Promoting Socially Inclusive and Sustainable Agricultural Intensification in West Bengal and Bangladesh

Stakeholder-driven Discussion Support Tool for Agricultural Development through Suitable Crop Choices

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Australian Government
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Summary

- Quantitative engagement with community using participatory scenario building modelling tools is an important compliment to the largely qualitative social engagement of SIAGI
- The scenario generating model considers a number of resources such as land, labour, capital to produce a certain number of crop-vegetables (as activities) based on a certain number of constraints
- The scenarios use community perceptions (gender-disaggregated) on risk, labour use, market, price-volatility, and self-consumption to explore the consequences of different crop-vegetable choices on (e.g.) income, labour (gender sensitive), use of inputs (environmental impact of intensification), markets. Thus it explicitly considers the trade-offs of pursuing different development pathways (in the context of intensification)
- The scenarios development to adopt a reflective learning process based on the Plan–Do–Observe–Reflect of the Kolb learning cycle
- The quantitative scenarios tool supports a co-learning process among researchers and the farming community
- These tools help build capacity in researchers (Project team) in the first place so their interactions with the community are more informed and effective

1. Introduction

Agricultural policies aim at directing agricultural development in such a way that it leads to attaining a number of socio-economic goals, e.g., increased agricultural production, employment, profit, environmental sustainability, and pollution abatement. A feasible development objective must consider all these goals. Modelling tools should enable analysis in such a way that possibilities and limitations, relationships and interdependencies become explicit. It is especially important to identify conflicting goals and to explicitly quantify the trade-offs among the multiple goals that contribute to sustainable agricultural intensification. Interactive Multiple Goal Linear Programming (IMGLP) is one such modelling technique that has been widely used to integrate different types of information and to generate different agricultural development pathways. This report describes how a discussion support tool, based on the IMGLP technique, is being used by the farming community and SIAGI research team, to make explicit the possibilities and limitations, relationships and interdependencies of different crop-vegetable choices (Zander and Kachele, 1999).

The bioeconomic modelling is developed in the context of the ACIAR supported SIAGI project promoting socially inclusive agriculture intensification in the Eastern Gangetic Plains (EGP). Intensification of agriculture by use of high-yielding crop varieties, better animal breeds and animal husbandry, aquaculture, fertilization, irrigation, and pesticides has contributed substantially to the tremendous increases in food production over the past 50 years. In aggregate terms, agricultural intensification is undeniably increasing food production and ensuring food demand is met. In broad terms it is also helping alleviate poverty. However, this has come at the cost of an increasing social dichotomy between more affluent land holders and socially disadvantaged groups such as landless or marginal smallholders, women-headed households, and tribal minorities. This is because affluent land holders and landlords are in a stronger position to capture the benefits of agricultural intensification. Consequently, these marginal groups are much more exposed to unintended consequences of agricultural intensification.

Accordingly, the aim of the SIAGI project is to understand drivers, apply tools, develop opportunities and provide policy options to promote more socially inclusive and environmentally sustainable agricultural intensification in West Bengal and Bangladesh. This will be addressed through the following project objectives:

1. To understand how key social, institutional, economic and environmental factors affect livelihood risks, social exclusion, adverse incorporation and environmental degradation in agricultural intensification
2. ***To identify opportunities to manage risk and promote social inclusivity and equity under different agricultural development scenarios using scenario and trade-off analysis***
3. To promote the development of socially inclusive, equitable and sustainable agricultural intensification policies and engagement processes

The complex nature of the research being undertaken requires an interdisciplinary systems approach that integrates social, institutional and biophysical research methods, that bridges the community to policy scales, and that engages key next-users (NGOs, government agencies, private enterprises) as integral project partners. The bioeconomic rabi vegetable choice modelling component contributes to objective 2 above at a village scale.

