Using microfinance for flood mitigation and climate adaptation in Bangladesh

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Draft paper for the 32nd International Conference of the System Dynamics Society
Delft, The Netherlands — July 20-24, 2014

ABSTRACT

This draft paper describes the preliminary outcomes of a model-based investigation of long-term strategies to reduce the impacts of coastal flooding in Bangladesh. Specifically, a system dynamics model was constructed to simulate the effect of flood mitigation methods on the population, rural economy, housing and welfare of Bangladeshis in the coastal district of Cox's Bazar, if they were to be implemented. The model shows how microfinance-based investments could endogenously contribute to such infrastructures, in the context of policies for climate adaptation and rural development. Additional policy insights were observed by analyzing overall system behavior using techniques for Exploratory System Dynamics Modeling and Analysis (ESDMA).

1 Background

The People's Republic of Bangladesh is situated on a low-lying delta formed by the confluence of the Ganges, Brahmaputra and Meghna rivers. In addition, its proximity to the Himalayan range, as well as the local climate's pronounced monsoon seasons, all combine to make Bangladesh prone to severe flooding on a yearly basis (Alexander, 1993). For example, extreme monsoonal flooding inundated more than 60% of Bangladesh's land area in 1988, killing close to 45,000 people and displacing another 28 million (Dartmouth Flood Observatory, 2008).

While the immediate death toll due to these natural disasters is of obvious concern, damage to shelters and sources of livelihood, especially agriculture and aquaculture, yield further long-term implications that exacerbate the causes of poverty in this developing country.

However, the tropical climate is also of benefit to the Bangladeshi people; regular monsoons and fertile floodplains help rank the country among the top ten rice producers in the world, among other crops (Papademetriou, 1999). In fact, the dependence of agricultural output on the local climate was demonstrated in recent years when effects of El Niño dramatically reduced production levels across Asia (FAO, 2010).

The tenuous relationship of both prosperity and adversity with the Bangladeshi climate has not been good for the economic growth and development of Bangladesh. Indeed, Bangladesh's GDP per capita is ranked 166th by the World Bank (2013). Nearly 50% of the population is below the national poverty line, which corresponds closely with the fact that 45% of the population is employed primarily in the rural agriculture sector (CIA, 2013).

The Bangladeshi predicament arising from its geographic characteristics is made worse by the threat of climate change (UNDP, 2007). Not only would the associated sea level rise inundate a disproportionate landmass within the country, the rising temperatures could potentially result in more frequent and more severe cyclones. Moreover, the encroaching salinity of soil with rising sea level would also reduce the productivity of nearby agricultural land, in addition to damaging fields inundated with seawater (Hossain & Hossain, 2012).

One World Bank project (2000) calculated an estimated 10 cm, 25 cm and 1 m increase in sea level by 2020, 2050 and 2100 respectively. These scenarios are projected to result in the effective loss of up to 17.5% of Bangladeshi landmass by 2100, making climate change a imminent priority to be dealt with, even alongside shorter-term development efforts.

The challenge for Bangladesh is thus to take advantage of its climactic suitability for agriculture while minimizing the devastation caused by extreme weather, in order to foster robust development. In the coastal regions of southern Bangladesh, for example, the major economic drivers are agriculture, aquaculture, salt cultivation and tourism (Hossain & Hossain, 2012), all of which are threatened by seasonal disasters and well as the long-term changes expected from climate change. As such, adaptation and the mitigation of local impacts are the most practical options available to populations in this region.

While Bangladesh has evaluated policy frameworks involving coastal flood mitigation in the past, these initiatives are considered to have failed to significantly address the problem (Siddiqui & Hossain, 2006). Debate is ongoing as to why these initiatives failed; the lack of national funds for the continued maintenance of the measures is considered to be the primary reason (Siddiqui & Hossain, 2006). The Bangladesh Flood Action Plan (FAP), for instance, was an initiative from 1989 to attempt to control flooding with sluice gates and secondary embankments. However, the policies and plans were not implemented, as the economic returns from such actions were predicted to be insufficient (Brammer, 2010).

The success of microfinance in Bangladesh

In 1983, Professor Muhammad Yunus initiated the Grameen Bank Project (GBP) to accelerate the uplifting of the poor in Bangladesh (Mahjabeen, 2008). Specifically, the GBP tackles abject poverty by employing microcredit schemes, empowering poor entrepreneurs to set up micro-entreprises. The GBP model is considered a success, with close to 140 billion Takas (1.77

billion USD) in total assets and close to 8.5 million members (loanees), who collectively own 95% of the bank (Grameen Bank, 2012).

The successes of the GBP and other microfinance institutions (MFIs) are laudable. However, micro-lending schemes typically address the symptom of dire poverty whereas one of the systemic causes – social and economic instability due to flood damage – is not directly addressed. In parallel, microfinance and community-based initiatives have increasingly been studied as a possible approach for funding climate adaptation in developing countries (Agrawala & Carraro, 2010; Francisco, 2008). As such, there remains significant potential for the further development and refinement of microfinance schemes in the specific context of Bangladesh.

2 Model objectives

The system dynamics approach applies principles of control systems to diverse sets of problems. Many real-world processes are driven by complex systems, characterized by time dependence and intricate feedback mechanisms (Pruyt, 2010). As such, the SD approach can highlight the true impact (or lack thereof) of proposed solutions. Good models also help decision-makers visualize and clarify the relationship between the system, its underlying structures and time.

In this paper, the model serves an additional purpose as well. As a preliminary approach to the problem, it is used to evaluate the potential of investments in flood mitigation and their long-term impacts, so as to identify important causal drivers and areas for further investigation. This aspect is vital in the Bangladeshi context, as the country has limited reserves and resources to tackle multiple crises such as flooding, poverty, economic development and agricultural productivity, among others. As such, presently, actions that yield the greatest benefit in the least time using least resources are prioritized. However, demonstrating the complex interplay of flooding on all other sub-systems may highlight the benefits of strategic long-term policies.

While there are existing studies that evaluate the success of the Grameen Bank (and other MFIs), the literature review did not yield any exploratory studies that have investigated the overall relation between the MFIs, agriculture, population, micro-enterprises, welfare and development and housing. Moreover, the systemic effects of flooding and flood-related damages are not adequately addressed in the financial evaluation of MFI sustainability.

The goal of this paper is to explore the possibility of utilising the collective wealth of regional MFIs to sustainably finance long-term flood mitigation infrastructure, such as coastal breakwaters and extensive drainage. Specifically, the paper focuses on the economically significant coastal district of Cox's Bazar in the Chittagong Division in south-east Bangladesh.

A system dynamics approach to this issue is a practical way of exploring the impact of flood mitigation on the inter-related interactions between the relevant sub-systems. This is particularly important because constructions like coastal breakwaters are significant investments with long construction delays. Furthermore, these constructions themselves may be damaged intermittently by the yearly flooding during the construction period, adding extra time and costs to construction.

