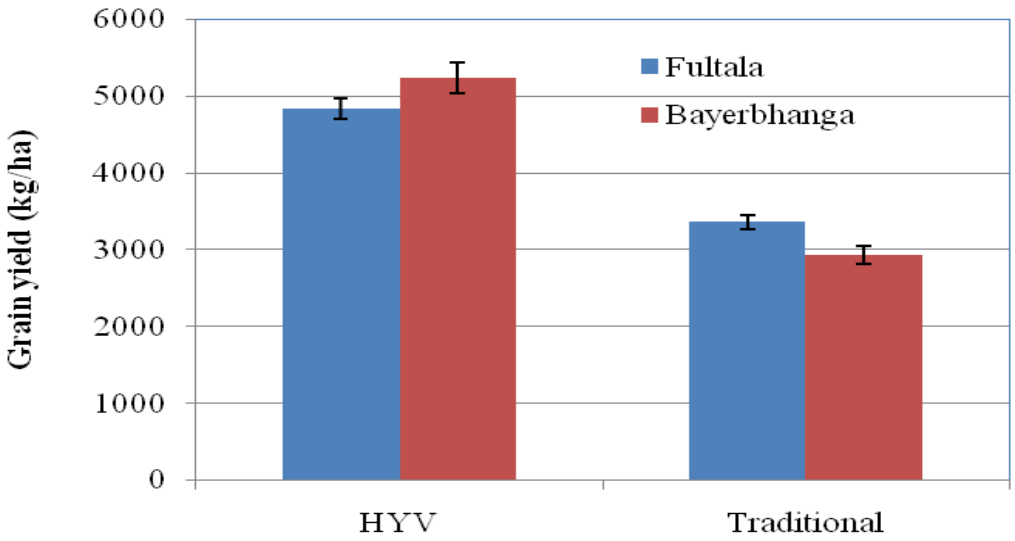

Figure 8. Yield of high-yielding (HYV) and traditional rice varieties under improved drainage in aman *season (adapted from Mondal et al., 2022).*

4. Discussion

We studied the structure and different competencies (management, governance, and economic) to evaluate the capabilities of WMGs in improving water governance and water management of the coastal polder zone.

Regarding financial management, our study revealed that while WMG members generally expressed satisfaction with banking plans, monthly savings, and the record-keeping practices undertaken by WMG officials, there was a notable discontentment with the investment strategies for their savings. This dissatisfaction extended to the WMG management, as well. This dissatisfaction may arise from either a lack of awareness regarding where to invest or the limited investment opportunities available within their locality. It highlights the existence of significant information gaps within the community. Therefore, the imperative need for organising Annual General Meetings (AGM) becomes evident, as these events can facilitate better information dissemination and contribute to the sustainability of WMGs. This aligns with the findings of Kenia and Buisson (2015), who also highlighted the lack of information sharing regarding savings and investment plans among WMG members. It is very critical that for financial accountability, the sharing of information is paramount, as it forms the bedrock for establishing trust among members of community-based organisations like WMGs, as highlighted by Widyaningsih (2015).

The operation of sluice gates for efficient in-polder water management represents one of the most contentious and debated issues. Decisions on the timing of gate opening and closing are ideally supposed to be made collaboratively by all members of the WMOs (Kenia and Buisson, 2015). The significance of these decisions becomes especially apparent as farmers cultivate rice varieties of varying growth duration in *aman* season. Therefore, the WMG management should engage in extensive discussions with public representatives, who also serve as advisors to WMGs, and ensure that the community is well-informed well in advance of any sluice gate operation related to terminal drainage. Our observations reveal a lack of reliability in communication between WMG management and these public representatives, who could exert significant influence in sustaining WMOs in the polder zone. Furthermore, only a fraction of general members or farmers were aware of the importance of terminal drainage to facilitate *aman* rice harvest and early or timely establishment of the dry season crops. These observations echo the concerns raised by Dewan et al. (2014) regarding the side-lining of ordinary farmers' voices in the decision-making processes related to sluice gate operations for water management.

Efficient water governance and management in the context of variable land topography, power dynamics within society, and the community's crop choices necessitate effective conflict management (Kenia and Buisson, 2015). While the WMG management expressed confidence in their ability to handle socio-political conflicts, the community was unsatisfied with polder water management, which is critical for sustaining the WMOs. The study revealed that WMG managed the disputes in collaboration with the officials of WMA, BWDB, and the public representative of Union Parishad (WMG advisor) very effectively, and the respondents at all three levels were satisfied with the way conflicts were managed. The UP representatives play a pivotal role in conflict resolution and infrastructure management, given their status as representatives of local government institutions. Their administrative authority and social influence make them key stakeholders. Dewan et al. (2014) emphasised the significant role played by Local Government Institutions (LGIs) in managing water resources within the polder zone despite their lack of formal recognition in the GPWM.

