CSISA Research Note 18

Mental models and the potential for crop intensification in coastal Bangladesh: How do farmers' perceptions reflect proposed agricultural development pathways?

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Background and Objectives

The expanded use of surface water for irrigation, intensified farm management, and double cropping have been highlighted by the Government of Bangladesh as policy priorities and development imperatives in the coastal region[1]. A deltaic country, Bangladesh has a dense network of interconnected rivers and over 230 tributaries flowing into the Bay of Bengal[2]. Most farmers cultivate rice during the summer monsoon. In the subsequent winter season that is characterized by low amounts of rainfall, many farmers do not irrigate despite available surface water resources in naturally flowing canal systems. Rather, they tend to fallow their fields or grow pulses without intensive management practices. Use of available water resources for irrigation, intensified farm management, and double cropping are relatively rare.

The reasons for this 'ironic' situation are complex. They involve challenges with soil and water salinity, lack of infrastructure and market integration, and farmers' generally low investment capacity and aversion to risk, among others[2]. Most studies in the coastal region have focused on addressing these issues from a biophysical or agronomic standpoint, or by using econometric approaches to examine farmers' interest in intensified crop management and the use of irrigation. Considering agronomic management, there are many approaches that have been deemed as technologically feasible[3]. Less information is however available on how different kinds of farmers perceive and approach these complex issues. Similarly, the relevance for policy and development initiatives in coastal Bangladesh is relatively under-researched. Therefore, the objectives of this study were to analyze farmers' perceptions of their predominant farming systems and explore corresponding constraints and perceptions of the use of surface water as a means to intensify farm management.

The Cereal Systems Initiative for South Asia (CSISA) is a regional initiative to sustainably increase the productivity of cereal-based cropping systems, thus improving food security and farmers' livelihoods in Bangladesh, India and Nepal. CSISA works with public and private partners to support the widespread adoption of resource-conserving and climate-resilient farming technologies and practices.

The initiative is led by the International Maize and Wheat Improvement Center (CIMMYT), implemented jointly with the International Food Policy Research Institute (IFPRI) and the International Rice Research Institute (IRRI), and is funded by the US Agency for International Development (USAID) and the Bill & Melinda Gates Foundation.

Methodology

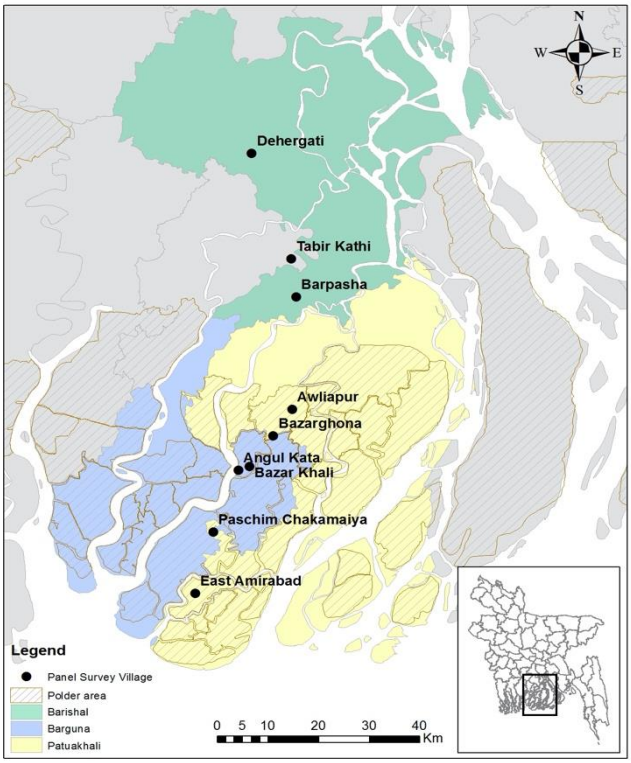

Figure 1. Map of Bangladesh highlighting the study area in the south-central coastal region.

