Promoting Socially Inclusive and Sustainable Agricultural Intensification in West Bengal and Bangladesh (SIAGI)

Development of Prototype Models Using Fuzzy Cognitive Mapping

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Summary

Integrated modelling is one key contributor to achieving Objective 2 of the SIAGI project: *To identify opportunities to manage risk and promote social inclusivity and equity under different agricultural development scenarios using scenario and trade-off analysis*. This document provides an overview of Fuzzy Cognitive Mapping, the modelling approach selected for use in the SIAGI integrated modelling activities. The modelling approach and a web-based software, Mental Modeler, has been trialled with the SIAGI partners. One of the demonstration models built through this trial is presented and some of the challenges of the approach are identified. The proposed model themes and questions and an outline of the upcoming modelling activities are also provided.

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1 Introduction

The SIAGI project contains all the elements of a "wicked problem", whereby there is a high degree of uncertainty, cause-effect relations are complex and tangled, and solutions are unclear. Such problems require a concerted, collaborative effort of all affected parties (Parrott 2017). Modelling can contribute to this process as a tool for organising data, knowledge and assumptions and facilitating some of the dialogue between parties, including the community, stakeholders and scientists. Integrated models combine multiple and diverse components, crossing disciplinary, organisational and conceptual boundaries, to provide a broader picture of the problem and system. In SIAGI, integrated modelling will also serve to gain deeper understanding of the interrelationships between different components (e.g. social, environmental, political/institutional and market). Important to note is that we are more concerned with the process of developing and using model(s) to gain insight than with the model itself.

This document reports on the progress made in the development of the integrated models, under Objective 2 '*To identify opportunities to manage risk and promote social inclusivity and equity under different agricultural development scenarios using scenario and trade-off analysis*'. Firstly, an outline of the steps involved in the integrated modelling process is provided, giving context to the modelling activities completed and those underway (Section 2). This is followed by an overview of Fuzzy Cognitive Mapping (Section 3), the modelling approach selected for SIAGI. In early 2018, part of the SIAGI team trialled Fuzzy Cognitive Mapping and the software Mental Modeler – one of the demonstration models created during this trial is presented in Section 3.1.3. This is followed by an overview of the on-going development of the prototype models, including the model themes and questions and the planned modelling activities.

2 IM process

The integrated modelling (IM) process generally contains the following steps (Hamilton et al. 2015):

i) definition of the problem and its scope, including the objectives, system boundaries, stakeholders and issues of concern,

ii) system conceptualisation, including identifying the key variables, processes, indicators/criteria and scales,

iii) definition of management scenarios or interventions,

iv) model development, from selection of the modelling approach, and defining its structure and parameters

v) model simulation of scenarios and potential impacts

vi) evaluation of management scenarios, and finally

vii) communication of findings and their implications, including a comparison of alternative scenarios and the tradeoffs involved.

These steps are broadly chronological, but they can occur concurrently and be iterative, particularly if new insights on the problem or system come to light.

Steps i to ii above correspond to the SIAGI project activities 1.1 to 1.8, where efforts were focussed on understanding the various social, institutional, economic and environment issues and processes affecting the communities with respect to agricultural intensification. Steps i and ii are addressed more explicitly in companion reports by Hamilton et al. (2018) and Merritt and Hamilton (2018). The identification of management scenarios also started emerging through activities 1.1 to 1.8, namely interventions related to irrigation, value-chains, farming group collectives and community-based water management. The specific management scenarios that will be addressed in the modelling are currently being defined in an iterative process with the SIAGI team (Section 4.1).

The model development step (iv) has also commenced, with the modelling approach selected (Section 3) and the building of prototype models underway (Section 4). The model development will include community-based collaborative modelling to gain deeper understanding of the given problem. Steps v to vii will be based on the final models co-developed with the community.

3 Fuzzy Cognitive Mapping

3.1.1 Overview of FCM

A Fuzzy Cognitive Map (FCM) represents a system or problem as a network of interrelated concepts, which represent different characteristics or factors of the system. Relationships between these concepts are described by arcs (directed arrows) with a weight between -1 and +1, where -1 indicates the 'parent' has a strong negative effect on the 'child', +1 indicates a strong positive effect, and values close to zero imply weak causal effects. The process of developing an FCM involves identifying the most important variables in relation to a problem (*defining the concepts*), and defining the direction and strength of relationships between these variables (*defining the weight arcs*). This can be a fairly intuitive process, making the approach suitable for participatory and collaborative modelling.

An example of a simple FCM, developed using the Mental Modeler software is shown in Figure 1. This example demonstrates how a FCM can be developed from qualitative data. The structure was defined from notes taken in February 2018 documenting discussions between the lead author and the CDHI team. The concepts are phrases from the discussion around enablers to the community accessing available government schemes. The blue line with the + sign indicates that two variables are positively correlated. An example of this is *Facilitation and advocacy* leads to greater *Awareness of a scheme*. A negative relationship between two variables is indicated by the red line with the - sign. For example, as the community's *Confidence to assert rights* increases, it could be expected that the incidence of the capture of schemes by influentials (*Elite capture*) would decrease.