Improving information-sharing mechanisms is pivotal for enhancing the transparency and sustainability of WMGs. In our study, we discerned a significant level of mistrust between WMG management and general members (farmers) across nearly all aspects, with the exceptions being the selection of special group members and the distribution of agro-inputs among farmers. This mistrust may stem from the presence of BWDB personnel during member selection and input distribution. While farmers raised several concerns related to transparency, Dewan et al. (2014) pinpointed the primary information gap in sharing WMO activities with the farming community.

Regarding organisational hierarchy and decision-making, our findings indicate that the chairman and secretary of WMGs play a pivotal role in water management. They primarily contribute to guiding the operations and maintenance of sluice gates and determining the timing of terminal drainage from the sluice catchment. Within the current governance settings, this group of stakeholders is of paramount importance for in-polder water management. Despite promising activities undertaken by WMGs, community (general member/farmer) participation in these activities was significantly lacking. The community perceived that EC officials predominantly managed budgetary matters without keeping the general members informed. Dewan et al. (2014) also underscored the prevailing perception that participation in decision-making is heavily influenced by power and economic status, often side-lining the voices of ordinary individuals. Kenia and Buisson (2015) also noted that financial decisions were typically made collectively by EC members.

According to the GPWM, community participation should be evaluated not solely based on the empowerment of communities or their influence in decision-making but also on the state of infrastructure maintenance (NWP, 1999; Dewan et al., 2014). Maintenance of coastal water infrastructure, including embankments, canal desilting, and sluice gate operation, necessitates a general fund. Historically, the BWDB was responsible for maintaining polder infrastructure, and community members lacked knowledge about the upkeep of large engineering structures like sluice gates. The community seemed reluctant to shoulder recurrent substantial costs but was willing to contribute in emergencies to protect their crops. The community's perspective is that the government should bear the responsibility for maintaining water management infrastructure in the polder zone, as they already pay land development taxes to the government. This historical arrangement harkens back to the era when landlords (Zamindars) collected taxes from farmers and provided irrigation and flood control facilities to the community (Dewan et al., 2014).

The issue of waterlogging poses a significant challenge in the polder zone, causing extensive damage to agriculture (Alam et al., 2017). Mondal et al. (2022) demonstrated the potential for reducing waterlogging in polder 30 through gravity drainage, given that the elevation of most agricultural land is higher than river water levels during low tides. Effective water management practices, particularly drainage, are critical for enhancing production and addressing food insecurity. Many rural households in the polder zones are highly vulnerable and struggle to meet their food needs in this climate-affected environment (Kabir et al., 2020). Shifting to HYVs of rice, coupled with improved drainage facilitated by strategic sluice gate operations, boosted *aman* season

productivity by a minimum of 1.5 tonnes per hectare compared to traditional farming practices (Mondal et al., 2022). These findings hold profound implications for the food security of farming households residing in the 1.2-million-hectare polder zone. Additionally, transitioning to HYVs by replacing long-duration traditional rice varieties could support sustainable intensification and diversification of cropping systems, enabling year-round cropping in the polder zone. This, in turn, could yield an additional harvest of 3–6 tonnes per hectare per year from the polder zone (Mondal et al., 2022; Yadav et al., 2020; Yared et al., 2021). Therefore, investments in polder water infrastructure to enhance water governance and bolster the capacity of WMOs, particularly for drainage management, could serve as a significant catalyst in securing the country's future food security and elevating the livelihoods of climate-vulnerable communities in coastal Bangladesh.

5. Conclusions and Recommendations

The hydrology of the coastal zone in Bangladesh presents unique challenges distinct from other regions in the country. Managing the substantial influx of water into the polder ecosystem through sluice gates is a challenging task. Our study underscores the necessity for community coordination and synchronised cropping, with water management organisations playing a pivotal role in fully harnessing the potential of the polder zone. While the existing WMOs are registered entities, our findings reveal that they lack knowledge across the spectrum of integrated water governance and improved agricultural production systems. A wide gap exists between the WMGs and the farmers in almost all aspects of WMG governance, particularly in-polder water management for the adoption of improved agricultural technologies in the coastal polder zone. This study highlighted the potential of increasing production gains by integrating the water management plan of WMOs with the farmers' cropping activities. This could be achieved if the WMOs were formed and mentored as a single-purpose voluntary organisation solely for improved water management to create the favourable water environment required for the adoption of improved agricultural production systems in the coastal polder zones of Bangladesh. These findings are highly useful to agriculture and water management professionals and policymakers seeking to reshape water governance and adapt water management policies to address future food security challenges in Bangladesh.

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7. Conflict of Interest

There is no conflict of interest among the authors for agreement on the final statement.

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