The authors hypothesize that investment in long-term flood prevention would indeed positively impact the Cox's Bazar region, both economically and socially, while still allowing the MFIs to perform sustainably (i.e. without compromising their core mission of funding conventional micro-loans).

The results of the analysis may be particularly useful in a Bangladeshi context; large-scale infrastructure projects are normally initiated and overseen by national or regional governments. However, in the case of Bangladesh, the low levels of economic development as well as more immediate priorities such as eliminating abject poverty may not be favourable for such sizable and therefore risky investments.

On the other hand, if the local MFIs, of which a majority stake is owned by the loanees/members, were to invest a portion of their assets into such a project, there is potential for catalyzing investment in large-scale infrastructure for public benefit. It would therefore crucial to evaluate the potential benefits as well as the risks of this approach, so as to establish its feasibility and promote further analysis.

3 The model

3.1 Conceptual model

The following figure is a high-level causal loop diagram for the system dynamics model, which shows the interplay between the different sub-systems. The model boundary is limited to the Cox's Bazar District in South-Eastern Bangladesh. Cox's Bazar is chosen as it is one of the coastal areas that are significantly affected by annual flooding; furthermore, there was sufficient empirical data available to model the sub-systems appropriately.

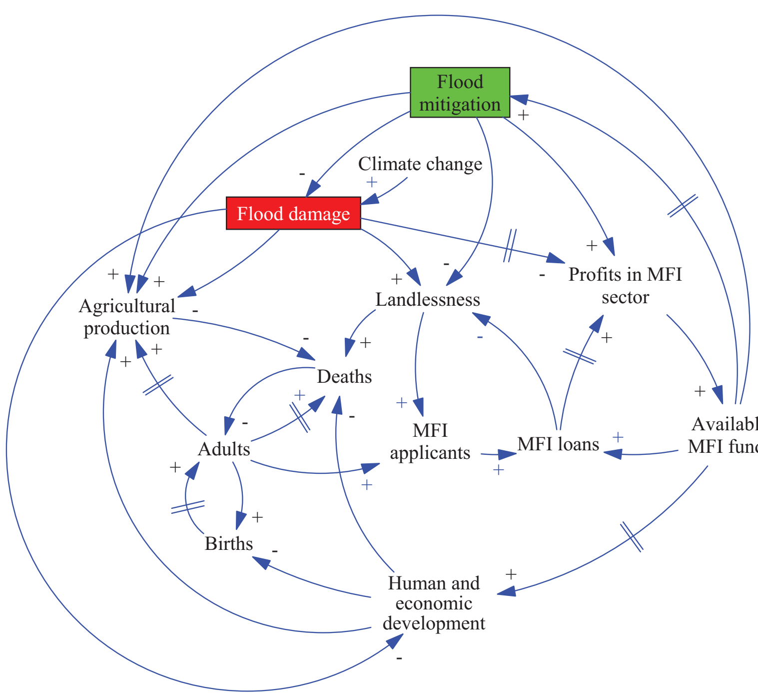

Figure 1: Aggregated causal loop diagram of the model

Cox's Bazar as a whole is modelled as operating primarily on an agrarian economy, with heavy emphasis on seasonal harvest of rice. The working population are initially unskilled adults who will typically end up in farming-related employment.

Within this context, the existence of the MFIs allows some enterprising individuals (particularly women, as per the GBP's credit policies) to take loans to start micro-enterprises and augment the families' basic income from agriculture. The micro-enterprise ecosystem results in a new segment of the local economy, which complements the agricultural economy. The MFIs also help reliable borrowers with additional loans to build their own houses, which they are otherwise not able to, since materials for more permanent constructions are relatively expensive. The houses are themselves at risk during extreme flooding events, in addition to natural degradation over time, contributing to landlessness. MFI loans are thus prioritized for applicants who do not own houses (i.e. landless), since their needs are more urgent.

The MFIs are tied to the success of these micro-enterprises in order to remain financially sustainable. The MFIs sustain themselves primarily from the repayments (with interest) and compulsory savings by the loanees. Additionally, as the most organized financial institutions closest to the population, they receive some portion of the financial aid and disaster relief funds that reach Bangladesh yearly. This financial aid is also vital for the establishment and functioning of NGOs and welfare institutions such as schools, clinics and other such development-related agencies. The number of welfare and development institutions then influences the community acutely. For example, better education and widespread family planning information can be assumed to decrease the birth rate (Banerjee & Duflo, 2011).

The floods in Cox's Bazar are either monsoonal or coastal floods (Hossain & Hossain, 2012), and these occur seasonally. However, the severity of the flooding can vary from year to year. While the typical loss of lives due to flooding is relatively small compared to the total population, the flood-related damage has a great impact on the local economy, agriculture and housing. For example, flooding not only damages crops on the field, but also spoils grains in storage. Without a long-term strategy to directly tackle the flooding problem, the system is chronically unstable. As such, the proposed flood mitigation policy is primarily aimed at reducing the severity of flooding. In addition, the policy must minimize the damage caused by flooding to individual sub-systems by various means, e.g. reinforcing and maintaining structures to reduce susceptibility to flood-related damage.

3.2 Simulation model

Appendix I presents the stock-flow model as implemented in Vensim 6.0. It consists of 8 sub-systems: Housing, Welfare & Development, Agriculture, Flooding, Population, Micro-enterprises, Flood Mitigation and MFI Resources.

3.3 Model testing and analysis

The figures below depict several key performance indicators for a baseline scenario, without MFI-funded investments in flood mitigation.

