DECCMA

Working Paper

A framework for the design and evaluation of adaptation pathways in large river deltas

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About DECCMA Working Papers

This series is based on the work of the Deltas, Vulnerability and Climate Change: Migration and Adaptation (DECCMA) project, funded by Canada's International Development Research Centre (IDRC) and the UK's Department for International Development (DFID) through the **Collaborative Adaptation Research Initiative in Africa and Asia (CARIAA)**. CARIAA aims to build the resilience of vulnerable populations and their livelihoods in three climate change hot spots in Africa and Asia. The program supports collaborative research to inform adaptation policy and practice.

Titles in this series are intended to share initial findings and lessons from research studies commissioned by the program. Papers are intended to foster exchange and dialogue within science and policy circles concerned with climate change adaptation in vulnerability hotspots. As an interim output of the DECCMA project, they have not undergone an external review process. Opinions stated are those of the author(s) and do not necessarily reflect the policies or opinions of IDRC, DFID, or partners. Feedback is welcomed as a means to strengthen these works: some may later be revised for peer-reviewed publication.

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List of acronyms

CBA:	Cost-Benefit Analysis
CEA:	Cost-Efficiency Analysis
DECCMA:	DEltas, vulnerability and Climate Change: Migration and Adaptation (project)
DRR:	Disaster Risk Reduction
MCA:	Multi-Criteria Analysis
UNFCCC:	United Nations Framework Convention on Climate Change

Introduction

Deltas support over 500 million people globally, with particular concentrations in southern and eastern Asia and Africa. Large sections of these deltaic populations live in extreme poverty. By nature deltas are transient environments, being formed and reformed in response to variations in sediment load. Climate change will both change fluvial patterns of erosion and deposition, and also increase exposure to coastal flooding due to their low-lying nature. Supporting adaptation for delta populations is thus essential to reduce the adverse impacts of climate change. Determining the most appropriate ways of enabling adaptation is an important policy challenge.

Our aim herein is to develop and execute a framework for evaluating the impacts of alternative adaptation policy pathways for DECCMA's four river delta systems (Volta, Mahanadi, West Bengal, and Ganges-Brahmaputra), simulated in the DECCMA (Work Package 5) system dynamics model. In particular this paper focuses on the development of different pathways of adaptation into the futures of our deltas and identifying suitable criteria against which to measure the success of those pathways.

Climate change and deltas

River deltas around the globe face intense and diverse pressures. At the same time as experiencing rapid economic development, population growth, land-use change, and urbanization, all of which have profound impacts on the local social-ecological system, deltas are subject to many exogenous environmental changes (Syvitski and Saito, 2007). Perhaps most importantly, many large dams have been constructed in river basins around the globe (estimated to be around 70,000), with many more expected (Maavara et al., 2015). Dams can fundamentally alter the hydrological regime which flows through river deltas, affecting ecosystem service provision and dynamics (ibid). The implications are potentially serious, the height of many mega-delta land-surfaces is not accreting fast enough to counter the local rates of subsidence (Syvitski et al., 2009). Key drivers of this phenomenon are local ground-water extraction, which accelerates subsidence, and sediment starvation due to upstream trapping behind dams. To compound these issues, climate change is accelerating the rate of relative sea-level rise and driving short and long-term changes in the freshwater hydrological regime (Collins et al., 2013).

While climate change may bring benefits in the form of small improvements in long-term crop-growing conditions in some delta regions (Eastham et al., 2008), the sinking of deltas around the globe and the increased severity and frequency of extreme weather events present serious challenges. Indeed, the very survival of many deltas might be considered as under threat (Blum and Roberts, 2009; Schiermeier, 2014). Deltas explored in the DECCMA project were classified by Syvitski et al. (2009) as "in peril" (Ganges-Brahmaputra) and "at greater risk" (Mahanadi). There is an urgent need for policy makers to set a course of adaptation for delta systems in order to mitigate severe, unequal, and unpredictable loss and damage.

The importance of effective adaptation evaluation methods is also great, and is illustrated starkly in the case of the world's large river deltas. River deltas are important for their contribution to global food security and because they provide a home to hundreds of

millions of the Earth's citizens. The wellbeing of these individuals relies on informed and balanced decision making with regard to the broad adaptation strategy pursued at the large-system scale. Delta regions face fundamental challenges and adaptation choices which involve consideration of value-laden actions such as migration and societal restructuring (especially with reference to gender and inequality), factors which are difficult to comparatively evaluate. Yet decisions are being made in the present, particularly between hard and soft adaptation strategies (Wesselink et al., 2015), which will determine the long-term sustainability and functioning of these crucial components of the global social-ecological system (Ibáñez et al., 2014).

Defining and conceptualizing adaptation

To meet the pressing need for efficient, effective, and systemic adaptation of earth's social-ecological systems a meta-field of adaptation science continues to evolve. This meta-field spans a multitude of disciplines, approaches and institutions. We see a typology of adaptation evolving in the literature which is designed to bring order to the science, this distinguishes (i) types of action being studied (**Table 1**), (ii) types of approach being utilised (**Table 2**), and (iii) different study objectives (**Table 2**). The fourth (iv) variable in this typology is the classification of study-system scale, a variable which cuts across all of the other variables (i-iii). Researchers are encouraged to locate their project on these different dimensions to bring clarity and consistency across the thousands of outputs in production. The majority of adaptation case studies select a scale, and investigate a single context in each of (i), (ii), and (iii), or perhaps make comparisons between a limited number of different variables in the typology.

Table 1: Divisions of adaptation

Human	Proactive	Transformational	First-order	Hard	Policy driven	Mainstreamed
Ecological	Reactive	Incremental	Second-order	Soft	Private (autonomous)	Segregated
	Berrang-Ford et al. (2011)	*Kates et al. (2012)*	*Birkmann (2011)*		*Wamsler (2016)*	*Uittenbroek et al. (2013)*

Table 2: Aims and approaches to studying adaptation

Adaptation problems	Approaches
Identifying adaptation needs	Disaster risk reduction
Identifying adaptation measures	Vulnerability
Appraising adaptation options	Resilience
Hinkel and Bisaro (2016)	*Eakin et al. (2009)*

Pragmatic methods for evaluation of adaptation remain in their infancy. In large part this reflects our still developing understanding of what adaptation is (e.g. Wise et al., 2014). In closed systems or communities, where a single climate change impact threatens a key local objective, adaptation can be pinned down. An approach can be selected from the three outlined by Eakin et al. (2009) and an action selected which meets the desired objective(s). As such, assessments of small-scale community level adaptation are most

frequent in the literature, especially in developing world contexts (Berrang-Ford et al., 2011). However, whether or not adaptation is effective is difficult to tell before future hazard exposure has taken place and indeed, when viewed retrospectively, evaluation can be difficult because no direct alternative actions are available for comparison with. Thus whilst adaptation can be observed, its effectiveness is much more difficult to determine. Even where assessments of the small-scale community level adaptations exist, these studies tend to consider little with regard to the synergy of the action taken with other actions, objectives on a broader scale and time-horizon, and across sectors; all key recommendations for effective adaptation evaluation from the UNFCCC (2011).