Six villages from three districts (Barisal, Patuakhlai and Barguna of Barisal division) selected for this study. These villages were purposefully chosen considering their potential to make use of surface water as a resource for irrigation (Figure 1). Villages were located in south central Bangladesh, in a hydrologically active zone with access to freshwater for at least part of the dry season[4]. Villages located within polders (in Patuakhali and Barguna districts) and outside polders in (Barisal district) were included. Polders are coastal embankments meant to protect against salt water intrusion. They are common in coastal Bangladesh, and have been shown to influence the localized characteristics of farming systems[5]. Our goals were to develop a broad understanding systematic understanding of issues related to surface water irrigation and crop intensification in the winter ('*rabi*') season (which spans from mid-November to mid-March).

Study participants: Prior to finalizing surveys, we conducted six focus group discussions with groups of farmers in different regions of Barisal division during a preliminary research phase. Surveys were subsequently developed by asking farmers about the interrelationship of different farming components, their cultivation methods, double cropping, cropping patterns, crop management, irrigation systems and surface water irrigation. The number of farmers surveyed represented at least 5 percent of the total household number in each village. This resulted in a total sample size of 240 farmers. To identify the number of targeted households we used population census data in Bangladesh[6], after which each selected village was divided into four blocks with 10 farmer households randomly in the cardinal compass directions. Face to face surveys were then completed with 40 farmers from each village.

Focus group discussions and surveys: In focus groups, discussions aimed at elucidating farmers' present and previous experiences and knowledge of farming practices, which are passed from generation to generation. We also sought to identify farmers' perceptions of their agricultural systems and to relate them to precieved external drivers affecting their choices for crops and crop management practices. Based on this information, a structured questionnaire was developed to query farmers on their perceptions of 34 components identified as relevant following in focus group discussions. Those components were categorized into three categories: (i) Farm functional factors factors (e.g. land size and amount of fallow land, cropping patterns, livestock ownership, and availability of water in canals), (ii) socio-economic factos (e.g. gross income of farmers, remittances, off-farm income, the amount of crops marketed in the last year, and acces to markets), and (iii) environmental factors (e.g. unpredictable precipitation, effect of

flood and cyclones). To obtain detailed information and to collect necessary data, individual surveys were administered during September of 2015. The survey insturment included two sections; (1) demographic information of the farm household and farm configuration, and (2) farmers' perceptions on selected components that had been identified through focus group discussion.

Fuzzy cognitive mapping: Fuzzy cognitive mapping (FCM) is a useful method where causal factors and their effects are difficult to directly quantify – as is the case in perceptual and psychological systems – and where there may be uncertainty in complex socio-ecological systems[7]. FCM is a semi-quantitative method that can be used to identify and depict important factors governing farmers' perceptions of farming systems and elucidate their decision-making process[8]. These methods can be used to generate a conceptual 'mental map' of a given perceptual system that identifies internal perceptual constructs and structures of an external environment[9], in this case the coastal farming systems of the study area. A set of closed-ended questions were added to surveys using a seven-point Likert scale to allow farmers to state the positive and negative degrees of strength of relationships between internal factors and perceived external drivers of their agricultural systems. 'FuzzyDANCES' software[10] was used for this analysis, where selected components were presented by different weights (ranging from -1 to 1) to define the causal relationship between linked concepts. A positive relationship between two components in the cognitive map indicates that an increase of one component would result in the same directional influence on the other component. Conversely, a negative value indicates an inverse relationship between two associated components. A neutral value represents the absence or non-effectual value of a perceived relationship[11].

After 20 rounds of matric multiplications, a cognitive map was developed to describe farmers' average perceptions of their farming systems for those cultivating land both within and outside of polders. To understand the strength of relationships and contribution of internal as well as external components in the farming system, centrality (absolute) values generated by 'FuzzyDANCES' software were considered. The influence of individual components to others was indicated through this centrality value[12].

Sensitivity analysis: To study the effect of influential external drivers (e.g., product prices, off-farm income generating activities, or the availability of water resources) on corresponding components in farmers' perceptions of their agricultural systems, we conducted a sensitivity analysis of the FCMs by employing the Winding Stairs algorithm[7] in 'FuzzyDANCES'.

Results

From the six focus group discussions, 34 primary perceptual components of farming systems were identified. Six crops were mentioned by farmers, including winter season '*boro*' rice, spring season '*aus*' rice, wheat, maize, mungbean and Lathyrus. *Boro,* wheat, and maize were grouped as 'irrigated crops'. Figure 2 demonstrates the complexity of farmers' perceptions of their farming systems and the linkages between irrigated and rainfed crops, access to and management of resources, markets, and environmental factors.