2. Study area

The project has case study locations in the two broad agro-ecological settings of the Eastern Indo Gangetic region:

i. Eastern Gangetic Plains - Coochbehar, India (Dhaloguri and Uttar Chakowakheti villages)
ii. Coastal Zone – Dacope (Khatail village) and Amtali (Sekendarkhali village), Bangladesh

3. Method

The crop-vegetable choice model was developed within the General Algebraic Modelling System (GAMS) that utilises an IMGLP approach (Fig. 1). The basic structure of the linear programme (LP) model has the form of a standard linear programming model, as given by Berentsen & Giessen (1995) and discussed by Van Calker et al. (2004):

$$\text{Maximize } (Z = cx) \quad (1)$$
$$\text{subject to } Ax \leq b \text{ and } x \geq 0 \quad (2)$$

where x is a vector of activities, c is the vector of gross margins per unit activity, A is the matrix of technical coefficients and b is the vector of constraints. The constraints, as given by Eqn (2), consist of resource and policy constraints. The objective function (Z) maximizes returns on inputs (capital, labour, etc.). Z is maximized at the village scale considering the village as a whole farm.

Using the resources and policy constraints, and based on the objectives and questions from the stakeholders, a number of scenario could be generated. These scenarios form the basis of the discussion with the research team and the farming community. Marginal farmers have been selected as the group to model the farms of as they form the majority of the farmers in the case study villages.

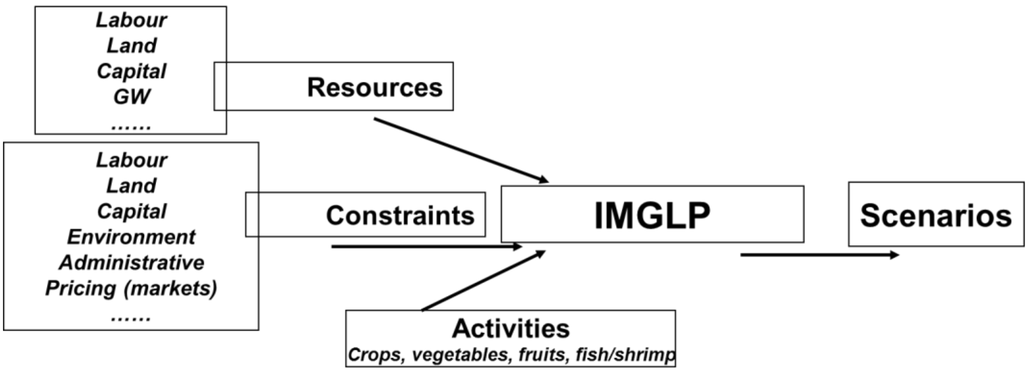

Figure 1: Schematic of the IMGLP approach

The model framework is given in Figure 2. The model at its core chooses an optimal set of crops/vegetables and area to be planted based on a set of resources and constraints. The area to be planted and the crop type are exogenous to the model which means these are 'chosen' by the model. However, the model can be constrained to choose a minimum or maximum area of a certain crop. Multiple objectives can be set such as profit maximisation, maximum or minimum labour use (by gender), maximum or minimum ground water use etc. The key innovation in this modelling work is including **gender based community perceptions on cropping** to influence crop/vegetable choice (See Section 3.4).