When evaluating policy and action at the large social-ecological system scale, a context in which there is notable system complexity (e.g. river deltas), adaptation evaluation research may have to contend with virtually all of the classes of adaptation in **Table 1**, potentially simultaneously, or at different times and in different places in the system's future. Adaptation at the large-system scale relates not just to individual adaptation policies, but to managing the broader direction of the system. The direction of the drivers of change in that system, however, can often be subject to high levels of uncertainty and as such the focus of adaptation research at the system-scale has trended towards the identification of 'robust' courses of action (Haasnoot et al., 2013).

Studies of large-systems will need to evaluate suites of adaptation policies, in and between multiple economic sectors and biotopes, implemented over periods of time. These have come to be known as adaptation/adaptive pathways. The suites of adaptation policies within each pathway will push and pull a system and its component parts (e.g. households) onto different trajectories, some of which will be desirable and others undesirable (**Figure 1** visualises how different pathways might lead to more/less resilient worlds). The different actions which develop a pathway over time have been categorized into: shaping actions, mitigating actions, hedging actions, and seizing actions (see Walker et al., 2013 for further detail). As shown in **Figure 1**, these actions recognise adaptation as an ongoing or iterative endeavor, constantly seeking to manage risk over time and, ideally, steering the system away from tipping points which threaten permanent undesirable change (Walker et al., 2013).

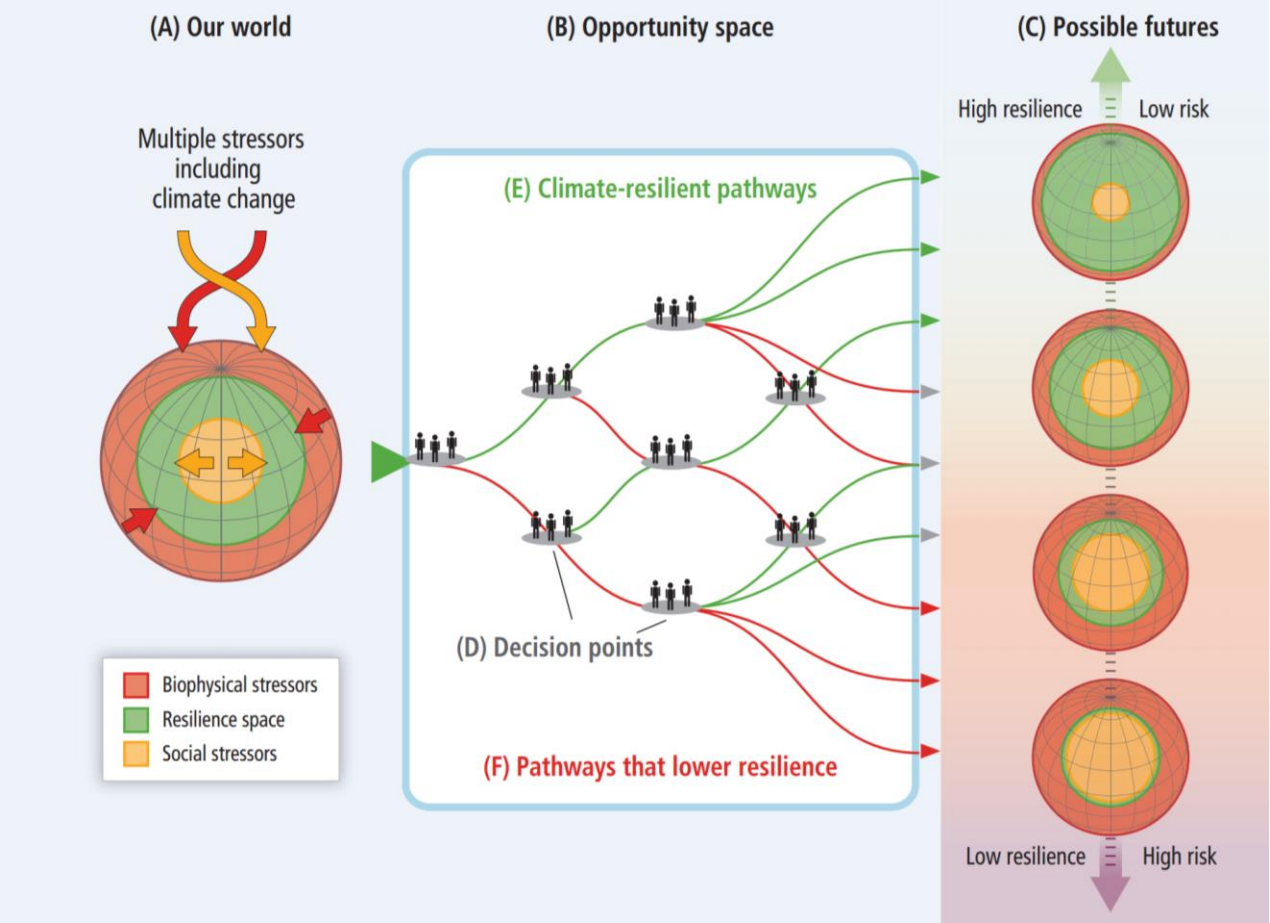

Figure 1: SPM.9 from Working Group II of the 5th Assessment Report of the IPCC (IPCC, 2014). Climate-resilient pathways (in green) within the opportunity space (B) lead to a more resilient world through adaptive learning, increasing scientific knowledge, effective adaptation and mitigation measures, and other choices that reduce risks. (F) Pathways that lower resilience (in red) can involve insufficient mitigation, maladaptation, failure to learn and use knowledge, and other actions that lower resilience; and they can be irreversible in terms of possible futures

The pathways approach to adaptation has been applied to delta regions previously, but to a limited extent, Haasnoot et al. (2012), for instance, explore a theoretical delta case. Perhaps the most pertinent example is Kwakkel et al. (2015), who systematically evaluate adaptation pathways in the Rhine Delta. They highlight the strong decision-support potential of systematic multi-objective evaluation of flexible pathways (i.e. pathways which can be switched between as the system evolves through time). Yet their policy set might be regarded as restricted when compared with the scope of the DECCMA project; they do not model household decision-making or diverse livelihoods, and consider primarily hard, hydraulic adaptation interventions. Most importantly they do not consider migration and relocation choices, which are now becoming pertinent in delta regions. The systematic evaluation of cross-sectoral adaptation pathways at the large-system scale seems largely unexplored, and worthy of consideration for methodological learning, and because of its potential role in enabling climate-resilient development.

A broad suite of approaches to adaptation evaluation have been theorized. Hinkel and Bisaro (2016) analyse the different contexts in which different approaches might appropriately be applied. For instance, their schematic can be used to recommend that an “experiment and learn” approach might be taken in a context where: “only short term options are available”, “there are risks due to current climate variability” and there is not a

“high relative cost of options” (p. 16). Yet due to the challenges of the evaluation task, described above, some of the largest and most ambitious studies to have reached completion thus far have sidestepped the issue of thorough evaluation of the different suites of adaptation they explore; preferring simply to present plausible scenarios to decision makers (e.g. MDP, 2013).