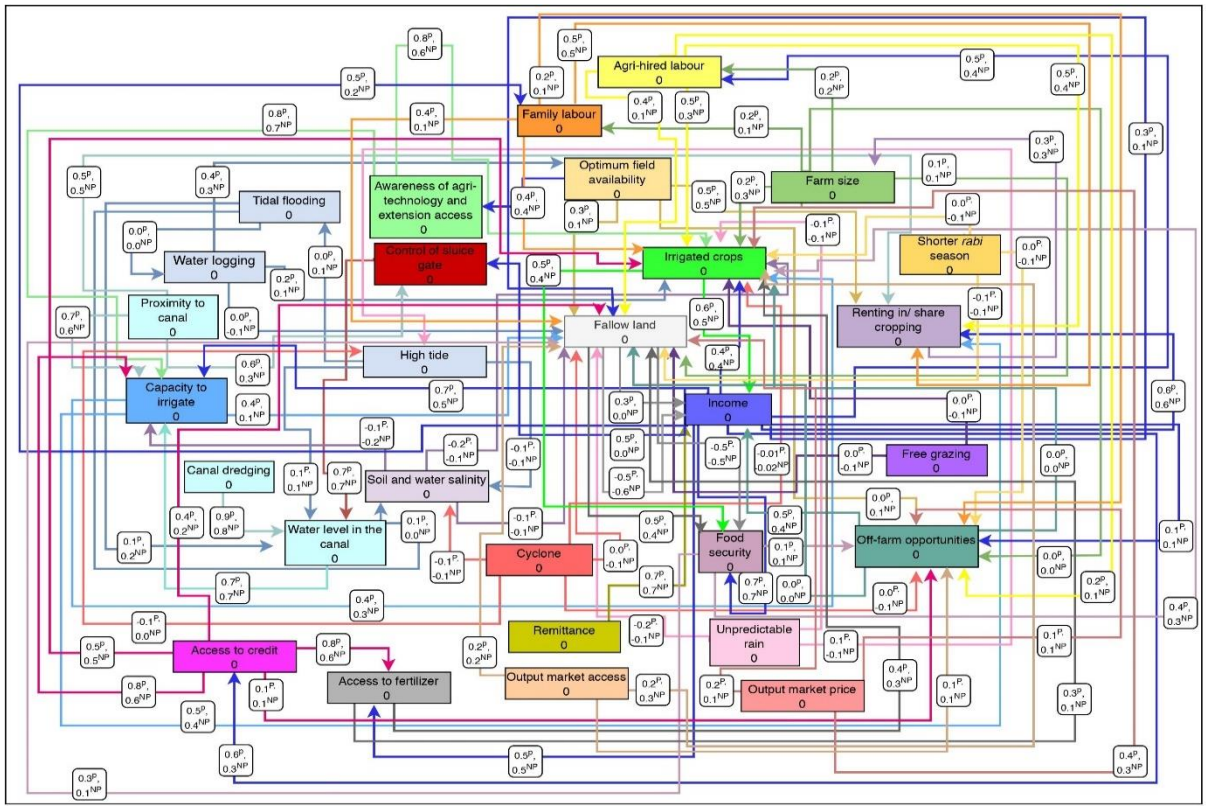

Figure 2. Fuzzy cognitive map depicting the perceptions of farmers and their farming stems within polders (P) and in non-polder (NP) environments in the central coast of Bangladesh. Each box contains different components of the farming systems and values on the lines indicate the strength of relationship between components as quantified during surveys.

Following sensitivity analysis, bar graphs describing the centrality values obtained for farmers' perceptions were generated. Figure 3 provides the observed centrality values and compares the results from the FCMs developed to represent the perceptions of farmers both within and outside of polders. Higher centrality indicates increased importance of a particular concept.