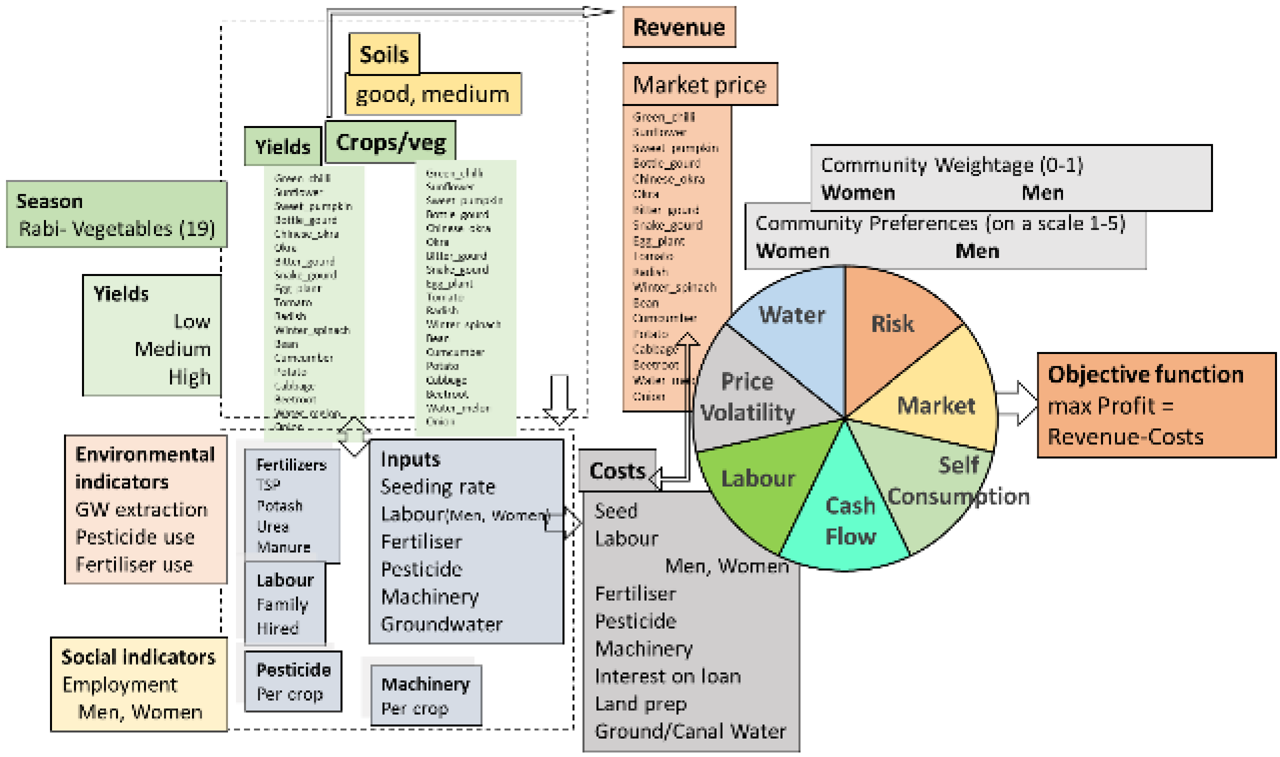

Figure 2: Model framework

Combining the classic optimisation with community preferenced weights connects this work to the larger ethical community engagement process. It is underpinned by modelling that uses community provided data and provides equal weightage to preferences of women and men farmers. A set of novel technical modelling approaches have been used (including integrated LP – NLP) in this process.

3.1 Development process

The development process and timeline of work to date is shown in Figure 3. The steps have been to define questions and objectives, refine and confirm modelling approach with the research team, develop the data collection framework, develop the draft model, conduct data validation with farmers, and demonstrate model and gain feedback from partners, farmers and extension staff.

3.2 Model objectives and questions

This modelling approach uses a set of objectives to drive the model. The objectives could be maximising profit for example while producing enough for family self-consumption. The initial set of objectives defined in consultation with the project team were refined following discussions with the farming communities in Dhaloguri.
The shortlisted objectives are

- Maximising farm income through intensification or yield
- Maximising/minimising labour use; male/female labour

- Minimising pesticide use
- Minimising ground water depletion
- Minimising risks (with respect to both production and income) of farming through crop diversification
- Maximize N use efficiency or minimize N surplus or N losses

Based on these objectives, a number of questions for the model to answer have been developed in consultation with the project team and the participating farming community. The questions include:

- What is the optimal crop-vegetable choice combination for the two seasons maximising for profit (Kharif, Rabi)
- What is the trade-off between maximising income and minimising pesticide use & maximising fertiliser /efficiency?
- How does minimising or maximising labour use impact crop-vegetable choice?
- How does crop-vegetable choice impact male vs female labour use?
- How does access to mechanisation influence crop-vegetable choice (labour, costs, efficiency etc)?
- How can resources be managed (eg water, nutrients) to maximise profit and minimise environmental impact?

These objectives and questions are the 'wish-list' and achieving these from a modelling perspective depends on the data availability in the first instance and the quality of data. Therefore, the modelling activity has been designed to utilise data available either as primary data collected from the participating farming community or from secondary sources such as those published in the District Statistics handbook or other references.