The delta context is one of urgency and complexity in which “expected outcomes” (as expressed by Hinkel and Bisaro) are subject to value-laden trade-offs, and in which transformational changes must be considered that are linked to decisions made at the present time. In such contexts the UNFCCC (2011) suggest there is an emerging consensus around three methodologies: Cost-Benefit Analysis (CBA), Cost-Efficiency Analysis (CEA), and Multi-Criteria Analysis (MCA). These approaches are not reviewed extensively herein. The UNFCCC (2011) provide a number of examples of each, but again those examples tend not to be large scale, cross-sectoral, or considerate of migration/relocation decisions. In addition, Kwakkel et al.’s (2015) analysis in the Rhine delta is primarily exploratory and not aimed at recommending a single pathway choice. However, utilising a technique similar to MCA -multi-objective optimization based on evolutionary algorithms- the authors successfully cut away sub-optimal pathways based on the pareto principle (though their decision to rely on a pareto frontier approach is normative and they highlight the limited nature of the indicator selection they have chosen). The literature thus highlights a gap for applying a comprehensive adaptation pathways approach at the large scale that considers both hard infrastructural adaptations at large scale as well as soft adaptation options at household level (including migration), and evaluates the success of different options with the aim of highlighting the most robust choices.

Methodology

Reflecting the emerging literature on adaptation pathways and the need to recognize complexity and tradeoffs, we apply these insights to the development of a framework. This framework identifies different pathways of adaptation into the futures of DECCMA’s four river delta systems (Volta, Mahanadi, West Bengal, and Ganges-Brahmaputra) and suitable criteria against which to measure the success of those pathways. Whilst the criteria are ultimately selected by MCA, to reflect the absence of universally-accepted definitions of successful adaptation they are informed by expert opinion and then ranked by stakeholders who are based in, and thus have familiarity with, the four delta contexts.

Outlining the framework

Broad framing

In delta regions, often threatened by large scale flooding and loss of land, migration and resettlement are often viable adaptation options (Warner, 2010). The evaluation of such migration options is likely to be affected by emotive personal, cultural, and gender differences. To appreciate such values we have opted for Multi-Criteria Analysis as our chosen evaluation approach, primarily for its efficient, transparent, stakeholder-oriented, and non-monetary system of comparison. In order to comprehensively analyse issues of migration and gender with relation to adaptation a method is required with a strong

capacity for evaluating distributional impacts and equity. UNFCCC (2011) highlights the strengths of the MCA approach over CBA and CEA in these regards. We combine our MCA with a pathways framing of adaptation. The primary novelty of our approach lies in its application at the large-system scale, across sectors, with our ability to perform direct comparisons across delta regions, and in our consideration of migration and relocation choices in our analyses. Necessary to executing a methodology with these novelties are some modifications and tailoring of traditional approaches to work with MCA and adaptation pathways, which are detailed below.

The framework we have adopted, based on the standard laid out by Dodgson et al. (2009), is presented in the lower half of **Figure 2**, with the key steps highlighted in blue. **Figure 2** highlights that we treat the MCA process as a post-modelling step, with indicators as outputs of the mode determining whether stakeholder-set success criteria are met. We now take each of the following in turn: the creation of adaptation pathways (including a description of the construction, validation, and implementation); and the evaluation of adaptation pathways, including: selecting stakeholder groups; eliciting and weighting stakeholder criteria of success; establishing suitable model indicators; and presentation of the process for generating the performance matrix which relates stakeholder criteria to the model.

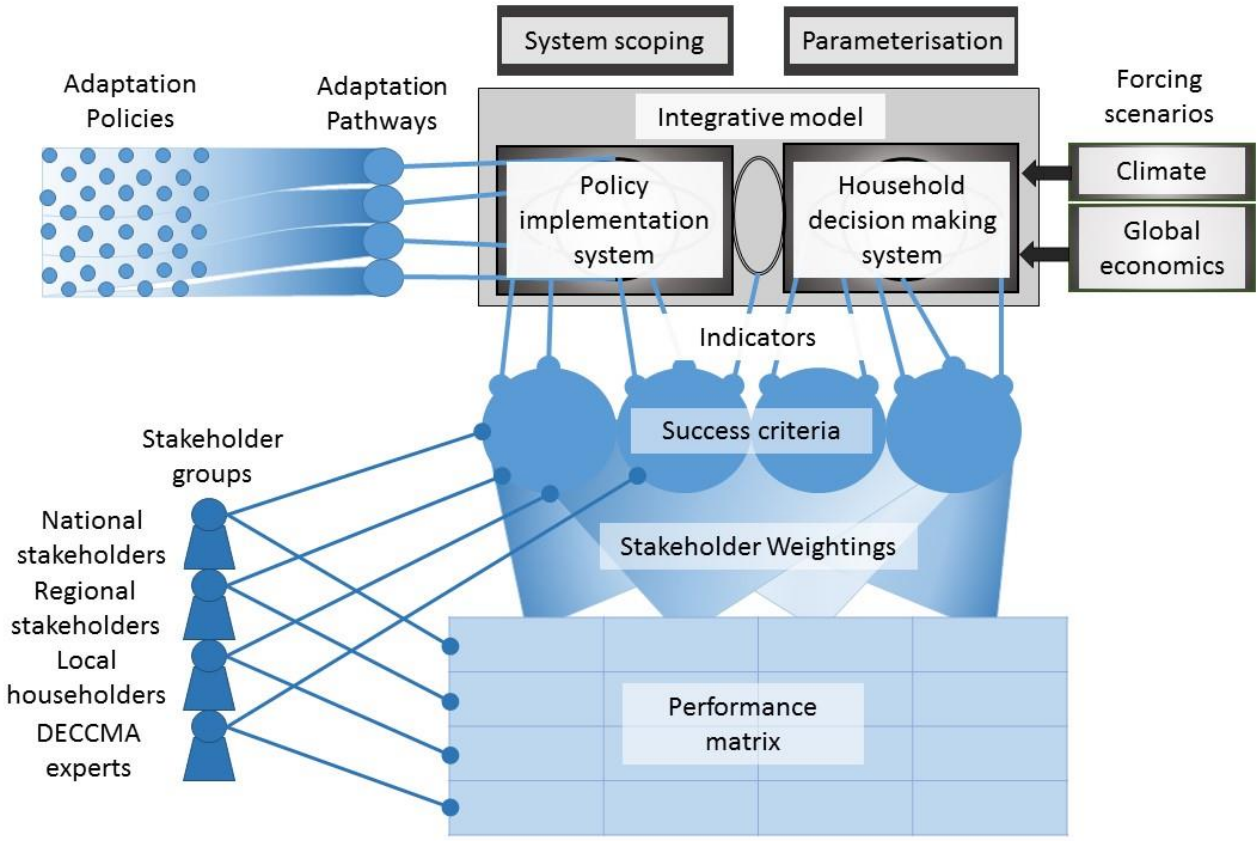

Figure 2: Framework for the evaluation of adaptation pathways in DECCMA deltas, with Work Task 6.4 (evaluating adaptation) areas highlighted in blue

Creating adaptation pathways

We have sought to build adaptation policy pathways (Wise et al., 2014) that are both visionary and realistic under future governments. The literature on the design of plausible

yet visionary pathways is extremely underdeveloped. Examples, such as Kwakkel et al. (2015), give very little detail on the exact formulation process and it might be inferred that their selection of policies is somewhat arbitrary. In studies of restricted scale and sectors such an approach might be sufficient but, for a study with broader scope a more systematic and less normative framework is required. Abel et al. (2016) attempt to provide such a framework. The development framework of Abel et al. is built on an initial set of possible actions developed through engagement with multiple stakeholders; recognizing the likelihood of conflicting actions emerging from different groups, Abel et al. then recommend "collective action processes" to address such conflicts. Once an initial set has been defined, the authors propose: *"the sequencing of actions would be enabled by six criteria:*