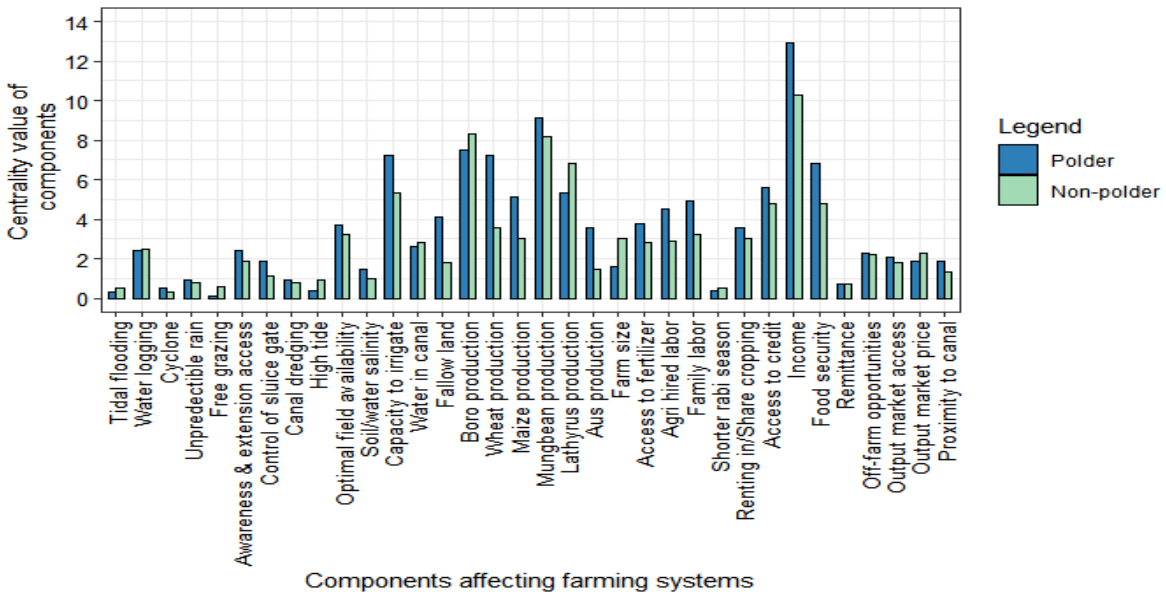

Figure 3. Centrality of components of concepts in the Fuzzy Cognitive maps developed using farmer farmers and their farming stems within polders (P; *n* = 120 farmers) and in non-polder (NP; *n* = 120 farmers) environments in the central coast of Bangladesh.

Components with higher centrality values for both groups included mungbean – with is an increasingly popular dry season crop grown without irrigation on residual soil moisture, irrigated winter *boro* rice production, and 'capacity to irrigate'. Map linkages indicate that farmers perceived that the irrigated crops could contribute to increased income generation where markets are sufficient. Farmers cultivating land within polders in the south of the study area greater emphasis on the perceived viability of the use of surface water for dry season *boro* rice production with irrigation, while also emphasizing interest in mung bean as a non-irrigated alterative crop that can augment income generation. Farmers with farms outside polders conversely placed less emphasis the importance of engineering structures to assist in water resources control and maintenance, for example sluice gates (which have been previously installed through governmental programs but which tend to be in a state of partial disrepair), and ability to tap surface water for irrigation when tides are high and when canals are full of water those outside of polders. On the other hand, farmers in polders identified clear relationships between water engineering structures, water management control, and the potential to augment household income through irrigated cropping. This observation was despite their perceptions that polder infrastructure was poor, and related to problems including soil and water salinity, drainage problems, canal siltation, and land use conflicts arising from inadequate maintenance.

Considering choice of crop type and crop management and their relationships to system outcomes such as food security, and income generated, the variable output market product price exerted considerable driving influence across all farms in the fuzzy cognitive maps developed. Farmers cultivating land within polders in the southern part of the study area appear to be more concerned with the effect of potential market prices to stimulate crop choice decisions than those outside of polders to the north. Given the cognitive maps developed, perceptual linkages are clearly observed that when product prices increase, farmers are likely to be more interested in the cultivation of irrigated crops. This linkages also has knock-on effects observable in the FCMs, with farmers potentially choosing to reduce the portions of their farms typically fallowed in the dry season by replacing them with irrigated and remunerative crops.