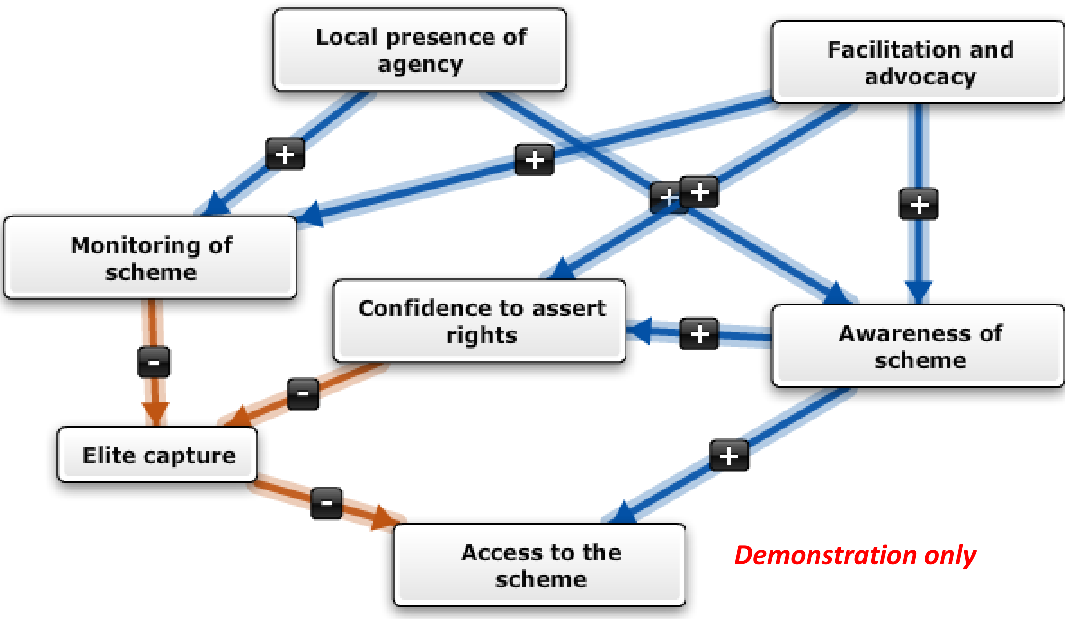


Figure 1 Example of a Fuzzy Cognitive Map developed using the Mental Modeler software.

Our review of integrated modelling approaches for the SIAGI project (Hamilton et al., 2018), identified the need for a flexible approach that was capable of representing a diverse range of variables and incorporating qualitative and quantitative data, and had the capacity to serve as a tool for engagement with the community and project team. FCM was deemed to be highly appropriate given its flexibility (in that concepts can represent any characteristic/factor) and its simple and intuitive structure. Its advantage over Bayesian networks, another modelling approach with those aforementioned features, stems from the capacity of FCMs to incorporate feedback loops as well as the relative simplicity of its quantification of relationships using weights between -1 and +1 (cf. conditional probabilities in Bayesian networks). FCM is considered useful in dealing with complex and broad domains, where there are only partial experts, information is mostly qualitative and fuzzy, and historical data is limited (Jetter and Kok 2014).

There are challenges in choosing whose knowledge to represent, how to collect and interpret that knowledge, and deciding how best to combine different mental models (Gray et al., 2014). Another challenge relates to managing model complexity. Although FCM are conceptually and mathematically simple, interpretability and utility can be compromised as the number of concepts and connections increase. However both these challenges apply to all types of models.

Specific advantages of the FCM approach are that it: can represent concepts that are hard or not desirable to quantify; provides flexibility to model across domains (and possibly scales); and is a relatively easy entry-point to modelling complex systems. The latter facilitates integration between modellers and non-modellers within the SIAGI team. Most importantly, the approach lends itself to application by a transdisciplinary team committed to *Ethical Community Engagement*. There have been several studies that have successfully used FCMs in co-developing models with the community (e.g. Diniz et al. 2015; Halbrendt et al. 2014; Murungweni et al. 2011; Singh and Nair 2014); see Hamilton et al., 2018 for more details of these studies. Also, by providing a bridge between qualitative and quantitative methods, the FCM approach can readily build on the conceptual modelling undertaken in Years 1 and 2 of the SIAGI project (see Merritt and Hamilton, 2018).

3.1.2 Mental Modeler software

FCMs will be developed in SIAGI using the web-based software Mental Modeler. This software was developed by Dr. Steven Gray and colleagues to *“support group decision-making, allowing users to collaboratively represent and test their assumptions about a system”* (http://www.mentalmodeler.org/, accessed 08/06/2018). It has been applied as a research tool to capture individual or group 'mental models' that often underlie human decision-making (Gray et al. 2015).