1. the role of the actions in paving the pathway for other actions;

2. the probability of an action averting transgression of a threshold;

3. the actions' resilience or robustness to a wide range of shocks;

4. the actions' effect on other adaptive options;

5. the time between action initiation and effect, and;

6. the consequences for equity." (p.4)

The criteria presented above are in effect criteria for the development of an optimum pathway. This approach supposes that a single optimum approach exists; we theorise that (as is assumed by multi-criteria analysis) multiple optimum pathways may exist dependent on which stakeholders' weightings are applied to the performance indicators. Different optimum pathways for different groups may be reached through different approaches to the pathway. This recognises that, even to obtain an optimum outcome, governments can emphasise different areas of policy, depending on their political preferences, the nature of the policy making environment (e.g. level of democratic accountability), and indeed the fundamental philosophy with which adaptation is approached. Therefore, at the top level there will be different policy making contexts/backgrounds (these backgrounds are being produced by Work Packages 1 and 5 and are not included in this document). These policy making backgrounds will lead our case study governments to prefer policies drawn from different fundamental approaches to adaptation pathway design.

However, we maintain within the restrictions of a governance context that policy makers have choices to make regarding their fundamental approach to adaptation. Creating a typology of different approaches to large scale system adaptation which might be chosen between presents many problems. On a very broad level there is the typology laid out by Eakin et al. (2009), which defines risk-based adaptation, the vulnerability approach, and the resilience approach. But these broad approaches are not sufficiently explicit to guide the construction of delta adaptation pathways, and the resilience approach particularly is highly theoretical. These approaches may also create an opportunity for a normative bias to enter the evaluation as, in modern rhetoric, the risk-based approach is commonly associated with many flawed or poorly performing adaptation initiatives. Instead, we have adapted Hall et al.'s (2016) typology, which was originally designed for decision making in infrastructural systems, to the delta system context. We have adopted four adaptation

pathways, each with a different fundamental approach (or 'philosophy') to adaptation and each containing a suite of adaptation policies which correspond to that approach. **Figure 3** presents an entirely theoretical example of one such pathway. In **Figure 3** fictitious adaptation actions can be seen being implemented over time, some having positive impacts on the health of the system (a normative concept which will in reality be determined from the stakeholders' success criteria) and some negative.

The four pathways are detailed fully in **Appendix 1**. The broad themes are:

A. *Minimum Intervention* – This pathway aims to keep costs down at the lowest possible level while still protecting citizens from climate change impacts.
B. *Economic Capacity Expansion* – This pathway focuses primarily on encouraging economic growth and utilizing the increased financial capacity it brings to protect the economic system from climate change-induced harm.
C. *System Efficiency Enhancement* – This pathway focuses on promoting most efficient management and exploitation of the current system, looking at ways of distributing labour, balancing livelihood choices, and best utilising ecosystem services to enhance livelihoods and wellbeing under climate change.
D. *System Restructuring* – This pathway links closely to ideas of 'transformational adaptation' (Kates et al., 2012) embracing preemptive fundamental change to the social and physical functioning of the delta system in response to serious threats to the delta's current social-ecological system.

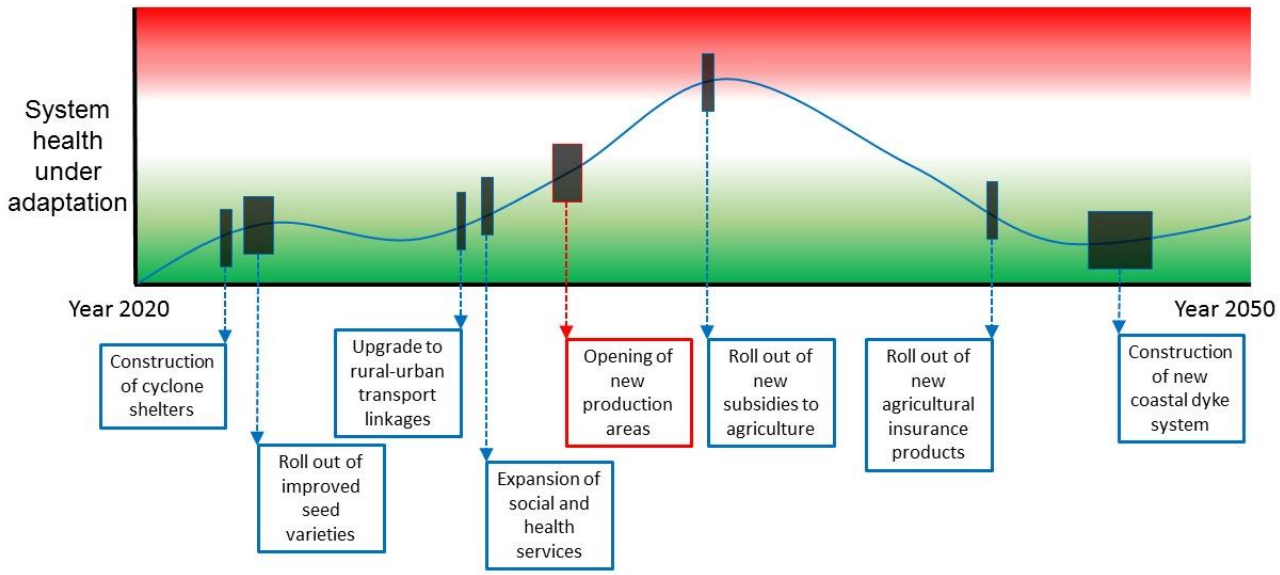

Figure 3: A theoretical adaptation pathway designed to illustrate how a pathway might attempt to control the trajectory of a system through 'themed' actions

The practical development of these four pathways will take place with due reference to, but not restricted by, the six criteria set out by Abel et al. (2016). In practical terms development will require considerable collaboration across the DECCMA project, utilization of expert and stakeholder knowledge, and integration of multiple components of the DECCMA workplan (as shown in **Figure 4**).