Off-farm activities also appear to influence farmers' perceived interest in dry season crops. This is likely because off-farm activities can generate additional income that could be invested in more resource intensive irrigated crops such as *boro*, rice, and wheat. Regarding the variable representing accessibility and availability of canal surface water for irrigation, no influential perceptual links were fount for irrigated crops, sharecropping, or land fallowing. Conversely, the variable capacity to irrigate – which represented access to irrigation pumps and cash and fuel resources to run them –had more influence on farmers' perceptions of the uses of surface water irrigation.

Other than these variables, we observed a few other external factors that appear to have linked influence on farmers' interest in intensification of their crop and farming systems. These included variables representing access to extension and technical information, the potential availability of bank loans or micro credit for agricultural investments, and farmers' participation in agricultural cooperatives. The perceived influence of these factors on the system and farmers' interest in increasing use of surface water for irrigated cropping in the winter season were further examined through sensitivity analysis. This was achieved by increasing the strength of these

relationships with other components in the farming system and examining how other variables in the FCM responded.

Results of sensitivity analysis indicated that investment opportunities represented by the access to bank loans or credit variable was perceived as an important constraint; if alleviated, farmers collectively perceived that access to finance could increase the proportion of irrigated dry *rabi* season crop cultivation on their farms, with a corresponding in reduction in fallowed land area during the winter season. Increasing the frequency of visits by extension agents and sharing knowledge also appears to be linked to these outcomes, with FCMs and sensitivity analysis indicating that an increase in this variable would result in the increased likelihood of farmers to intensify cropping and use surface water for irrigation. FCMS also indicated that farmers' capacity to irrigate will increase through efforts to assure increased and stable availability of water in canals, which could be tapped for irrigation to reduce land fallowing. This is however challenging given the temporally changing semi-saline and freshwater tidal nature of the stud areas in the south and north, respectively, and the need for canal rehabilitation to improve water flow and residency time in canals. Similarly, FCMs indicated linkages between output market prices for crops and off-farm activities. Both variabilities appear to be perceptually and positively linked to double cropping in the study sample.

Discussion and Conclusions

The Government of Bangladesh has placed emphasis on intensified winter season cropping in the coastal south of Bangladesh by using surface water irrigation to alleviate moisture constraints. Few policy documents or programs working to achieve this aim however consider the importance of farmers' perceptions and their potential interest in intensification. Where target groups of people can be identified that are most likely to spearhead intensification, development programs can be made more efficient, effective, and influential. We therefore accounted for farmers' perceptions of different farming components and interest in intensified management and surface water irrigation using methods commonly applied in socioecological systems analysis, namely FCM.

Our analysis indicated that farmers with more resource endowed intensive farms tended to be more intensively engaged with agricultural activities in both polder and non-polder area. These farmers are potentially good candidates for programs championing use of surface water irrigation and crop intensification, since they already have some familiarity with winter season cropping and already engage in rainfed production of pulses on some of their land in the winter. As the availability and accessibility of land is short in coastal Bangladesh[13], farmers who are already making some attempt at intensified cropping and who have access to land resources represent a logical starting point. Focusing on resource endowed farmers, however, is somewhat at odds with agricultural intensification projects aiming to support the poor and vulnerable as primary development clients. This is an important trade-off that needs to be surmounted to improve equitable and just development.

Similarly, farmers' perceptions have importance and provide some indication of their understanding of factors limiting intensification that must be tackled in development programs. Currently, farmers both in and outside of polders do not make intensive use of surface water resources for irrigation, despite the availability of pumps and some, albeit limited knowledge of agronomic management for winter season crops. Some of the limitations to changing this

scenario are highlighted by this study. Despite the presence of extension, farmers indicated that the frequency of contact remains low. In addition to issues with the maintenance and reconstruction of polders and use of sluice gate to assure consistent water flow[1], these factors appear to act as a constraint to surface water irrigation, reduced land fallowing, and double cropping. Issues such as water logging, salinity, late transplantation of monsoon season rice, and difficulties in accessing irrigation water were also identified. These variables were however but not as crucial as access to extension, finance, and use of agricultural cooperatives to de-risk investments in intensified cropping. Our sensitivity analysis indicated that at least for farmers with some background experience and initial interest in use of surface water for irrigation, tackling these constraints could help overcome perceptual barriers crop intensification and double cropping through expanded use of surface water for irrigation in the dry *rabi* season.

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