The software can be accessed without cost as an online tool which should facilitate the SIAGI team to co-develop and share models for our case studies. Given internet access we could use the tool in team workshops to explore model behaviour, test alternate model structures and run scenarios.

3.1.3 Trialling Mental Modeler with SIAGI partners

A pilot run of Mental Modeler in SIAGI was conducted by Wendy Merritt in February 2018. The trial included Pulak Mishra at IIT Salt Lake, the CDHI team in Jalpaiguri, and colleagues from both BAU and Shushilan in Dhaka. Overall, FCM proved a flexible approach that was reasonably intuitive to the non-modelling members of the project team. It seems suited to capturing the various issues at play in the SIAGI study villages for which we want to model a range of scenarios. In this section we run through a demonstration of an FCM, using one of the examples which was developed from the February discussions with BAU and Shushilan in Dhaka[1] about access to irrigation water in the dry season in Khatail and Sekendarkhali, and the role of the Water and Silt Management Committee (WSMC) in Sekendarkhali. Some extracts of these discussions is given in Box 1.

Box 1: Quotes from Merritt et al 2018 February trip report

[SEKENDARKHALI] "An example of ***improved community confidence and collective action*** was that when a new person took over the UNO [Upazila Nirbahi Officer] role and said 'no I cannot sign off on this now in case there is a problem', the ***community took charge*** and got clearance from all the necessary departments (e.g. agriculture and fisheries). There was a 3-month delay from government so the ***community went to the UNO and said 'this is last year's work and should be done'. The new UNO said I have to see the village for myself to make sure this will work***. He then signed off on the arrangement in early January. ***The community's action was not dependent on Shushilan***."

[SEKENDARKHALI] "There remains some constraints to ***community control over water***. There is a motivation issue with ***the politically connected*** who have in the past benefitted from sluice gates in that they could sell water; they have ***little interest in handing over control*** to the community. However the ***WSMC has become more capable and mature, enabling community water management to continually strengthen***. Additionally, Sekendarkhali is located ***close to a sluice gate and effective local monitoring is possible***."

[SEKENDARKHALI] ***Before the establishment of the WSMC, the canals (and therefore water) were 'public owned but not public controlled'*** and so was neither inclusive nor equitable. There was unequal capacity for farmers to access water with distance and lack of irrigation equipment being major constraints. Social barriers included ***conflict of interest***, societal-level gender issues and social customs that impact community allocation of available water. With the maturation of the WSMC and empowerment of the community the expected situation is that water in the canals will be 'public owned and public controlled' and distribution of water will be equitable. This is not yet the case ..."

[KHATAIL]: "At the start of the ACIAR ... saline water in Rabi was not being managed for farmers' requirements. Farmers were not acting collectively, had ***poor linkages with institutions, lacked political connections***, and are ***located a prohibitive distance from sluice gates*** and the primary canal. This led to ***conflict of interest of the influential in the area who controlled the primary canal*** and allowed saline water intrusion for gher operators.

[KHATAIL]: "Leaders are developing naturally and they are more important in Khatail than in Sekendarkhali because ***the UP in Khatail is not supportive***"

At the conclusion of that day's meeting, key concepts from the meeting notes were identified (shown as bold italics in Box 1) and used to demonstrate the Mental Modeler tool with the team the following day. In the demonstration model, comments specific to Khatail and/or Sekendarkhali were translated to 'generalise' social and other factors influencing the output (*community control of water*). The demonstration model in Figure 2 captures the following concepts (i.e. boxes in the figure and the italicized text below) and their relationships:

> The early process of establishing the WSMC and farmer groups was an intensive period of activity for Shushilan (supported by SIAGI and CSI4CZ partners) where their *Facilitation and*

[1] Participants: Wendy Merritt, Mustafa Bakuluzzaman, Mahanambrota Dash, Kazi Farid, Md Mojammel Haque, Md Ismail Hossain, Serajul Islam, Hasneen Jahan, and Wakilur Rahman

advocacy was critical in developing *Community ownership*, and *maturity and confidence of the WSMC* (and its individual members). *Community ownership of WSMC* positively affects *community monitoring of sluice gate*; however *distance from sluice gate* has a negative effect in that the farther the community is located from the sluice gates, the less effective the community is at monitoring the operation of the gates. More effective *community monitoring of sluice gate* leads to better *community control over water* (Figure 2). As noted in Box 1, the Sekendarkhali community are located close to the sluice gates which is in contrast to the SIAGI target beneficiaries in Khatail. Both *community ownership of WSMC* and *maturity and confidence of WSMC* were provided as evidence in Sekendarkhali as providing *capacity to initiate and prompt action by officials*, which is further enhanced by *UP chairman support of poor farmers*. The latter is another contrast between Sekendarkhali and Khatail; farmers in Khatail do not receive the same level of support from the chairman of Pankhali Union Parishad (who has an interest in gher farming which relies upon saline water). Both *capacity to initiate and prompt action by officials* and *UP chairman support of poor farmers* have a negative effect on the *self-interest of the politically connected* which in turn is has a negative effect on *Community control of water*.