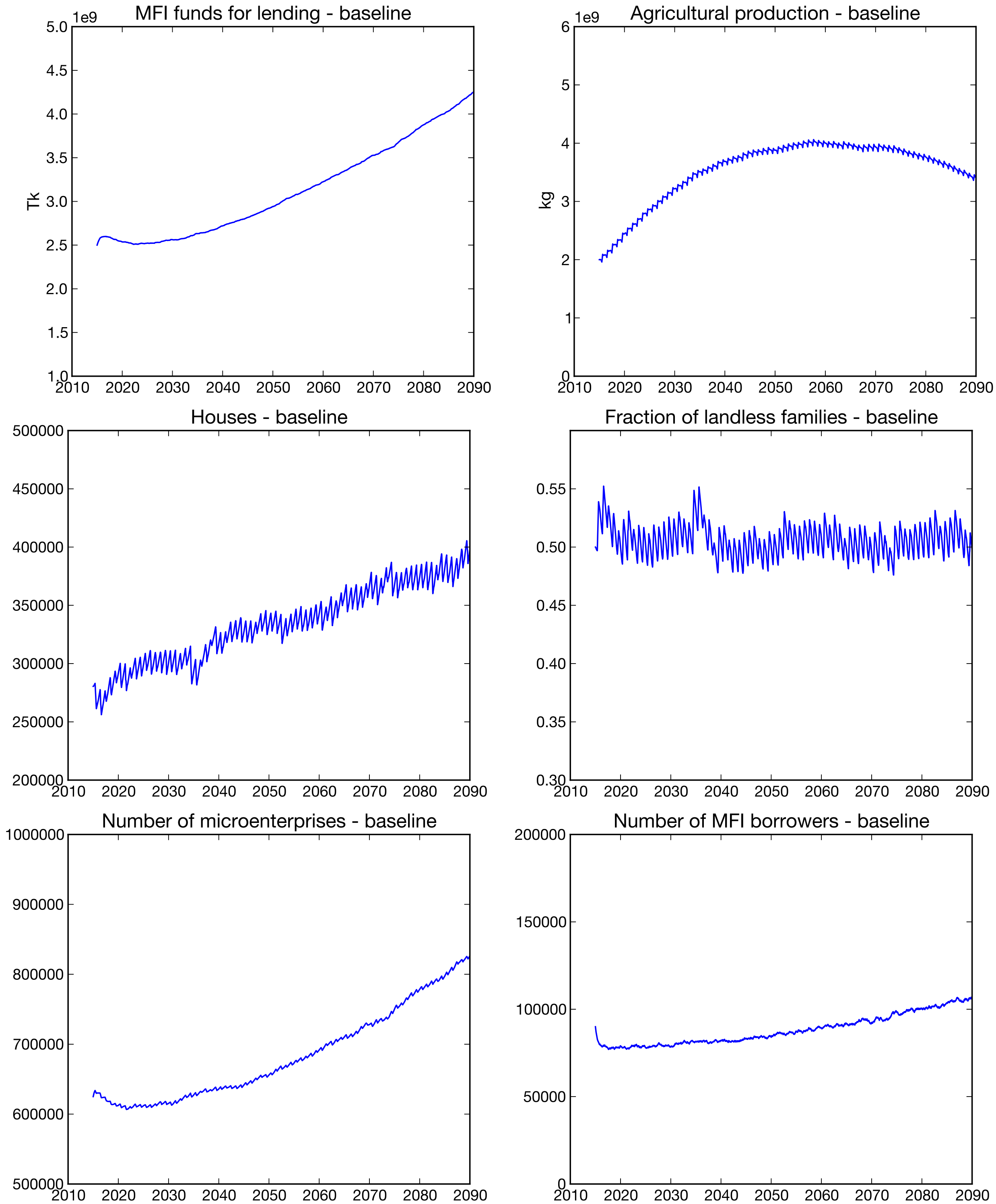

Figure 2: Baseline model results

Although the microfinance subsystem maintains its profitability and consistently generates new investments, the output of the agricultural subsystem tends to decline over time due to the increasing impacts of climate change and coastal flooding on productivity. Furthermore, the fraction of landless families essentially remains stable; in addition to direct flooding damage, this can be explained by observing that flooding severely reduces the area of cultivable land, with significant implications to harvest volumes. As such, the resulting profits from agriculture tend to decline in the long term. Since a significant portion of the profits are used to prepare cultivable land for the next harvest, the resulting feedback loop tends over time to decrease overall harvest volumes and profits, and increase landlessness.

4 Policy analysis

The results obtained from the model illustrate the significant impacts of seasonal flooding: although MFIs contribute to development in the short term, the lack of long-term investment in flood mitigation eventually leads to a significant decrease in agricultural production. This section presents a proposed policy in which three different mitigation measures would be initiated, starting from 2025:

- Yearly investments to reinforce the structural resilience of weakened buildings in coastal communities, thus increasing their lifespan;
- Better drainage (e.g. sluice gates and secondary embankments) to drain flood water more efficiently and reduce damage;
- Construction of floating/under-surface breakwaters at sea, reducing the severity of coastal flooding.

The investments are assumed to be partially funded by MFIs, in a proportion varying from 10% to 40% depending on the type of infrastructure. The figures below present preliminary results from the policy case:

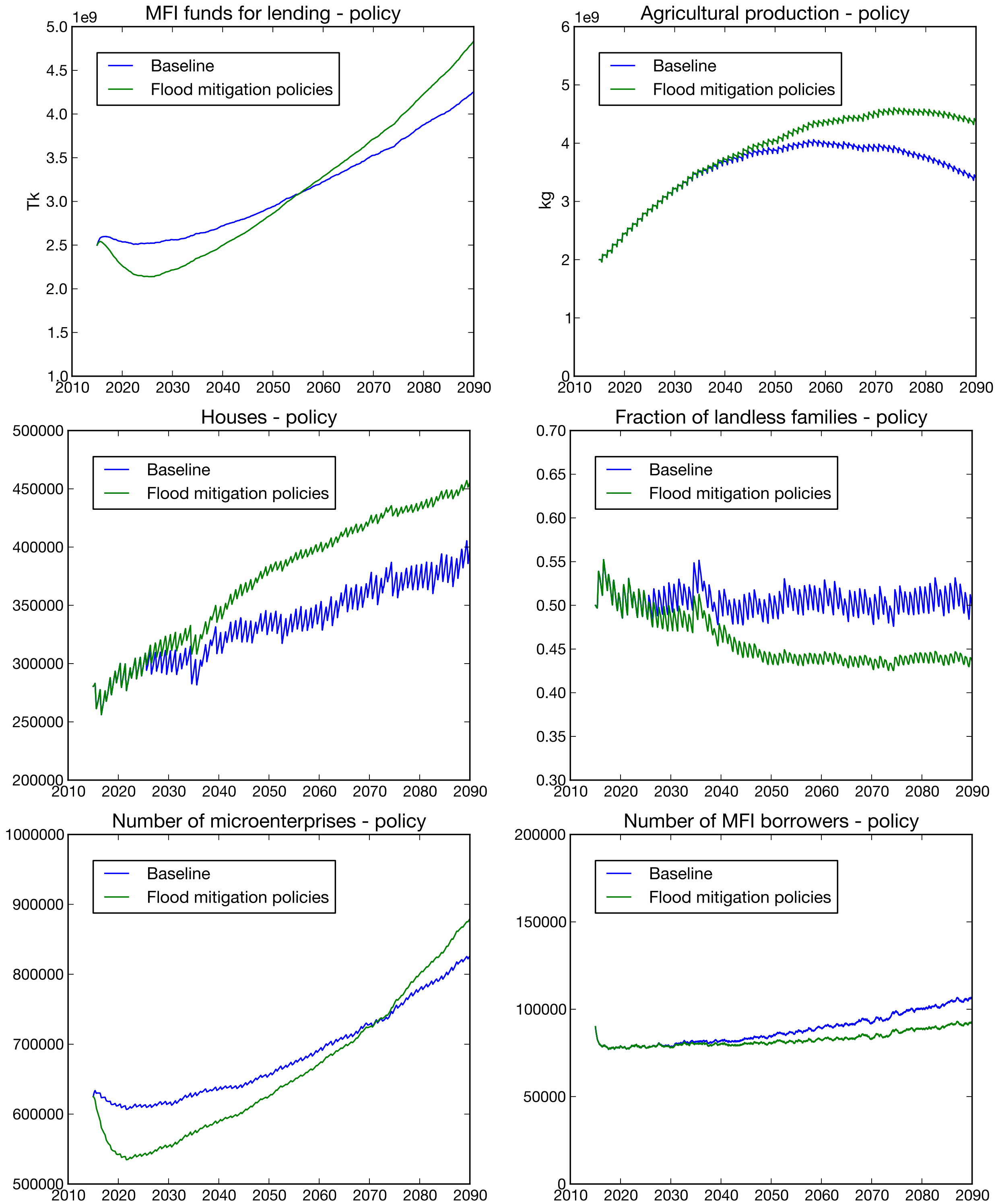

Figure 3: Model results with flood mitigation policies

The flood mitigation policies appear to have significant benefits for the agricultural sector, stabilizing long-term production despite the increasing severity of climate change-driven flooding. In parallel, the policy measures have a direct impact on the available housing stock and the fraction of landless families. Although the investments financed by MFIs decrease available resources in the short term, these investments then generate increased output over the long term, which is reflected in the funds available for lending. This outcome demonstrates that, with proper financing and control, partial community-based funding for large-scale infrastructure development may have significant potential. This is very encouraging and can be a good basis to begin serious consideration of flood mitigation policies in collaboration with community-owned MFIs.

The policy mitigation case was further analyzed by evaluating the system's behavior over a range of parametric uncertainties, summarized in the table below:

Variable	**Unit**	**Min. value**	**Max. value**
Average basic loan amount	Tk	6000	14000
Average basic loan repayment period	Year	0.5	2
Average housing loan amount	Tk	15000	35000
Average housing loan interest rate	%	0.06	0.12
Average housing loan repayment period	Year	4	8
Average loan interest rate	%	0.08	0.18
Average size of loan group	-	3	6
Average yearly wages per employee	Tk/year	7000	12000
Breakwater efficiency per km	1/Year	0.4	0.8
Cost of coastal protection per m	Tk/m	180000	320000
Cost of drainage per m	Tk/m	3000	6000
Drainage efficiency per km	1/Year	0.003	0.01
Loans per group	-	1	3
Percentage basic loan set aside	%	0.01	0.08

Table 1: Summary of parameter values for uncertainty analysis

A multivariate sensitivity analysis was performed for 1000 runs with Latin Hypercube sampling. The figures below present the resulting uncertainty envelopes for agricultural production and available MFI funds, in the baseline and policy scenarios; the panel to the right of each line graph presents the Gaussian kernel density estimator (KDE) of both scenarios, at the final time of the simulation. The KDE for the policy scenario over the full duration of the simulation is further detailed in the waterfall plots below.

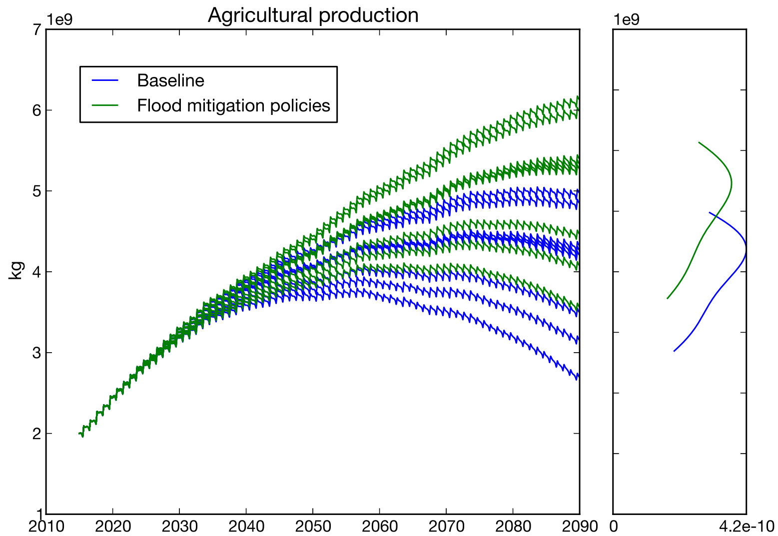

Figure 4: Comparison of uncertainty ranges for agricultural production with and without flood mitigation

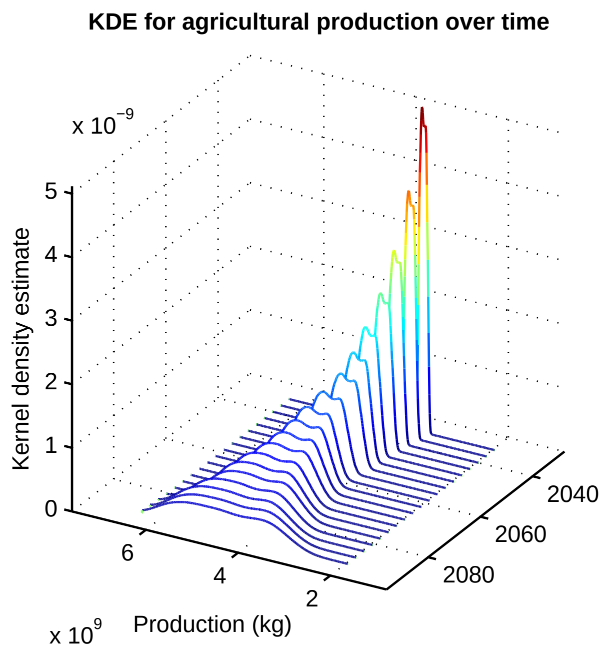

Figure 5: Kernel density estimator over time for agricultural production in the flood mitigation scenario

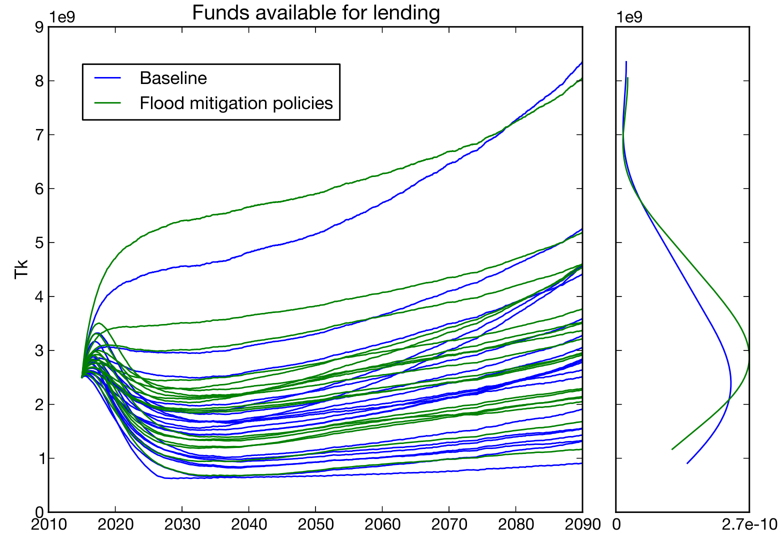

Figure 6: Comparison of uncertainty ranges for available MFI funds with and without flood mitigation