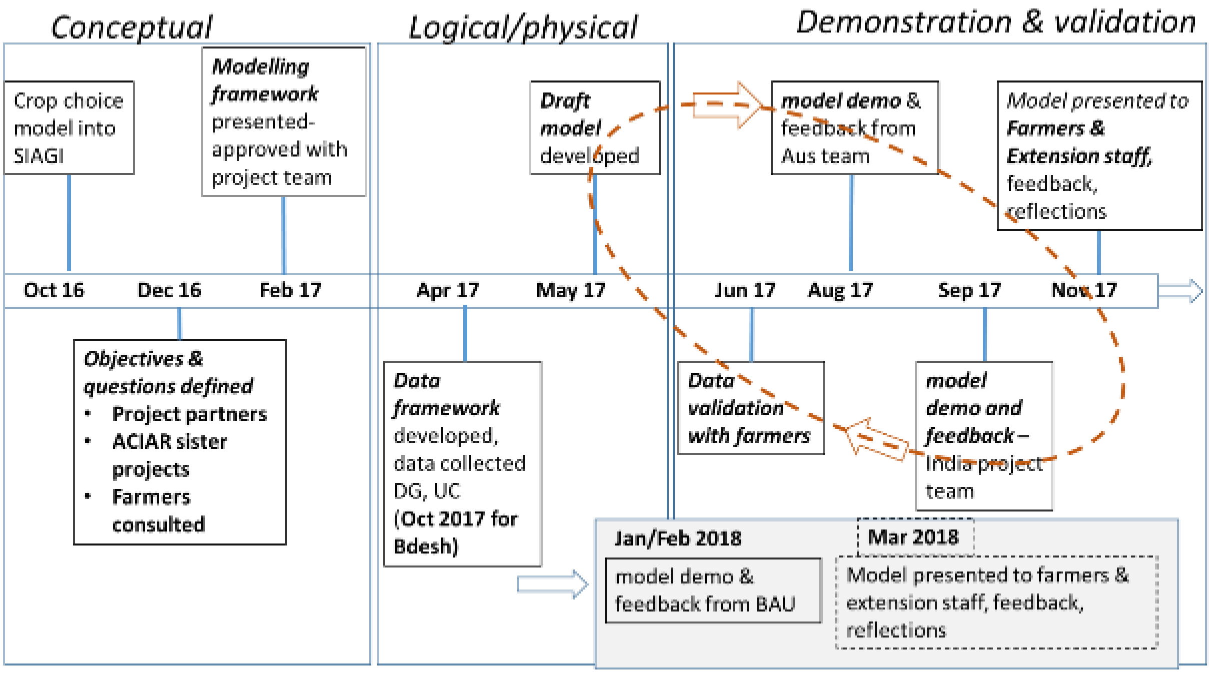

Figure 3: Key stakeholders part of the model development and testing

3.3 Data

Data on different crop and vegetables (cost of cultivation), yields, ground water use and related yields (for Rabi), input use (fertilisers, pesticides) have been collected from the marginal category farmers. A data framework based on the objectives and questions was developed via an iterative process with key stakeholders (Figure 3). Using the framework, data was collected over a two part survey conducted during March and April 2017 for Coochbehar sites and August –Oct 2017 for the Bangladesh sites. The data variables (technical coefficients) are

(i) Land area (good and medium soils)
(ii) Crop-vegetables yields
(iii) Ground water use by crop (rabi vegetables)
(iv) Cost of ground water (ground water data from sister project led by Erik Schmidt)
(v) Crop prices
(vi) Land preparation cost
(vii) Fertiliser use and cost
(viii) Pesticide use and cost
(ix) Seeding rate and cost
(x) Labour available, labour use by crop/vegetable and cost
(xi) Machine use and cost

All the above parameters are collected for each crop type that has been included in the model. For Rabi season, farmers listed the following crops

- Coochbehar site: cabbage, cauliflower, chili, potato, tomato, brinjal (eggplant), spinach, coriander
- Bangladesh site: green chilli, sunflower, sweet pumpkin, bottle gourd, chinese okra, okra, bitter gourd, snake gourd, eggplant, tomato, radish, winter spinach, bean, cucumber , potato, cabbage, beetroot, watermelon, and onion

Farmers have also defined soils in their village as good and medium in Coochbehar site and high and low in the Bangladesh sites and have provided data on yields for different vegetables on these soils.

3.4 Community scores and Weightage by Gender

As part of the data survey, men and women farmers were asked to score rabi vegetables on seven variables on their preference: labour (preference based on the labour time required and difficulty), risk of production (factors such as incidence of pest and disease, climate etc have been considered), access to market, self-consumption, water (water use by vegetable), cash-flow and price volatility. They have scored on a Likert scale of 1-5. Women and men farmers scored these in separate FGD meetings. A weight factor on profit and the seven variables is included where the farmers can score between 0-1 (total across all the 8 variables including profit should add up to 1). These weights along with the scores will influence the objective function to reflect the preferences of crop/vegetables gender-wise and the weight they place on these versus profit. For example, they may score on labour higher for a crop (i.e. it is less labour intensive) but when they have to weigh between labour and profit they may preferentially score profit higher.