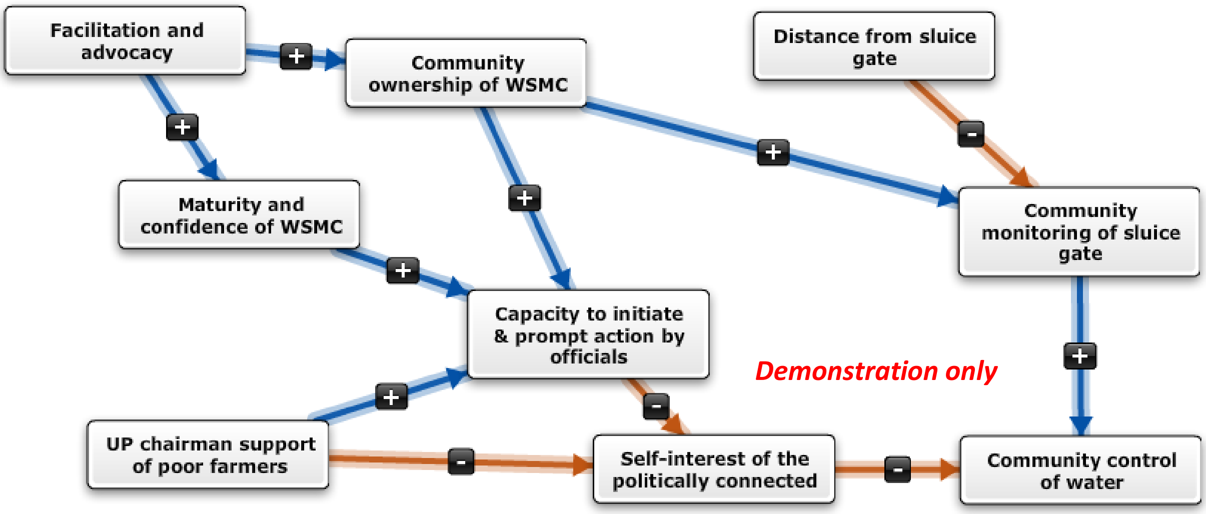


Figure 2 Using narratives to explore 'community control of water' using a Fuzzy Cognitive Map developed using the Mental Modeler software.

In this initial demonstration, all relationships are set as strong (either +1 [blue lines] or -1 [red lines]) but we could get more sophisticated and represent varying weights of importance in the software. Once a model is set up in the software, we can also explore scenarios by increasing (between 0 to 1) or decreasing (between -1 to 0) variables. In Table 1, some simple scenarios were run by increasing or decreasing three concepts in the model: *Distance from sluice gate*, *UP chairman support of poor farmers*, and *Facilitation and advocacy*. Numbers in blue and red indicate improvements or declines, respectively, in the changed variables with respect to their preferred state.

The scenarios could represent Khatail or Sekendarkhali, with or without the presence of *facilitation and advocacy* in the community. The impacts of scenarios on other variables are shown as relative numbers (between -1 and 1) in Table 2. Numbers in blue and red indicate improvements or declines, respectively, toward the preferred state. If we look at the first four scenarios (shaded in light grey in the tables) where the *distance from the sluice gate* is increased by 1 (i.e. set further away), we see improvement as we shift from an unhelpful UP to a supportive UP and again as we increase facilitation. Note that the results should be interpreted with care; although all of the first three scenarios show a negative response for *community monitoring of* *sluice gate* (due to the distance being set to farther from the sluice gate), facilitation lessens this negative response.

Table 1. Scenario settings

Scenario Settings	Unhelpful UP + sluice gates far[1]	Unhelpful UP + sluice gates far + facilitation	Supportive UP + sluice gates far	Supportive UP + sluice gates far + facilitation	Unhelpful UP + Sluice gates close	Unhelpful UP + Sluice gates close + facilitation	Supportive UP + sluice gates close[2]	Supportive UP + sluice gates close + facilitation
Distance from sluice gate	1 (farther from sluice gate)				-1 (closer to sluice gate)			
UP chairman support of poor farmers	-1	-1	1	1	-1	-1	1	1
Facilitation and advocacy		1		1		1		1