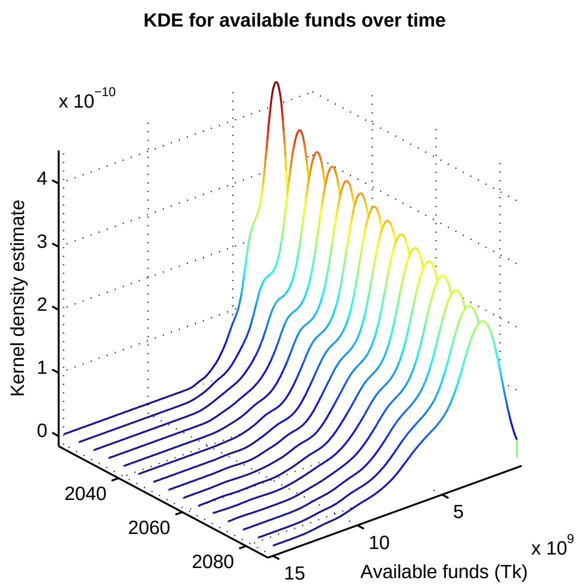

Figure 7: Kernel density estimator over time for available MFI funds in the flood mitigation scenario

These results appear to support the insights gained from the initial model runs: the distribution of outcomes for agricultural production is significantly different for both scenarios, with values being clustered higher for the policy case, yet the distribution for available funds remains comparable in both cases. As modeled, the level of infrastructural investment provided by MFIs would therefore not detract from their core functions for micro-loans and housing credit.

5 Discussion and recommendations

In building the model, and clarifying the complex relationships between the relevant subsystems, the systemic damage caused by seasonal flooding in Cox's Bazar has been illustrated. In parallel, the preliminary results from the model show that microfinance-supported investments in flood mitigation methods may benefit coastal districts without compromising the long-term financial sustainability of MFIs. In extension, it is intended to highlight the potential benefits for long-term flood mitigation for Bangladesh.

While microfinance has over the years at least overcome initial skepticism, the model tends to reinforce the hypothesis that MFIs may be unable to eradicate poverty on their own due to the systemic perturbations induced by natural disasters in the region. However, the strategic use of MFI funds for infrastructural investment, combined with comprehensive strategies to directly mitigate disasters and the threats posed by climate change, may enable regional microfinance to play an increasingly significant role in the long-term development of Bangladesh's coastal districts.

The links between development rate and flooding, development and birth rate, flooding and agricultural productivity, MFI loans and landlessness, among others have also been demonstrated. These relations clearly highlight the complex interplaying dynamics of the system, and the extent to which flooding does more than just short-term property damage: floods significantly affect the rate of development of Bangladesh. This further justifies long-term investments in flood mitigation.

In particular, the proposition of community-based investments for large-scale infrastructure projects has shown promise in the model, as opposed to the traditional reliance on private or public sector investments. While the MFIs contribute only a fraction of the required finances for such projects, the potential of such initiatives is put into perspective by keeping in mind that the MFI pool represents the collective wealth of some of the poorest communities in a single district in Bangladesh. As such, the model suggests that microfinance could reliably contribute to long-term, high-investment development projects.

As mentioned earlier, the model used in this paper is preliminary, and is intended as a first approach to illustrate the long-term negative effects of chronic flooding, and the potential of mitigation policies to alleviate the situation. Future work will focus on testing a more detailed representation of MFI funding mechanisms against empirical data, as well as on the regional economy of Cox's Bazar. Addtional research should investigate region-specific models, with additional factors like urbanisation, river flooding and the relationship between saltwater intrusion and agricultural productivity, among others. In building such region-specific models, an exploratory modelling analysis is recommended to evaluate the robustness of policies under deep uncertainty (Pruyt et al., 2011).

In summary, the current model justifies the investigation of strategic flood mitigation policies, while highlighting the potential contribution of community-based initiatives for climate adaptation. With more detailed, region-specific models that can more accurately correspond with statistical behaviour, the true impact of flood mitigation measures can be elucidated. Hopefully, these feasibility studies will further justify the call for long-term solutions.

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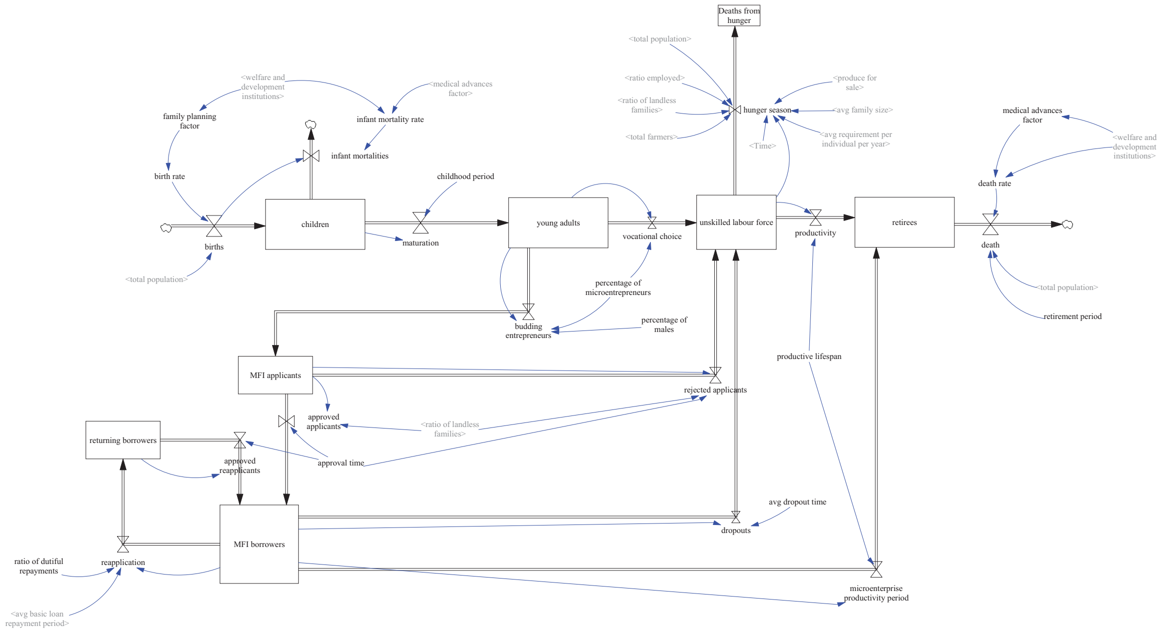
Appendix 1: Model specification

The following sub-sections detail each sub-system individually.