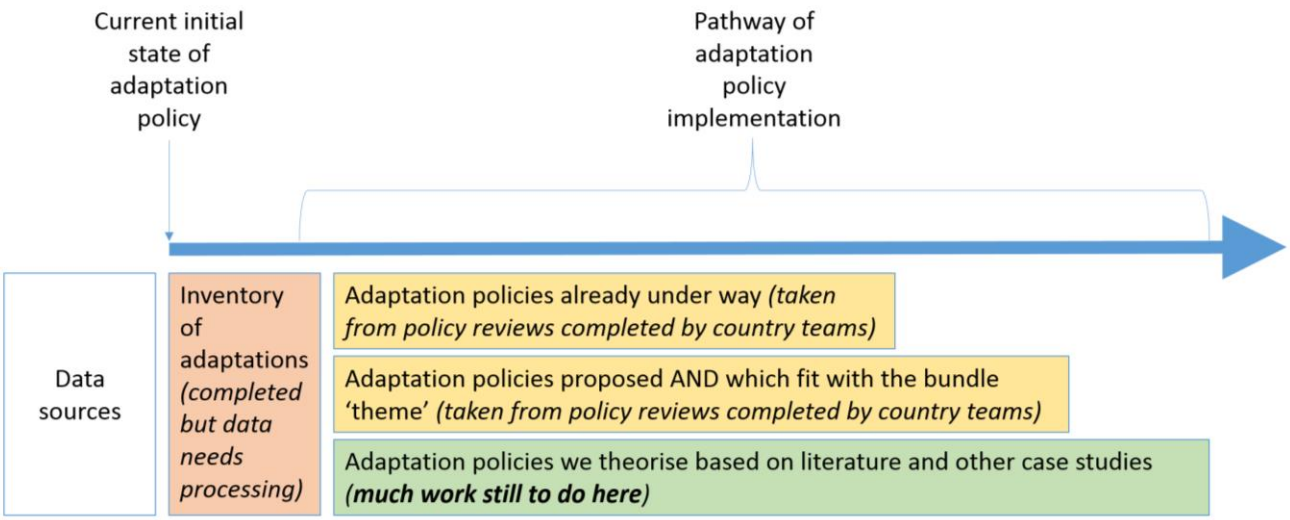

Figure 4: The adaptation pathway development process and data sources

1. Pathway policy areas

Broadly speaking each pathway (A-D) has a different strategy in terms of how it addresses adaptation. To make these different strategies tangible and applicable to the entire delta system we have divided adaptation policy in each pathway into nine sectors in which we believe adaptation policy is required for a delta, and between which sectors adaptation policies must have synergy. We propose that adaptation policy in the following areas should be represented (or noted as absent) in each pathway: i) DRR (Disaster Risk Reduction) policy ii) Agricultural policy iii) migration policy iv) vulnerability reduction policy v) gender policy vi) economic development policy vii) water and hydraulic management policy viii) ecosystem management policy ix) marine policy.

These policy areas have been selected for the following reasons:

(i) Most deltas are prone to natural hazards, notably seasonal flooding and drought, but many experience other hazards and *DRR policy* is at the forefront of almost all delta policy documents

(ii) Most deltas are highly productive agricultural areas, with the economies and food security of many nations currently dependent on their delta regions (e.g. the Nile, Mekong, and GBM) and hence we consider *agricultural policy*

(iii) Environmental changes, hazards, social change, and development can result in both forced and unforced migration in deltas (Szabo et al., 2016a) and therefore (also as a key interest area for DECCMA) we consider *migration policy*

(iv) Despite their economic importance and rapid development, deltas are commonly home to considerable levels of poverty (another driver of migration) and as such we consider *vulnerability reduction policy*

(v) Local conditions can often lead to women being among the more vulnerable groups in delta societies (Szabo et al., 2016b) and, as another focus area of the DECCMA project, *gender policy* was given its own dedicated sector

(vi) Often guiding the governance direction of deltas, particularly with regard to their agricultural production and intensification choices is *economic development policy*

(vii) Due to the physical characteristics of deltas, *water and hydraulic management policy* often facilitates, and is intrinsically linked to, economic development policy (Hung et al., 2012).

(viii) Delta formation is controlled by relatively short-term natural processes, and traditionally deltas are hotspots of biodiversity and unique ecosystems therefore, both the long-term integrity of the delta, and the preservation of valued ecosystem services depends on *ecosystem management policy* (Ibáñez et al., 2014).

(ix) Deltas often have long coastlines and hence large coastal populations engaged in marine-based livelihoods. Deltas contribute significantly to global food security through fish production and as such *marine policy* is important

In **Appendix 1** the four pathways are populated with a provisional set of policies in each of our nine policy sectors, these policy allocations should be taken as an early guide only.

2. Implementing adaptation pathways in a model

We envisage (and accept) that no real-world government is likely to fit exactly within our pathways (which are caricatures) of approaches to adaptation, and hence when we actually test adaptation pathways in the model we may test combinations of different policies from different pathways; with resources being split, to varying proportions, between policies within each pathway (e.g. 20%, 70%, 10%, 0%). Instead of committing entirely to one pathways, governments are likely to have a focus. In addition, adaptation policies may be implemented by NGOs operating within our case study deltas, these policies may sit outside of the government's focus.

Each adaptation pathway will involve the implementation of multiple policies by the governing bodies. Between the implementation level, and the response level (households), are many factors which will control and potentially distort the response from households (these process are described as the policy implementation system in **Figure 1**). These processes are the subject of investigation in Work Task 6.3. Ultimately the work from this package will help guide exactly how the policies manifest themselves in the system dynamics model being developed by DECCMA Work Package 5. However, at this stage it is possible to design provisional policy implementation mechanisms in the model, i.e. how the outputs of the policy implementation system will drive the household decision making system. **Figure 5** (below) represents the current working overview of the system dynamics model which will represent that household decision making system in the DECCMA project. In **Figure 5** various social factors (e.g. place attachment) can be seen feeding into the final decision a household makes as to whether, and how, to take adaptation action; but around that system are multiple points at which planned policy might act to change and affect that decision.

A key feature of adaptation policy, especially in disaster prone areas, is its often reactive nature, i.e. certain policies are (and sometimes can only be) implemented in the aftermath of an event which draws attention to a particular issue. In addition, some adaptation policies will only make economic sense once climate change impacts have progressed to

a sufficient severity. For these reasons Kwakkel et al. (2015) implement the policies in their pathways in a manner reactive to the conditions of their integrated model in each time step. This reactive element will need to be built into the DECCMA integrated model as adaptations become active; to facilitate this each policy will require a model-based trigger. For example, a planned policy in the sub-system marked 'B' in **Figure 5** might be triggered by a certain intensity or regularity of the hazard sub-system marked 'A'.

Evaluation of adaptation pathways

Once the simulation of the adaptation pathways has taken place, the multi-criteria analysis phase will proceed. The final objective is a performance matrix which highlights the broad comparative desirability of different adaptation pathways under different scenarios of environmental (including climate change) and global socioeconomic change (those components defined as exogenous pressures on the system model) for different stakeholder groups. The key inputs to the performance matrix are the stakeholder groups whose perspective are to be included, the criteria of adaptation success those stakeholders hold, the different weightings of those criteria according to each stakeholder group, and suitable indicators to represent those criteria in the integrated model.

1. Selecting stakeholder groups

At the large delta system scale there are virtually limitless ways of grouping stakeholders in the system, ranging from the most abstract groupings (e.g. foreign nationals with a vague concern) to the most practical (e.g. rice farmers whose survival is directly dependent on the delta environment). With scenarios of climate change, scenarios of governance, and adaptation pathways the DECCMA outputs are already subject to are large number of permutations. To keep results accessible we have opted to simplify the stakeholder groups considered as much as possible. We have opted for: *national policy makers*, i.e. those setting the overarching adaptation strategy, *sub-national (e.g. state and local level) policy makers*, i.e. those responsible for implementing the strategy, *householders*, i.e. those most affected by the strategy, and *international experts*, i.e. those with academic expertise on the delta system and its functioning.

2. Eliciting and weighting stakeholder criteria of success

Phase two of the evaluation process is to extract criteria from our stakeholder groups against which the success of the adaptation pathways might be evaluated. What constitutes success at the large-system scale is normative, as such, extracting criteria of success which all operate in the same paradigm, and can also be modelled, is challenging. As McDowell (2014) put it: "*adaptation is normative, and what is adaptive for some may be undesirable or maladaptive for others*" (p.86).