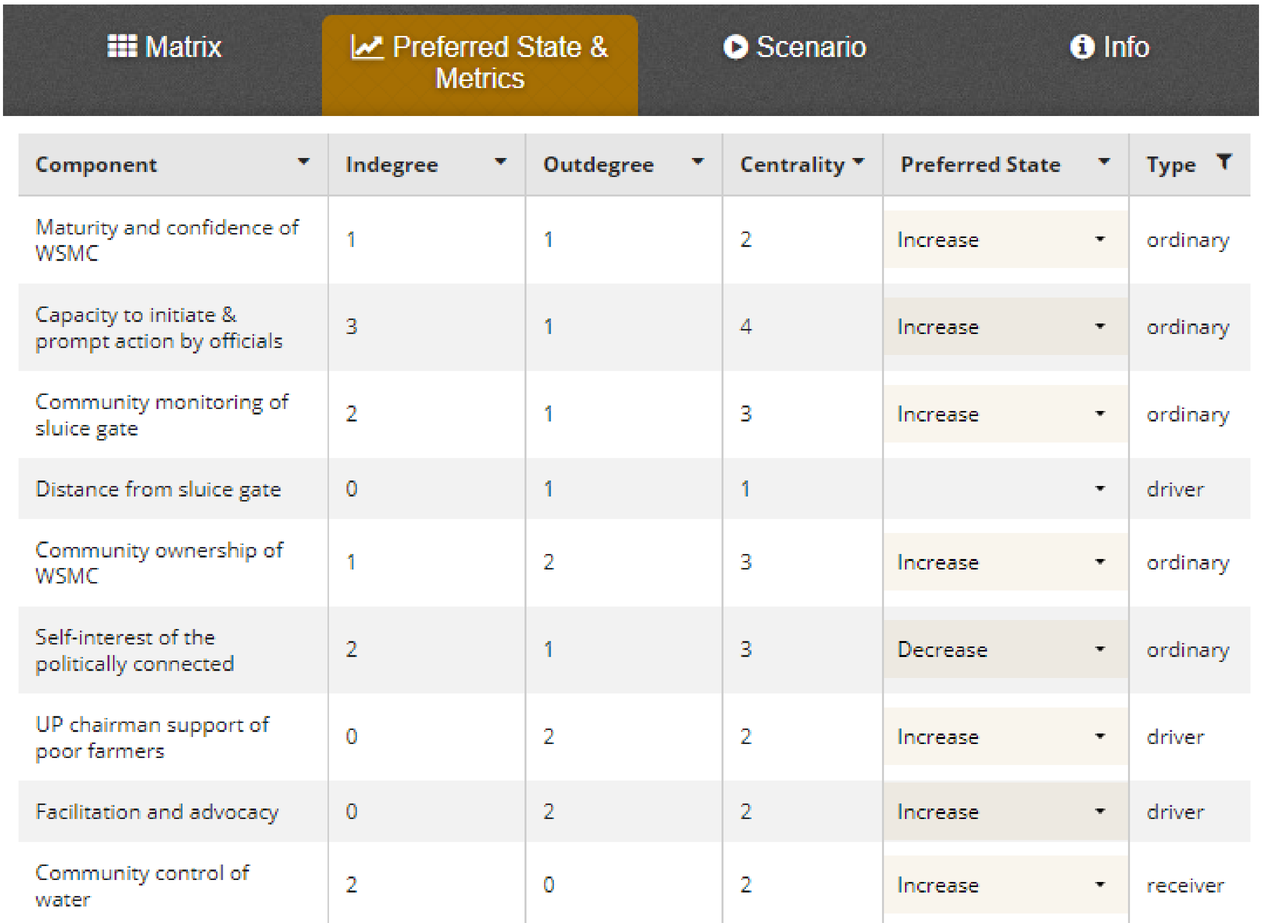
[1] This scenario could be considered to represent the situation in Khatail prior to the start of the ACIAR projects
[2] This scenario could be considered to represent the situation in Sekendarkhali prior to the start of the ACIAR projects

Of the eight scenarios considered (Table 1), the 'worse case' involved an unhelpful UP and farther distance from the sluice gate (first column in Table 2), which resulted in four of the variables (67%) showing a trajectory away from their preferred state and the remaining two (33%) variables showing no change. On the other hand, the 'best case' considered involved a supportive UP and a close distance to the sluice gate, with facilitation (last column in Table 2); this resulted in all six variables indicating a trajectory towards their preferred state. These results are in line with general expectations, indicating that the logic of the model structure is reasonable. A next step would involve assigning weights to the arcs, corresponding to the expected strengths of the cause-effect relationships, and then a rerun of the scenario analysis.