3.5 Model Formulation

The model has been coded using the General Algebraic Modelling System (GAMS). The model reads the data from a excel spreadsheet. The outputs are written into a comma delimited text that can be read into a spreadsheet. The model has been designed to be generic so data can be easily changed or modified and new or additional parameters can be included. Option for including a number of constraints have been provided. For example, minimum and maximum area for crops/vegetables can be defined if required so the model is constrained to choose a minimum area (for self-consumption for instance) or to respond to market signals (while price can be the other influence). Weights can also be used as a lever to skew the model towards a particular crop/vegetable based on the risk perceptions scored by the farmers.

4. Farmer engagement & scenario development

Once the model has been developed, we undertook an engagement process with the participating farmers; the discussion with the farmers of Dhaloguri took place in November 2017 (Figure 4). In this engagement activity, the objective was to present the interactive tool to the farmers and validate the data/information collected and the findings of bio-economic modelling on the basis of reactions/reflections of the farmers in case study villages. This was done through focus group discussions. In Dhaloguri, seven farmers participated in this engagement. This small group of farmers was selected as this was a first validation exercise with the famers and we wanted an intensive feedback and reflection session which was more likely with a smaller focused group. A second larger group engagement has been proposed by CDHI which will be organised in the next few months. It was emphasised that the tool was developed as a discussion support tool in order to have a 'structured discussion' on crop choice with farmers, NGOs and researchers. The tool is not prescriptive and is designed to develop "what if?" scenarios for implications of different crop choices. Before the data and tool were presented, there were interactions with the farmers about their current decision making process and the underlying factors on their crop choices such as what to cultivate (choice across crops across types, varieties, etc.), how they cultivate (choice of techniques, input combinations, etc.), and for whom they cultivate (for market versus self-consumption). Following this discussion, a presentation was made on the basic framework of the model, its various components, and data collected. This was followed by a display of the findings of the tool on how crop choices can change across gender under different scenarios. The key observations from this interaction were that farmers are making crop choices from a variety of *rabi* crop options such as potato, tomato, cauliflower, cabbage, garlic, broccoli, chilli, spinach, coriander etc. The underlying factors influencing choice vary across crops and include:

- Cultivation of potato for high returns (though with high risks), greater market opportunities, getting bulk returns at a time and use of the same for asset creation;

- Cultivation of vegetables for self-consumption and meeting daily cash requirements;
- Emergence of potato as the most preferred crop across farmers to maximize returns.

Farmers are trying to distribute land into growing different crops to minimise input costs as well as production and market related risks. Though farmers said they have ideas on what crops to grow, there is no regular practice of recording various costs of and returns from cultivation in a systematic way. Farmers were in agreement with the data on cultivated area, costs of cultivation for different crops. This was an important validation as the model is reliant on the accurate data from the farmers and all model scenarios will be based on this primary data.

A number of scenarios can be generated with the modelling tool. As an illustration of the model, we presented two scenarios for the farmers (that incorporate male and female preferences). The first scenario (Table 1) was maximising for profit without preferences and weights. The model selected most of the area of the cultivated land of the village for potato and a small area for cabbage (in medium soil). Farmers agreed that this would be the outcome if profit was the only motive. We then ran a model scenario (Table 2) that included the weights they would place on one among the six variables (risk, market, self-consumption, cash-flow, labour and price-volatility). As a start, the women farmers placed a weight of 0.9 (on a scale of 0-1) on 'labour' (ease of growing a crop labour-wise) while men farmers placed a weight of 0.8 on 'market' (ease of access to market). The model selected a large area for spinach and cabbage as a result of female farmer's preference weight on labour while the model selected only cabbage in relation to male farmer preferences. We then restricted the cabbage and spinach areas to 200 bigha which resulted in the model allocating a significant area to brinjal (eggplant) in case of women farmer preferences and a significant area to tomato reflecting the men framer preferences (Table 3). The response from the farmers to this sample demonstration was that it was realistic and that is what they would do have chosen with those preferences. We ran only a few scenarios as a demonstration of the model, a more detailed engagement will be undertaken in the coming months. Farmers clearly showed their interest in using similar tools for farming decision-making, especially for crop choices.