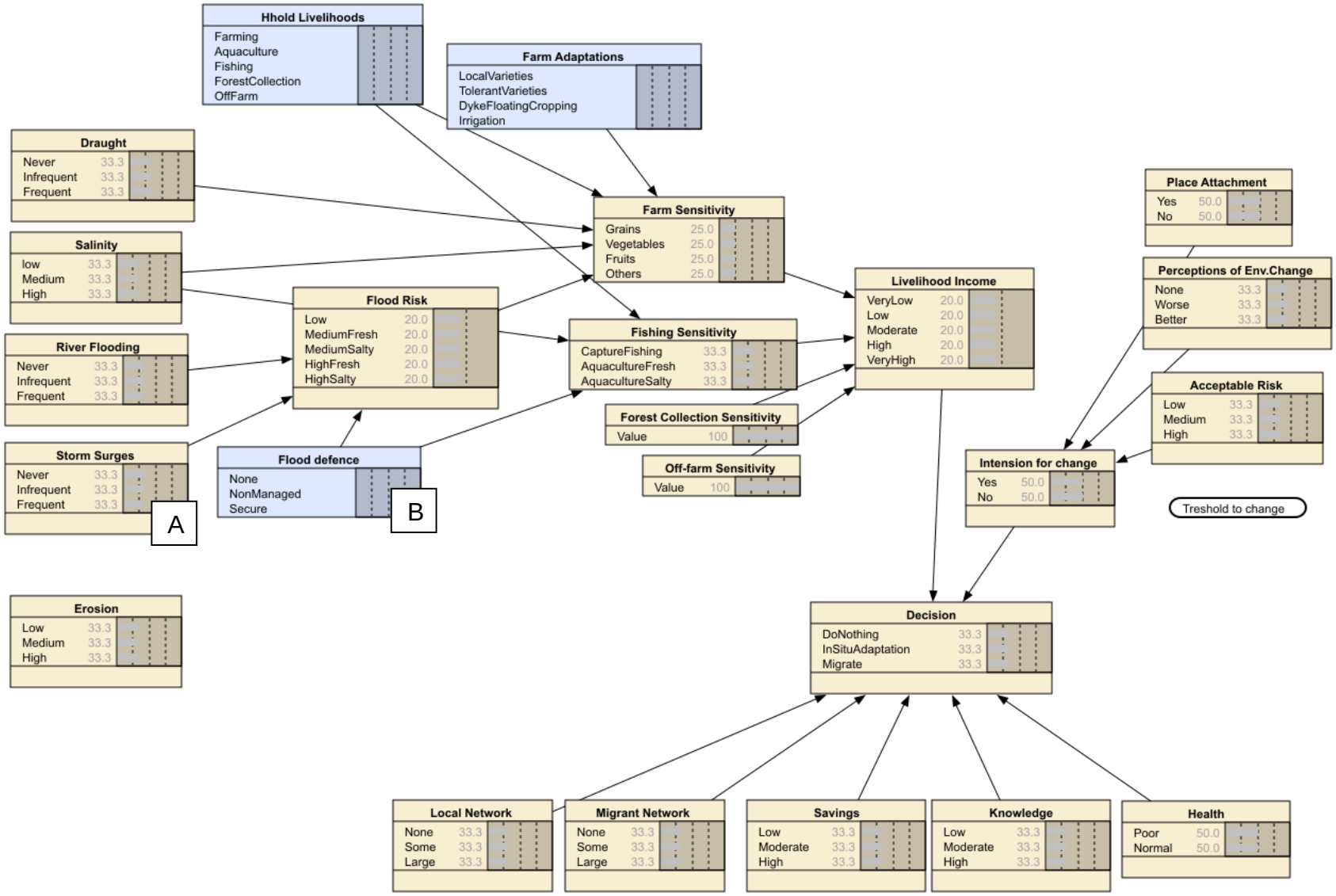

Figure 5: A draft overview of the different components of the integrated model. Each box represents a sub-system within which a more comprehensive model operates (not shown). Highlighted in blue, are some subsystems upon which planned adaptation policies might act.

Rather than offering all of our stakeholders a blank canvas on which to place their criteria, we have applied various levels of restrictions to data collection from different stakeholders as shown in **Figure 6**. This step ensures comparability but does risk mis-measuring or failing to take into account some criteria of success. Stakeholder checking of the final criteria set can prevent against this, and can be addressed through the DECCMA stakeholder engagement process.

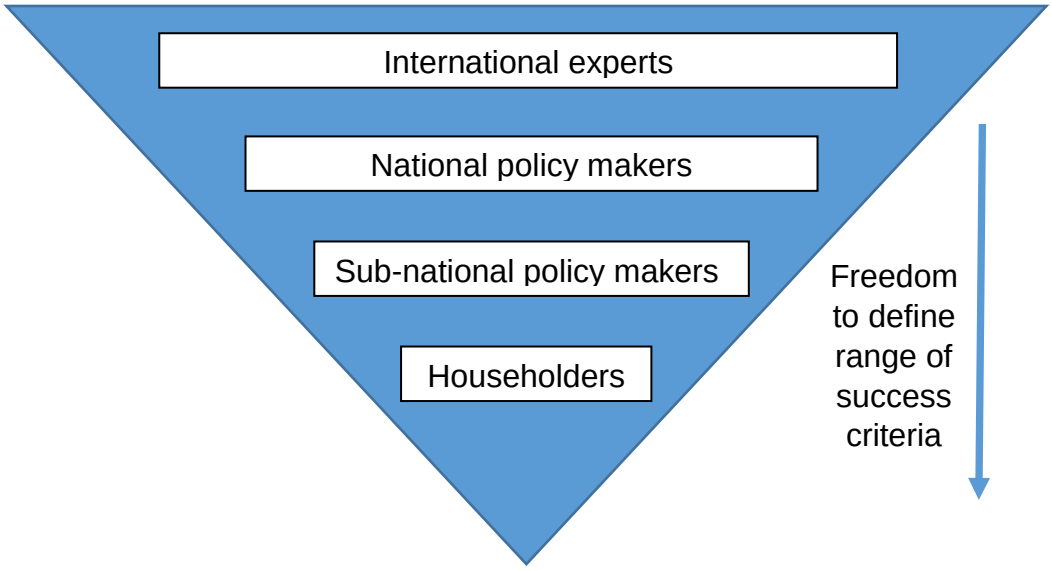

Figure 6: The stakeholder groups whose perspectives are to be considered by the multi-criteria analysis

Initially our international experts were given complete freedom to build a large catalogue of potential criteria of a successful adaptation. National and sub-national policy makers were then given the freedom to select from this list, and the option to add to this list. Householders were not given the freedom to define criteria, rather we will infer their preferences for different criteria in the catalogue built by the experts and policy makers from their responses to the household survey.

Data collection from international experts (represented by the full range of staff employed on the DECCMA project) has taken place in the form of an online survey (found in **Appendix 2**). Weightings for the criteria provided by the participants will be taken from the rankings the participants provided alongside their criteria. Data collection from the national and sub-national policy makers is taking place in the form of in-country focus groups. Small groups are asked to consider successful adaptation and then complete an individual questionnaire in which they highlight criteria they feel are important, and then weight them (**Appendix 3**). Data collection from householders is underway in the form of the main DECCMA household survey. Weightings will be inferred from the survey through analysis of the frequency of actions taken by householders.