Table 2. Scenario results

Variable name	Unhelpful UP + sluice gates far[1]	Unhelpful UP + sluice gates far + facilitation	Supportive UP + sluice gates far	Supportive UP + sluice gates far + facilitation	Unhelpful UP + Sluice gates close	Unhelpful UP + Sluice gates close + facilitation	Supportive UP + sluice gates close[2]	Supportive UP + sluice gates close + facilitation
Maturity and confidence of WSMC	0	0.11	0	0.11	0	0.11	0	0.11
Capacity to initiate & prompt action by officials	-0.29	-0.24	0.05	0.07	-0.29	-0.24	0.05	0.07
Community monitoring of sluice gate	-0.12	-0.1	-0.12	-0.1	0.3	0.32	0.3	0.32
Community ownership of WSMC	0	0.11	0	0.11	0	0.11	0	0.11
Self-interest of the politically connected	0.4	0.39	-0.08	-0.08	0.4	0.39	-0.08	-0.08
Community control of water	-0.13	-0.12	-0.01	0	-0.02	-0.02	0.09	0.09

Another basic analysis in Mental Modeler measures each variable's 'centrality', which is an indication of its relative importance for the system based on the strength of incoming and outgoing cause-effect relationships. The most central variable in the demonstration FCM (Figure 2) was *capacity to initiate & prompt action by officials* with a centrality score of 4 (Figure 3). In this example model, the centrality is based on the number of incoming and outgoing arcs since all relationships in the model were assumed to be equal; the measure would be more meaningful with appropriate weights assigned. The strength of the incoming and outgoing connections of a variable are represented by in-degree and out-degree scores. The variables with the highest out-degree scores with in-degree scores of zero, are considered the top driving variables, which have substantial impact on the system dynamics (Nyaki et al. 2014); these are *facilitation and advocacy* and *UP chairman support of poor farmers* in Figure 3.



Component	Indegree	Outdegree	Centrality	Preferred State	Type
Maturity and confidence of WSMC	1	1	2	Increase	ordinary
Capacity to initiate & prompt action by officials	3	1	4	Increase	ordinary
Community monitoring of sluice gate	2	1	3	Increase	ordinary
Distance from sluice gate	0	1	1		driver
Community ownership of WSMC	1	2	3	Increase	ordinary
Self-interest of the politically connected	2	1	3	Decrease	ordinary
UP chairman support of poor farmers	0	2	2	Increase	driver
Facilitation and advocacy	0	2	2	Increase	driver
Community control of water	2	0	2	Increase	receiver

Figure 3 Screen capture of the demonstration model metrics.

The Mental Modeler software with its underlying FCM approach seems to be a relatively intuitive and useful tool for the SIAGI project. The concepts discussed in the meetings were readily translated into demonstration models. The potential of the FCM is that concepts that are difficult (or not desirable) to quantify can be represented and there is flexibility to model across domains and scales. The key challenges identified by members of SIAGI are:

- managing the complexity of models namely by avoiding too many concepts or connections *(a modelling problem not restricted to FCM)*,
- eliminating ambiguity in the concepts and how they respond to scenarios,
- developing capacity in FCM by the research team members given limited prior exposure to integrated modelling, and
- designing data collection and participatory modelling to complement the project teams' commitment to ethical community engagement.

The latter will remain front of mind although should be noted that one of the reasons the FCM approach was selected is because it is considered the approach most aligned with ECE. There are several ways that the community can be engaged in the modelling process, some of which are touched on in Section 4.2 (also see Hamilton et al., 2018).

4 On-going development of prototype models

4.1 Model themes and questions

At the March 2018 project meeting, the SIAGI team broke into three sub-groups and brainstormed some themes and questions needing further investigation through integrated modelling or other SIAGI activities. Four themes emerged, each described in the next subsections. Following the workshop, the themes and their corresponding research questions have been revised by the teams (and continue to be), with the intent of devising a set of questions upon which to develop the prototype integrated models.

Two broad types of questions were identified from the literature review (see Hamilton et al., 2018 and Voinov and Bousquet, 2010). Type #1 questions try to understand how a system functions while type #2 questions explore how to affect change (Figure 4). The two types of questions are complementary and both relevant to SIAGI. In order to explore possible impacts of interventions and how to best affect change (#2), it is necessary to first understand the system and its dynamics (#1). This is of relevance because many of the questions identified in the March workshop were type #2, however the corresponding system processes are not fully understood. Therefore in those situations, the corresponding type #1 questions needed to be identified and added to the set of questions. The questions were also refined to ensure they are unambiguous and have a clear scope.