Table 1: Scenario 1: no weights on preferences, profit maximisation objective only

	Crop	**Area (bigha)**
Men	Potato	1227 (good soil)
	Potato	307 (medium soil)
	Cabbage	0.4 (medium soil)
Women	Potato	1227 (good soil)
	Potato	307 (medium soil)
	Cabbage	0.4 (medium soil)

Table 2: Scenario 2, run 1: Women 0.9 on 'Labour' and Men 0.8 on 'Market' on a scale of 0-1

	Crop	**Area (bigha)**
Men	Cabbage	1227 (good soil)
	Cabbage	307 (medium soil)
Women	Spinach	1207 (good soil)
	Spinach	287 (medium soil)
	Coriander	20 (medium soil)
	Coriander	20 (good soil)

Table 3: Scenario 2, run 2: Women 0.9 on 'Labour' and Men 0.8 on 'Market' on a scale of 0-1 with Cabbage area constrained to 200 bigha and Spinach constrained to 200 bigha also.

	Crop	Area (bigha)
Men	Cabbage	200 (good soil)
	Cabbage	200 (medium soil)
	Tomato	1007 (good soil)
	Tomato	87 (medium soil)
Women	Spinach	200 (good soil)
	Spinach	200 (medium soil)
	Brinjal	1007 (good soil)
	Coriander	20 (medium soil)
	Coriander	20 (good soil)

An important result of this exercise with the farmers was more than just discussing scenarios. Participating farmers said that before we presented this tool and discussion, they had had many visits from different project teams, who interacted with them to collect data and information. Farmers were uncertain why data was being collected and often wondered if it was waste of their time. After the tool was presented and the discussions, their impression was that their data was being put to use to develop tools as discussion support (as demonstrated to them in this meeting). They said they realise the importance of data/information/views they provide. There was a genuine feeling of recognition and importance to their data, views and feedback. We think this is an important outcome of this visit and is consistent with the ethical community engagement espoused by SIAGI.

Figure 4: Farmer group at Dhaloguri with SIAGI project team members

Figure 5: Subrata describing the crop choice scenario tool to the farmers in Uttar Chakowakheti

We also discussed this tool with the farmers of Uttar Chakowakheti (Figure 5) which is the second study site in Coochbehar. Some of our observations were that farmers were slowly developing knowledge of *rabi* crop cultivation and markets for their produce. Generally, they grow crops twice in a year, but carry produce to the market with very limited prior knowledge about market price. Both input and output markets are located at far off places and hence have huge transaction costs. There are also problems of animal depredation leading to crop loss. With interventions from different agencies including CDHI and UBKV as part of the DSI4MTF project, farmers are planning to cultivate mustard with zero-tillage technology for timely sowing. They are sourcing seedlings from Dhaloguri as the collectives of this village have guidance and technology by UBKV.

The study team feels that *rabi* farming has just started evolving in the Uttar Chakowakheti and farmers have less knowledge or experience about cultivation and relevant data is not yet available. Hence, at this stage, the village does not have as much scope to carry out a bio-economic modelling exercise.

In Jalpaiguri, we presented the crop choice tool to the district level agricultural extension department staff at CDHI. Before the presentation of the tool, the extension staff were of the view that farmers are not interested to follow guidance of extension staff members, instead are generally influenced by traders of inputs and output, money lenders, etc. However, after our discussions and the demonstration of the tool, the participating extension staff indicated interest to explore the crop choice scenario tool and expressed the view that this may be a useful tool for the farmers in discuss crop choice options. There are challenges in three major aspects – crop rotation, crop diversification and crop sequence. Bio-economic modelling can play a crucial role in this regard. The extension staff also suggested that the modelling template can be linked to the website of the state government. However, this requires further development and demonstration to the higher level officials to gain their support. At this stage, we think this group of extension staff at CDHI may be part of our stakeholders that the tool is best targeted towards.

In March 2017, we undertook a similar engagement process with the farmers in Bangladesh sites (Sekenderkhali and Khatail villages). In Sekenderkhali, a focus group discussion was organised involving 20 farmers including six women who were members of the SIAGI groups such as marginal, landless and women managed households and water & silt management committee (Figurers 9-10) . The objective was for the team members of CSIRO, BAU and Shushilan to validate the bio-economic data and understand the farmers' reflections and comments. Moreover, it was a good opportunity to interact with farmers and explain to them how the data they have provided over the previous few months is being used to develop a model and explore crop choice options with them. We assisted the farmers to reflect/write their choices of the current key factors that influenced them to make crops choice decisions before the presentation. Almost all of them chose chilli, ground nut, sunflower and sweet potato due to mostly factors of home consumption, high market price and others factors such as lower irrigation requirements, market opportunity (close to market), meet the expenses of children's education and crops that are less perishable.