3. Establishing suitable model indicators

Once the final criteria list has been established, with every criterion weighted by every stakeholder, indicators will be established, in collaboration with the other DECCMA work packages, which can represent those criteria in the model. The most challenging part of this process is likely to be the development of a mechanism for considering the temporal element to each indicator. In traditional economic analyses a discount rate is usually applied to manage stakeholders' desires for indicators at different points in the future e.g. a farmer might place great importance (weight) on short-term cash income, but the value of future cash income might be relatively low; conversely the non-monetary importance (weight) of healthy local biodiversity might be low in the short-term, but might not

depreciate in value into the future if a farmer wishes to pass that biodiversity on to future generations. However, for non-monetary indicators such a process may not be appropriate. Again, this issue can be addressed through stakeholder engagement and the adding of a temporal component to the criteria described above can also be performed in the DECCMA stakeholder engagement process.

4. Generating the performance matrix

Multiple tools are available to a researcher for the purpose of processing indicator performances and their weightings to build the overall scores for each scenario/pathway combination. Dodgson et al. (2009) lay these tools out in some detail.

Moving forward

This document has set out a framework for the development and evaluation of adaptation pathways in large river delta systems. The framework contains originalities in its cross-sectoral, large scale scope, its consideration of migration and relocation as parts of a suite of valid adaptation actions, and in its attempt to systematically evaluate themed pathways. If successful the framework should provide a guide on what theme or philosophy of adaptation (from the four pathways) produces the most successful adaptation for the four stakeholder groups considered over the next 30 years in each delta. The framework is ambitious but checks and balances have been built in, primarily in the form of stakeholder engagement and grounding in existing policy literature, to ensure the pathways considered are realistic in each delta's context and are evaluated on robust criteria of success.

Appendix 1: Full details of the four adaptation pathways being tested. The policies populating the nine areas of policy in each delta are shown. Unless otherwise stated all policies are policies mentioned somewhere in the national policy documents examined by the DECCMA project (Dey et al., 2016; Haq et al., 2016; Hazra et al., 2016; Mensah et al., 2016). The source for each policy is shown with a code (V – Volta Delta adaptation policy report; M – Mahanadi Delta adaptation policy report; GBM – Ganges-Brahmaputra Delta adaptation policy report; WB – West Bengal Delta adaptation policy report) and a page number.

Policy component	Adaptation pathways			
	A: Minimum intervention	B: Economic capacity expansion	C: System efficiency enhancement	D: System restructuring
Example deltas	Okavango (Motsholapheko et al., 2013) Mahanadi	GBM-BD delta	GBM-BD delta	Vietnam MDP (agro-industrial scenario)
Pathway Philosophy	Either a fundamental preference for non-interventionist government, or a government lacking the capacity to act	A guiding fundamental position that production and export-led growth, and hence a larger economy, improves livelihoods for all through financially empowering the government and the people	A fundamental position that growth cannot be limitless therefore success is achieved by most efficient distribution and (sustainable) utilization of current resources	A guiding belief that significant landscape modifications are justified to create long term delta system resilience despite short term costs that may be accrued in rural areas
Disaster risk reduction (DRR) policy	- Data collection (Vp15) (GBMp23) - Data dissemination (Vp15) (GBMp23) - Building connections between scientists and local (traditional) stakeholder knowledge (Vp15) - Developing institutional capacity (Vp16) (GBMp22) (Mp12) - Early warning systems (Vp15) (GBMp28) (Mp26) (WBp17) - Develop emergency preparedness (including	Construction of (multipurpose) cyclone shelters (GBMp22) (Mp11) (WBp18)	- Build more efficient structures, provide new and affordable technologies or improve design standards (Vp18) (GBMp23)	- No adaptation policies at present

Policy component	Adaptation pathways			
	A: Minimum intervention	B: Economic capacity expansion	C: System efficiency enhancement	D: System restructuring
	requiring products and fuel to be held in reserve) (Vp15) (WBp16) - Disaster insurance (Mp26) (GBMp24) - Develop prevention and control practices for wildfires and floods (Vp18) - Review and increase investments in existing social services to ensure that the key Public Social Services are able to recover after climate related disasters (Vp23) (GBMp26)			
Agricultural policy	- Research and development (drought, salinity, flood tolerant crop varieties) (Vp17) (GBMp26) (Mp11) - Reviewing the training curricula of agricultural training colleges to include climate change and variability (Vp21)	- Provision of improved breeds and new seed varieties (Vp21) - Intensification of farming (Mp11) - Introduction of high-yielding and short duration crop varieties (including the development of disease and pest resistant varieties) (Vp21)	- Development of multi-purpose water/rain harvesting and storage facilities that will promote in- field harvesting and conservation (Vp20) (GBMp25) (Mp28) (WBp17) - Promotion of environmentally sustainable cropping practices (Vp21) - Training on post-harvest technologies to minimise post-harvest losses (Vp21) - Promote livelihood diversification and resolve conflict between shrimp	- Re-zoning of agricultural areas to be used for 'voluntary' inundation or needed as flood buffer zones (proposed) - Construction of large sand banks (sediment nourishment) for storm and inundation protection (proposed and expensive)

Policy component	Adaptation pathways			
	A: Minimum intervention	B: Economic capacity expansion	C: System efficiency enhancement	D: System restructuring
			and paddy cultivation by encouraging their cultivations either concurrently or by rotation within polders (GBMp21) - encourage crop diversification (GBMp22)	
Migration policy	- No adaptation policies at present	- Increase the capacity of rural-urban transportation linkages (proposed) - Financial assistance for displaced populations to move to newly created production areas (proposed)	- Discourage rural-urban migration (GBMp31) - Encourage movement of labour and skills to locations in need (proposed) - Assistance towards retraining and relocation of displaced populations to areas with skills and workforce deficits (proposed)	- Support relocation of settlements and economic activities away from flood-prone areas (Vp18)
Vulnerability reduction	- Raise awareness of climate change related health issues (Vp19) - Promoting access to improved sanitation and potable water through rural investment (Vp19)	- Expand the provision and delivery of social and health services (Vp21) - Construction of new freshwater pumping networks to transport fresh drinking water to flood affected areas (WBp17)	- No adaptation policies at present	- No adaptation policies at present
Gender policy	- Facilitate the participation of women across all sections of society in training, public awareness	- Secure access to dry land for small scale women farmers on a long term basis (Vp27)	- Empower women through training at all levels to perform their roles in water resource	- No adaptation policies at present

Policy component	Adaptation pathways			
	A: Minimum intervention	B: Economic capacity expansion	C: System efficiency enhancement	D: System restructuring
	campaigns, formal and non-formal education and decision-making processes in environmental management (Vp22) (GBMp29) (WBp19)	- Promote land reforms that ensures equal access to irrigated land for women and Persons with Disability (Vp22) - Provide selective subsidies for the procurement of improved agriculture inputs for women (Vp22) (GBMp23) - ensure crop insurance and/or other safety nets for female farmers (GBMp23) (Mp24) - Developing the financial literacy of women and their links to markets (GBMp26)	management and sanitation (Vp22) - Encourage capacity building for women in the energy sector (Vp22) - Training on post-harvest technologies to minimise post-harvest losses for women (GBMp25)	
Economic development policy	- Improving farmer access to market information (Vp16)	- Creation of new production areas (proposed) - Encourage private sector to invest in the organic fertilizer industry. Credit should be made available to small scale farmers to enable them purchase and use mineral fertilizers (Vp24) (GBMp25) - Improvement of market access facilities and roads (especially feeder roads) that support distribution of food across various communities, including vulnerable areas (These include climate proof transportation, cold chain facilities, financing, and	- Provide financial incentives to adopt affordable and appropriate technologies in waste management (Vp24) - improving access to credit facilities for crop and livelihood diversification (Vp24) - building technical and financial capacities on alternative livelihoods (Vp24) - Support off-farm livelihood activities through training and credit schemes (Vp23)	- Facilitate alternative livelihoods, including eco-tourism support schemes for fringe communities along buffer zone (Vp24) - Create employment opportunities and sustainable livelihoods in rural communities through forest plantation development (Vp23) (GBMp24)