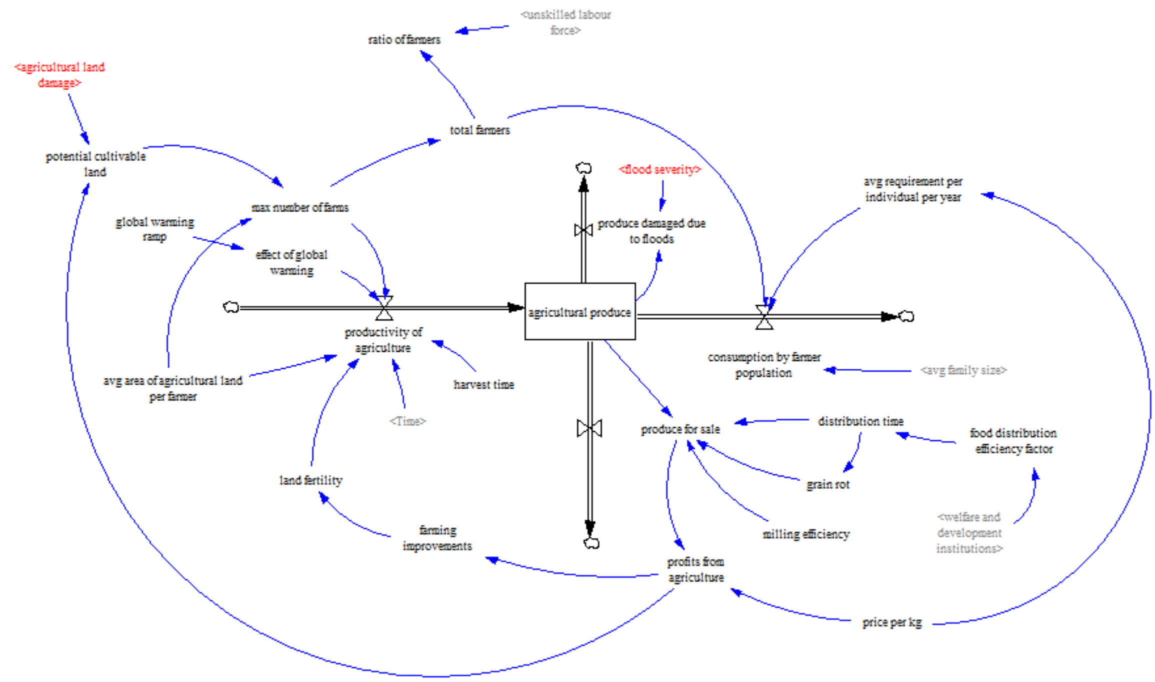


The core of the population sub-system is a typical aging chain, from children to young adults, working adults and finally to retirees. Young adults mostly end up in the unskilled labour force, of which a majority are employed in the agriculture industry with some unemployed individuals. The existence of the MFIs grants entrepreneurial female young adults an alternative to becoming employed in the local agriculture industry - namely to become micro-entrepreneurs. The restriction to only females is justified by GBP's prevailing policy where 97% of loanees/members are women (Grameen Bank, 2012).

MFI loans are approved when potential loanees meet certain conditions; in this model, landlessness is the primary factor to get a loan from the MFIs. Landless MFI applicants may become approved MFI borrowers, while the rest are unsuccessful and end up in the unskilled labour force. A small percentage of MFI borrowers may default their payments even after the grace period of 12 months (a total of 2 years). In this case, the defaulters are also removed from the pool of MFI borrowers. On the other hand, loyal borrowers who pay back their loans within the allotted time are given the option of borrowing another time (returning borrowers). Only returning borrowers are trusted with housing loans. MFI borrowers use the basic loans from the MFIs to set up micro-enterprises. The side-effect is that these micro-enterprises also create a secondary avenue of employment for some in the unskilled labour force - namely as employees.

Each year, in Bangladesh, there is a serious hunger season right after the sowing of the future crops, locally referred to as "monga". While monga is very pronounced in northern Bangladesh, there are still spillover effects in the south, resulting in a significant seasonal problem. This yearly crisis results in a significant number deaths due to malnourishment or starvation. In the model, the hunger season is assumed to claim only landless, unemployed unskilled labourers who may be unable to afford food during the lean season.

The other variables of interest in this sub-model are family planning factor and medical advances factor, which influence the birth rate, infant mortality rate and the (natural) death rate. These variables are themselves influenced by the extent of development in the region, dictated by the number of welfare and development institutions in the region.

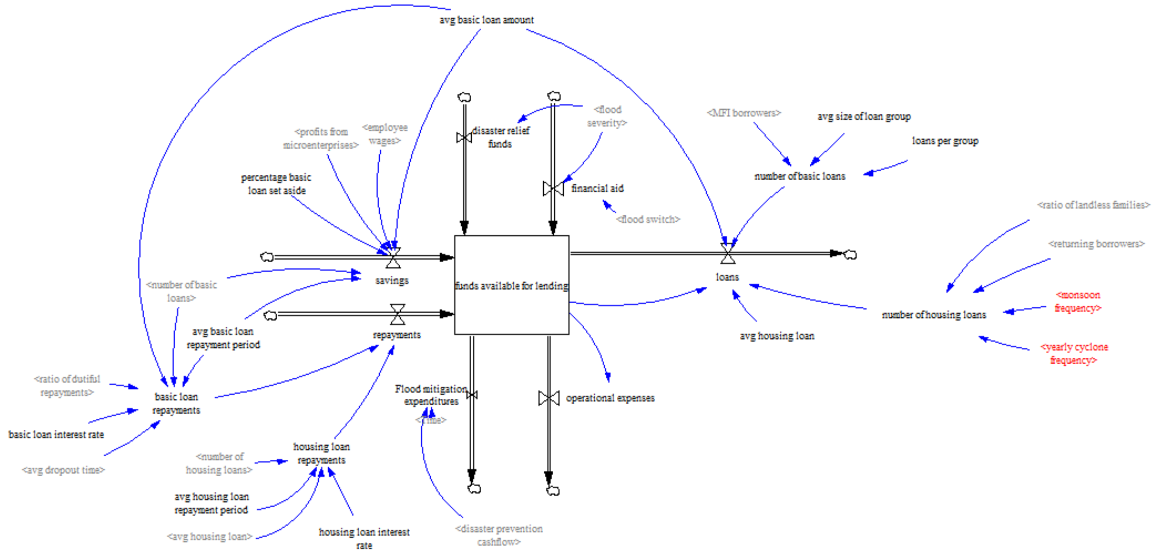


As mentioned earlier, the majority of the unskilled adults are assumed to be employed in local agriculture. This sub-system keeps stock of the agricultural productivity of the system. The total agricultural produce is governed by the inflow from harvests and the outflows of consumption by farmers and produce for sale. Some of the produce is also spoilt due to the floods.