Similarly, we organised a farmer FGD in Khatail in which 12 farmers participated (7 women and 5 men) (Figures 6-7). We followed the same approach of engagement as in Sekendarkhali. Before we proceeded to explain the modelling and scenario building, we requested them to fill-out two basic questions about their knowledge on crop choice decisions. We translated these two questions into Bengali and also clarified the questions orally. Mahanam and Wakil presented the modelling concept, since the same set of farmers participated in the data collection phase of the model development we again validated the data with them before running scenarios. Some prices were adjusted according to their suggestion. Once the data was agreed to, we ran the model scenarios. As an illustration of the model, we presented two scenarios for the farmers (that incorporate male and female preferences). The first scenario was maximising for profit without preferences and weights (Table 4). The model selected most of the area of the cultivated land of the village for sweet potato, bottle gourd, potato and water melon as shown in the table below. Farmers agreed that this would be the outcome if profit was the only motive. We then ran a model scenario (Table 5) that included the weights they would place on one among the seven variables (water, risk, market, self-consumption, cash-flow, labour and price-volatility). As a start, the women farmers placed a weights on Profit 0.20, Risk 0.60 and Water 0.20; while men farmers placed a weight on Profit 0.40, Risk 0.20 and Market 0.40. The model selected a large area for bottle gourd and sweet pumpkin as a result of female farmer's preference weights on labour while the model selected sweet potato, bottle gourd, potato and water melon in relation to male farmer preferences.

Khatail Farmer sample scenarios:

Table 4: Scenario 1: profit maximisation only, no weights on preferences

	Crop	Soil_type	Area (bigha)
Women	Sweet_pumpkin	high_soil	75
	Sweet_pumpkin	medium_soil	75
	Bottle_gourd	medium_soil	170
	Potato	high_soil	170
	Water_melon	high_soil	50
	Water_melon	medium_soil	50
Men	Sweet_pumpkin	high_soil	75
	Sweet_pumpkin	medium_soil	75
	Bottle_gourd	medium_soil	170
	Potato	high_soil	170
	Water_melon	high_soil	50
	Water_melon	medium_soil	50

Table 5: Scenario 2: Women Profit 0.20, Risk 0.60 and Water 0.20; Men Profit 0.40, Risk 0.20 and Market 0.40

	Crop	Soil_type	Area (bigha)
Women	Sweet_pumpkin	High_soil	75
	Sweet_pumpkin	Medium_soil	75
	Bottle_gourd	High_soil	220
	Bottle_gourd	Medium_soil	220
Men	Sweet_pumpkin	Medium_soil	75
	Bottle_gourd	Medium_soil	170
	Potato	High_soil	245
	Water_melon	High_soil	50
	Water_melon	Medium_soil	50

Farmers also indicated their knowledge on choosing crops for upcoming Rabi season. As per their perception, the rate of their current knowledge was on the scale of 3 to 7 before the presentation of the crop choice model and 6 to 10 post-workshop. In Sekenderkhali, participants reflected that they were impressed and felt good after presenting the model separately considering men and women farmer choices. With some limitation of data (particularly of water issue), the model had showed the most profitable crops such as potato and bottle gourd. Farmers recognise that a computer based model "can do many things within a short time that will help them to discuss crop choice options". However, they do realise that the ultimate decision must be taken by the farmers from their experiences and interest and also that the person who is running the model is there to help the process but may not prescribe crops decisions. During the Sekendarkhali FGD, the farmers noticed that we missed water variable for the case study scarcity in that project area. Post-FGD, we included this and pulse crops which were also raised by farmers. In Khatail, the response from the farmers to this sample demonstration was that it was realistic and that is what they would do have chosen with those preferences. We ran only a few scenarios as a demonstration of the model, a more detailed engagement will be undertaken in the coming months. Farmers clearly showed their interest in using similar tools for farming decision-making, especially for crop choices.