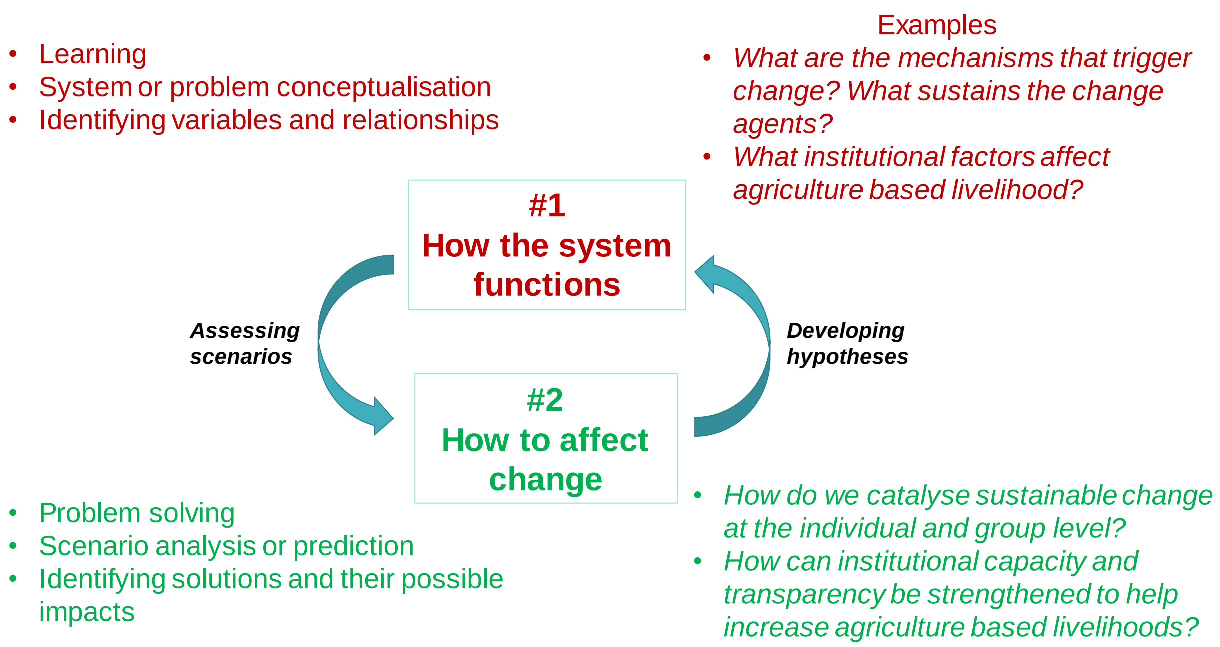


Figure 4 Types of questions IM is broadly used to address, and examples of pertinence to the SIAGI project.

4.1.1 Canal and community water use and management

In Sekendarkhali, the focused theme identified by BAU and Shushilan was *"Canal and community water use and management"*. This theme reflects how economic, social and governance arrangements have influenced the water management system and its impacts, including how these arrangements are changing with the SIAGI project. With the recent establishment of the WSMC, there are questions about whether changes have started to occur in terms of the social processes and the outcomes in water distribution ('Social processes' in Table 3). There are also questions regarding the linkages between environmental conditions (i.e. water availability and salinity) and social (e.g. perception of inclusion or equity) ('*Biophysical* ←→ *Social*' in Table 3). It is not expected that all these questions would be addressed in the integrated modelling. Some questions, such as the more biophysical-focussed ones (indicated by # in the table below), may be better answered by the CSI4CZ project and may provide a point of collaboration between the two projects.

Table 3. Questions for the *Canal and community water use and management* theme.

#1 Understanding how the system functions	#2 Learning how to affect change
Social processes	
How do/did individuals and groups interact and make decisions around the management and distribution of water resources? (pre-WSMC, now)	Will establishing the WSMC and farmer groups lead to more inclusive decision making and more equitable distribution of water resources?
Who has control of water and water infrastructure?	
Who does (not) have a voice? Why (not)?	
How do different members of the community perceive inclusion and equity (with respect to water distribution)?	
Biophysical ←→ Social	
What are the water demands of the different groups? (including timing, salinity levels, minimum thresholds) What are these demands based on? (crop choices, farming practices)	For each group, what canal management and water distribution scenarios are needed to satisfy their demands? How does each scenario affect other groups? Is it possible to achieve water distributions that satisfy all groups given water availability?
How much water resource is there available for distribution? # What are the drivers of water salinity levels? How do salinity levels vary with these drivers? # How does climate affect water availability? #	

4.1.2 Addressing the absence of agriculture-based livelihoods in the Rabi season

The theme identified by BAU and Shushilan for Khatail was *"Addressing the absence of agriculture-based livelihoods in the Rabi season"*. This is a broad issue, reflecting the many challenges facing the Khatail community encompassing water and soil constraints, water use and management, institutional complexities, agricultural knowledge, markets and inputs, and natural calamity. These amount to rather severe constraints to environmentally sustainable and financially viable crop-based livelihoods in Khatail, particularly in the Rabi season, and the need for strengthening of institutional support for both agricultural and non-agricultural livelihoods. The questions identified for the theme are listed in Table 4.

Table 4. Questions for the *Addressing the absence of agriculture-based livelihoods in the Rabi season* theme.

#1 Understanding how the system functions	#2 Learning how to affect change
What opportunities and constraints exist to increase agriculture based livelihood?	How can institutional capacity and transparency be strengthened to help increase agriculture based livelihoods?
What opportunities and constraints exist to increase local non-agriculture based livelihood?	How can institutional capacity and transparency be strengthened to help increase local non-agriculture based livelihoods?
Why are farmers leaving Khatail in the Rabi season?	If agricultural and non-agricultural livelihood options can be developed, will farmers choose to stay in Khatail in the Rabi season?