The quality of the harvests are determined by the area of tilled land available as well as the fertility of the land. The latter can be improved with some investments from the profits of the sales, e.g. fertilizers and pesticides.

Since the main food crop is rice, which has a distinct harvest period, the productivity is highly seasonal. Of the accumulated produce, the model assumes the farmer population (including their families) covers their own consumption, with a portion of the rest being put for sale for the local population. Here there is a counter-intuitive behaviour between the price of rice and the average consumption per farmer per year. It has been observed that when the market value of crops is higher, the average consumption by the farmers goes down; this is because the poor farmers prefer to capitalize and make more profits than eat healthily. On the other hand, when the market value is lower, they eat more healthily.

While there are profits from the sales of the produce, this money does not end up in the MFI circulation because there is no incentive nor obligation for farmers to put it in the bank. Instead, these profits are used to propagate better agriculture, i.e. irrigation and tilling of cultivable land and increasing farming efficiency.

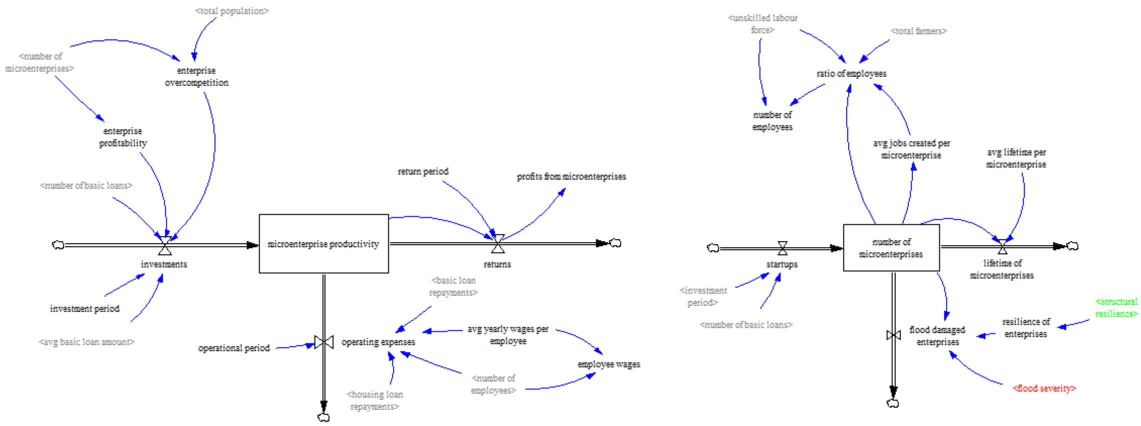


In this sub-model, the MFIs present in Cox's Bazar are simplistically lumped together, in order to represent the aggregate role of generic institutions. The major inflows are financial aid, disaster relief funds, loan repayments and savings. The outflows are loans disbursed (basic loans and housing loans), operational expenses and flood mitigation expenditures (policy).

Financial aid comes in on a yearly basis whereas disaster relief funds are immediately following floods and proportional to the severity of the flood damage. The number of basic loans disbursed is proportional (but not equal) to the number of approved loanees, as the MFI model works on the principle of shared liability (Grameen Bank, 2012). A portion of the loan amount (roughly 5%) is mandatorily set aside in a savings account; this functions as both a savings deposit for the borrowers as well as insurance against defaulters. Repayments comprise of loan amounts returned by loyal borrowers (within one year) and others (within two years). Housing loans on the other hand, are given exclusively to loyal borrowers, to be repaid in five years. While there are defaulters, the net amounts being lost are negligible enough to assume these debts are written off. This corresponds to the GBP practice of not litigating against defaulters (Grameen Bank, 2012). However, defaulters are permanently removed from the pool of eligible loanees.

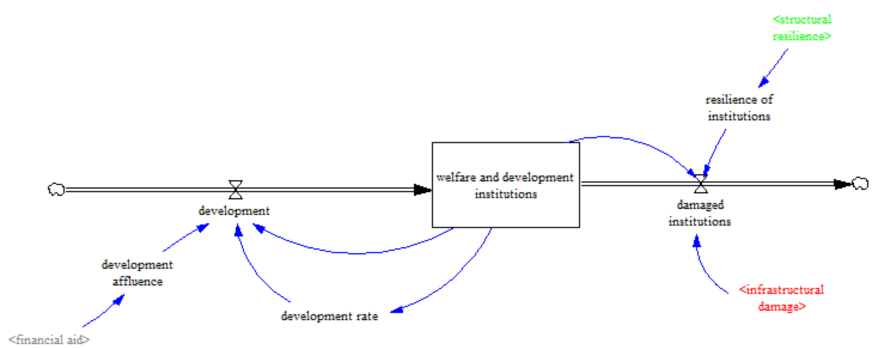
The operational expenses of the bank are relatively high due to the particular operating conditions of MFIs, e.g. representatives personally visit villages on a weekly basis to collect repayments as well as to recruit new members. An additional assumption in this sub-model is that only loanees go on to become micro-entrepreneurs, and that only the profits from micro-enterprises contribute to the repayments. This implies that the sustainability of the MFIs is primarily dependent on the success of local micro-enterprises. This assumption may be justified by the fact that before MFIs started operations, there was significant poverty and a minimal number of micro-enterprises, suggesting a significant portion of new cash flows are the direct result of investments from microfinance loans.

Finally, an outflow from MFI funds finances the flood mitigation measures (as described in the policy recommendations). As mentioned earlier, large-scale infrastructure developments like these are normally financed by government funds. However, this is practically not possible in the Bangladeshi context. On the other hand, MFIs are not purely private institutions, and could possibly use member funds to finance local infrastructure development.