Figure 6: Khatail farmers looking at the data and validating it (data collected from farmers)

Figure 7: Bangladesh Agricultural University and Sushilan partners (Wakilur and Mahanam) explaining the model to the participating farmers

An important outcome of the engagement process in both the villages was that Shushilan and BAU partner took the lead in discussing the model with the farmers (Figures 8-10). This was a result of their close collaboration in the model development process, data collection and outreach. In terms of the model utility beyond the life of the project this is a foundational capacity building within the team.

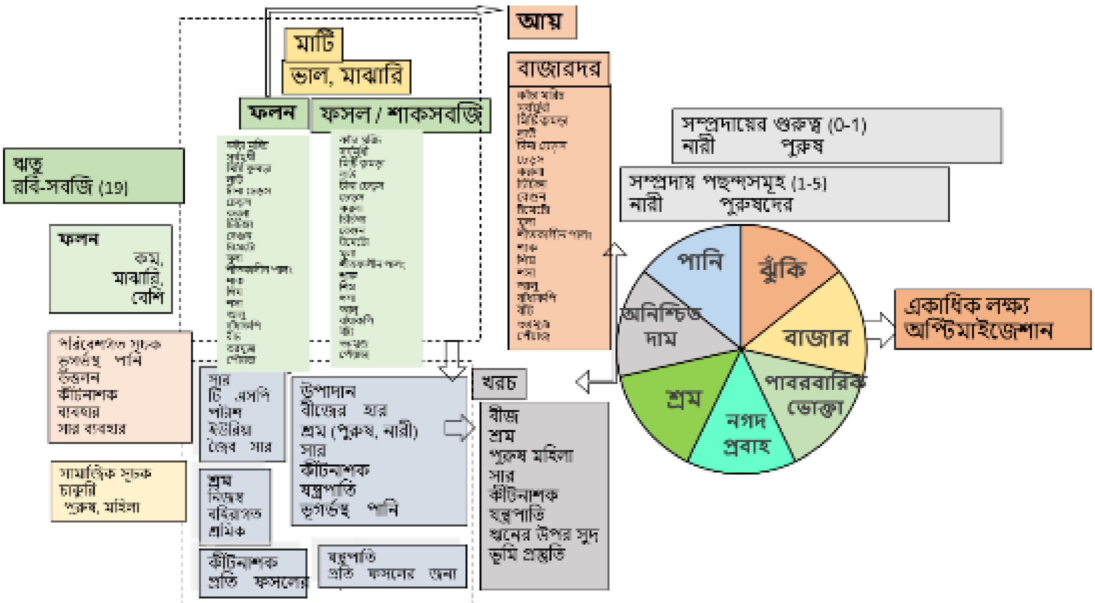

Figure 8: A Bangla language version of the model formulation that was used to explain the different elements of the model to the participating farmers.

Figure 9: NGO partner Mahanam Dash explaining the model to the farmer group

Figure 10: Data for the model being edited real-time to update women farmer preferences in relation to water

5. Benefits of the model development process

An important contribution of the participatory model development process has been the building of 'social capital' (Coleman, 1988) and 'social learning' (van der Wal et al., 2014) around agriculture intensification and crop-vegetable-choice among the farming community in the case study village. We adopted a reflective learning process based on the Plan–Do–Observe–Reflect of the Kolb learning cycle (Hayman et al., 2013; Kolb, 2004) highlighting that the modelling is not an end in itself but supported a co-learning process among researchers and the farming community (Nidumolu et al., 2007; Nidumolu et al., 2011; Nidumolu et al., 2016). The objective of IMGLP approach is to indicate the *Pathways- Scenarios* and explore consequences of each of these, it is not prescriptive or predictive and it is up to stakeholders to make the decisions.

6. Next steps

- There was a demand from the NGO partners for training to use the model with the farmers. An easy to use graphical user interface (GUI) will be developed that will run using an Excel interface. Data input/modification will be carried out in excel and the outputs will also be accessed via excel. The users do not need to work with GAMS software. We will re-implement the model in the free to use version of GAMS so the model will be accessible to the NGO and University partners saving large licence fee. A training session will be organised for the university and NGO partners in the coming months once the user interface is developed.

- There has been a demand to apply the approach to other regions such as from the West Bengal APDMP and PRADAN. We will explore options to extend this modelling tool to other geographies as well outscaling and upscaling the model (regional scale from the current village scale).

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