4.1.3 Reaping the benefits from collectives

The CDHI, IIT and Lilly Lim-Camacho distinguished the *"Reaping the benefits from collectives"* theme, which reflects the ACIAR sister projects' focus in Dhaloguri and Uttar Chakowakheti. This theme is also of relevance to the other case study areas. The theme centres on understanding the benefits of collectives, beyond just income, and ensuring that the poor receive these benefits. The premise of this is that firstly, anecdotal evidence from the collectives in West Bengal has indicated that income benefits have not been significant, or at least other impacts in terms of agency have been more important. Secondly, collectivisation entails the risk of adverse incorporation of the poor, whereby the well-resourced farmers disproportionately capture its benefits; the aim is to avoid or mitigate this risk. The questions identified for the theme are listed in Table 5. It is expected that there are multiple pathways through which the various benefits of collectives can be achieved. By exploring these impact pathways, we may identify opportunities to improving the livelihoods for the poor through, for example, the type of institutional support provided to collectives.

Table 5. Questions for the *Reaping the benefits from collectives* theme.

#1 Understanding how the system functions	#2 Learning how to affect change
What are the incentives/reasons for joining or leaving collectives?	How can we increase and sustain benefits for the poor from collectives?
What benefits can be gained from collectives (by the whole group and individuals within, or by the poor)?	
How are each of these benefits realised (or not)? (i.e. what are the enablers, magnifiers and constraints?)	

4.1.4 Catalysing and sustaining change (for all development actors)

PRADAN workshopped the following theme with Lucy Carter: *"Catalysing and sustaining change",* which applies to all development actors. 'Change' was identified as necessary across various institutional scales (e.g. individual, village, organisational) and comprised of 1) triggering sense of agency/empowerment, 2) resourcefulness, and 3) action (e.g. behaviour change).

There are internal and external influences on capacity to trigger and sustain change at individual and group levels and in processes. For development effectiveness, change needs to happen at individual, group and institutional levels. These are interrelated and connected parts of a system. The questions for this theme are listed in Table 6.

The scope of this theme extend beyond a geographical boundary and explicitly recognises that implementers and researchers, are integral to the change process. SIAGI partners and funders are active learners, champions and change agents and in fact can influence (negatively or otherwise) the development outcomes aspired to. This theme and its questions can be considered in conjunction with the three previous themes.

Table 6. Questions for the *Catalysing and sustaining change* theme.

#1 Understanding how the system functions	#2 Learning how to affect change
How do the decisions I make lead to my desired state? What are the processes that I use to trigger change?	How do you catalyse internal change at individual and group level?
What are the factors needed to motivate change? (that sustains). For all development actors? For NGOs and their beneficiaries?	

4.2 Next steps in the model development process

The integrated modelling efforts will concentrate on the themes for Sekendarkhali, Khatail, Dhaloguri and Uttar Chakowakheti (outlined in subsections 4.1.1 to 4.1.3). The next steps will involve:

- Continued refining of the themes and questions to ensure they are well-defined and with a clear scope
- Assessing what we currently do (or do not) 'know'
    - What do we know about the how the 'system' functions?
    - What are our hypothesised or observed ways to affect change?
- Develop prototype models within the team based on current understanding
- Devise a plan for addressing the questions
    - Which questions will the integrated modelling activities focus on? Which are best addressed by other SIAGI activities?
    - Scope how we engage the community and collect the necessary data

- Engage with the sister projects (DSI4MTF and CSI4CZ) about possible collaboration points.

These activities will be carried out in the last half of 2018. The final models will be built in early 2019; these models will be co-developed with the community.

The prototype models will be built and evaluated within the SIAGI team using learnings from the project to date. The prototype models are intended to identify any gaps in knowledge or data, and inform the methodology for the community-based collaborative modelling. One option being considered is the use of community-based collaborative modelling to capture the community's understanding about the structure and workings of their livelihood system (in relation to the given theme), and possibly explore perceptions or understandings held by different parts of the community.

Two possible approaches to this community engagement include working with small, relatively homogenous groups, or working with a larger, more diverse group. Working with the homogenous groups (e.g. women, landless, small-holder), may generate a deeper understanding of how each group thinks (e.g. Halbrendt et al. 2014, Murungweni et al. 2011). On the other hand, working with more diverse groups can become an exercise in mutual learning, whereby the different 'subgroups' have the opportunity to share their perspectives and assumptions, and come to a shared vision or consensus on how the system works (Henly-Shepard et al. 2015). With the second approach, there may be challenges in achieving consensus and ensuring that voices are heard (Tschakert et al. 2014). The two approaches can be complementary. The design of the community engagement will draw on the expertise and experience in the SIAGI team.

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