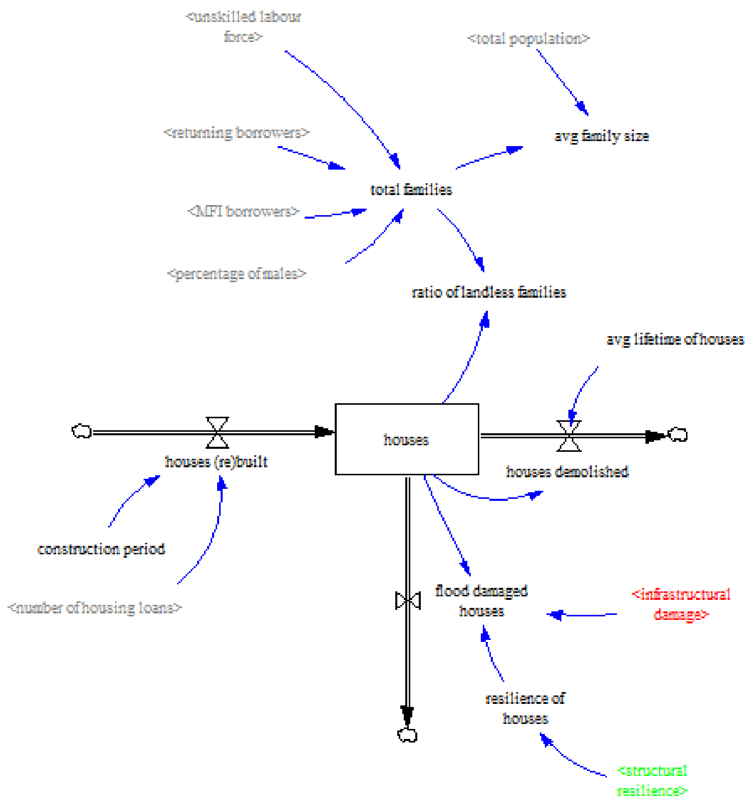


This sub-model consists of two structures; the structure on the right is the stock of the number of active micro-enterprises and the structure on the left determines the monetary flows in and out of these enterprises. The primary assumption is that each basic loan corresponds to the start-up of a new micro-enterprise. There are also some enterprises which are destroyed due to the floods. From the number of enterprises, the number of jobs created can be calculated; the number of employees combined with the number of farmers yields the employed fraction of the unskilled labour force.

The structure on the left represents the multiplier effect of investments going into micro-enterprises; in this way, net revenue is calculated. A fraction of the net revenue is designated as net profits from all the micro-enterprises. Two competing influences affect micro-enterprise productivity: below a certain threshold, the more micro-enterprises there are, the higher the profitability – because the local economy functions like an interdependent eco-system. On the other hand, if there are too many micro-enterprises within a small area, there is over-competition with net losses.

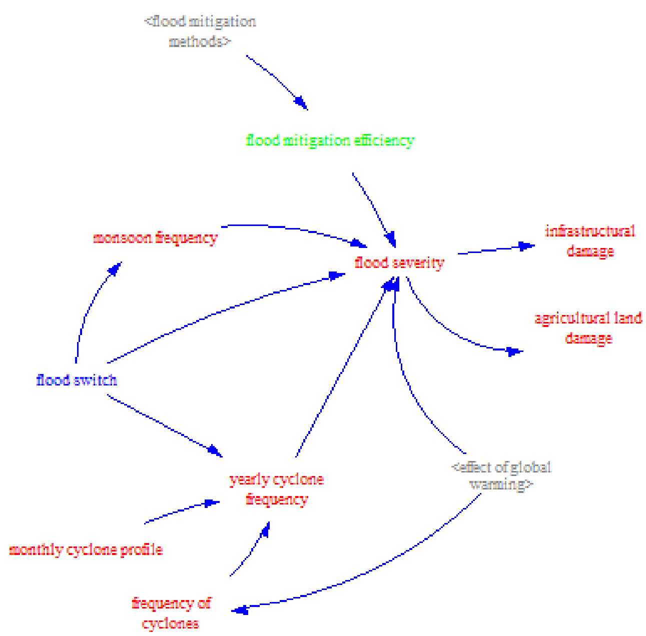


Welfare and development institutions refer to every form of social welfare, including NGOs, schools and hospitals, among others. These constitute the development backbone of the community. The rate of development is primarily dependent on the investments in development, i.e. proportional to incoming financial aid. In turn, the level of development influences birth rate, death rate, infant mortality rate as well as food distribution.

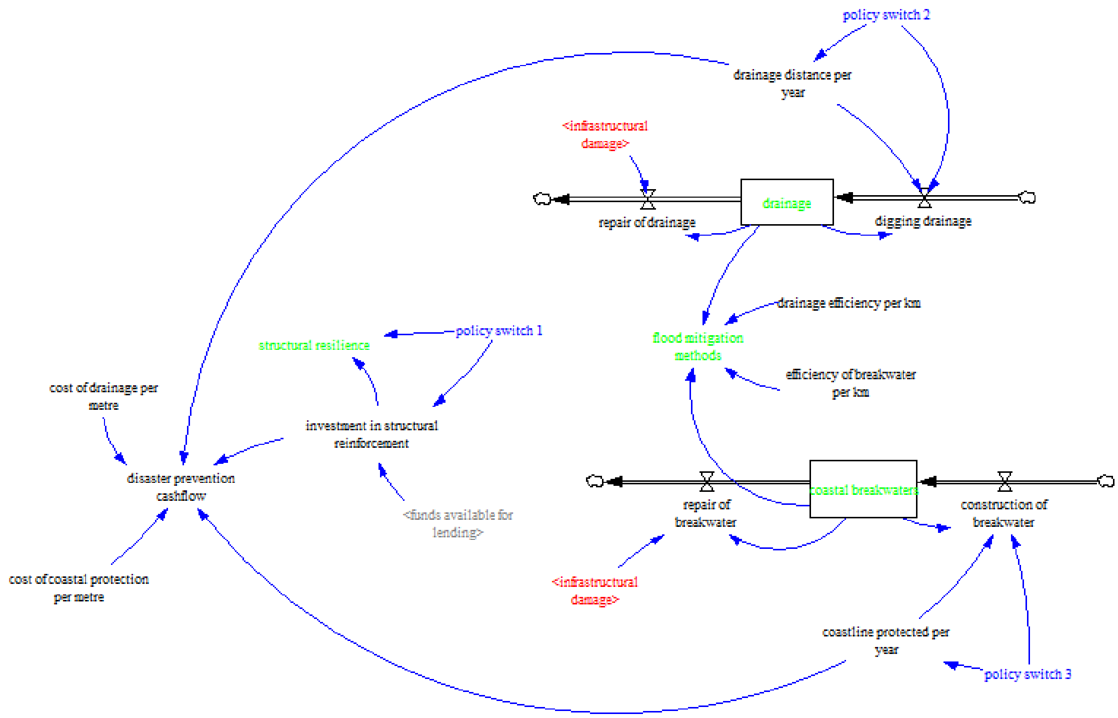


Low-cost housing is assumed to have a natural lifetime of ten years after which they must be demolished. On top of this, yearly flooding also damages a large number of houses leading to increased landlessness among the population. The assumption is that the houses are too expensive to rebuild without a housing loan from the MFIs.

The number of houses is used in the calculation of ratio of landless families, which in turn is the prime driver of loan approvals by the MFIs.



In this sub-model there are no explicit stocks and flows. Instead there are seasonal pulses of monsoons and cyclones combined with randomizers yielding variable severity over the years. In turn, severity is used to calculate the specific damage to agriculture and infrastructure.



In the final sub-model of the system, three different mitigation measures are initiated starting from year 10 of the simulation. The first measure is yearly investments in reinforcing the structural resilience of weakened buildings in the community, thus increasing the lifespan. The second measure is better drainage (e.g. sluice gates and secondary embankments) to drain flood water more efficiently, in order to minimize damage. The third and most expensive measure is the construction of floating/under-surface breakwaters at sea, to reduce the severity of coastal flooding.

In combination, these measures are designed to nullify between 25 to 50 percent of flood related damage. The funds to finance these measures are partially drawn from the local MFIs.