Policy component	Adaptation pathways			
	A: Minimum intervention	B: Economic capacity expansion	C: System efficiency enhancement	D: System restructuring
		specialized markets for trading of forest plantations stands) (Vp21) (GBMp25) - Provision of processing, value addition and storage infrastructure at individual and community levels to open up public and private sector investments in post-harvest management operation along the value chain (Vp21) (GBMp26) - Develop innovative term and seasonal financial products for irrigators (Vp24) - Provide selective subsidies for the procurement of improved agriculture inputs for poor peasant farmers and women (Vp25) - Improve access to financial services and develop a more comprehensive insurance market for agriculture (especially for poorer farmers) (Vp25) (GBMp25) (WBp17) - Increase ease of access to insurance for fishers and shrimp culture operators (GBMp24) - Increase ease of access to loans and credit for farmers (collateral free) (GBMp25)	- Give incentive and compulsion measures to encourage users of the environment to adopt less exploitative and non-degrading practices in agriculture (Vp24) - Align the economic incentives confronting fishers with imperatives to promote the generation of wealth and sustainability rather than economic incentives to maximise individual catch volumes (Vp24) - Create incentives for investors (diversification) in tree crops and plantation (tax relief for private sector investment in research and development (Vp24) - Provision of efficient waste management systems including improved regulation, monitoring, and enforcement of measures to reduce risks (Vp19) - Promoting the benefits of alternative	

Policy component	Adaptation pathways			
	A: Minimum intervention	B: Economic capacity expansion	C: System efficiency enhancement	D: System restructuring
			uses of waste through reduction, re-use, recycling and recovery (Vp19)	
Fresh water and hydraulic management policy	- No adaptation policies at present	- Build hard control sea defence structures (coastal embankments) to protect coastal areas (Vp18) (GBMp22) (WBp17) - Build river dykes (WBp17) - River dredging to increase water capacity (GBMp22) - River dredging to ensure transport links (GBMp25) - Development of small-scale dams and reservoirs (Vp20) (GBMp25)	- Develop new pumping systems to meet the needs of a diversified crop base (proposed)	- Facilitate strategic flooding of regions to reduce downstream impacts and ensure floodplain sediment deposition takes place in key areas (proposed) - Large scale sediment redirection through channel construction and redesign to ensure land-building is maximized (proposed and expensive)
Ecosystem management policy	- Development of forest conservation and management techniques (Vp18) (Mp24) - Research and development (energy conservation, forest plantation development) (Vp19)	- Land and pond reclamation to bring areas into aquaculture and agriculture production (saline/waterlogged/degraded land) (Mp25) (WBp17)	- Developing approaches to land-use planning to protect natural resources (Vp18) (GBMp23) - Develop and use open spaces, green belts and other ecologically sensitive areas for alternative livelihood such as urban farming (Vp24) - Development of more efficient energy use	- Create biological corridors and green spaces (Vp18) - Mangrove restoration (Mp12) (WBp18) - Create riparian buffer zones along river banks (Vp18) - Create coastal green belt, including through

Policy component	Adaptation pathways			
	A: Minimum intervention	B: Economic capacity expansion	C: System efficiency enhancement	D: System restructuring
			technologies (to take pressure off forests) (Vp19)	tree planting (GBMp24) - Afforestation (Vp18) (GBMp24) (Mp24)
Marine policy	- No adaptation policies at present	- Encourage brackish water fisheries in canals (WBp17 incl. locations) - Construction new modern fish landing centers to reduce post-catch losses (GBMp25)	- No adaptation policies at present	- No adaptation policies at present

Appendix 2**:** Survey of the DECCMA staff (national experts) to identify the criteria against which they would measure adaptation success. This was an online questionnaire.

Please enter your name:

Do you consent to the data you provide being used in the DECCMA project?

Which work package(s) are you associated with?

What is your highest level of qualification?

With which gender do you associate yourself?

Which regional team are you affiliated with?

What is your area of academic expertise?

Poverty/Development/Economics/Migration/Demography/Governance

Which of the below definitions most closely represents how you view a successful adaptation?

At least one person in the delta is better off and no one in the delta is worse off

The poorest in the delta are better off, even if others are worse off

The adaptation that generates the least worst outcome in the worst case scenario

The adaptation that minimises the risk of maximum losses occurring

Other...

(1) Please provide your first criteria to evaluate the success of adaptation in 2050 (most important):

(2) Please provide your second criteria to evaluate the success of adaptation in 2050:

(3) Please provide your third criteria to evaluate the success of adaptation in 2050:

(4) Please provide your fourth criteria to evaluate the success of adaptation in 2050:

(5) Please provide your fifth criteria to evaluate the success of adaptation in 2050:

(6) Please provide your sixth criteria to evaluate the success of adaptation in 2050:

(7) Please provide your seventh criteria to evaluate the success of adaptation in 2050:

(8) Please provide your eighth criteria to evaluate the success of adaptation in 2050:

(9) Please provide your ninth criteria to evaluate the success of adaptation in 2050:

(10) Please provide your tenth criteria to evaluate the success of adaptation in 2050 (least important):

Appendix 3**:** Form used at the focus group of national and regional policy makers to establish the criteria against which they would measure the success of adaptation.

Discussion and survey:

Criteria for successful adaptation

Official title:_____

Organisation:_____

Sex: Female:_____ Male:_____ Prefer not to say:_____

Date of interview:_____

Dear Sir/Madam,

Thank you very much for making time for this survey. This survey is part of the research project on "Deltas, Vulnerability and Climate Change: Migration and Adaptation (DECCMA)", led by the University of Southampton, University of Ghana, BUET and Jadavpur University and their partner institutions. For this survey we are interested in finding out what you believe successful adaptation looks like. We are developing plausible 'adaptation pathways' – or packages of various different adaptation policies which could unfold within your delta system.

In this session we would like you to do two things:

(i) In groups discuss some different ideas of what successful adaptation is very broadly and provide us with your preferred definition.

(ii) Individually rank some different criteria of a successful adaptation according to importance, and tell us if you think any criteria are missing from our list.

We expect all of this to take 20 minutes at most.

What does successful adaptation look like? Below are four statements please discuss them with other attendees in the session, and then tell us your own idea.

A. ***Successful adaptation is where at least one person is better off, while nobody is worse off***

B. Successful adaptation will ensure that the most vulnerable in the delta are better off, even if others are worse off

C. Successful adaptation will mean that damage is most effectively minimised under the worst possible case scenario of climate change

D. Successful adaptation pathway will improve the livelihoods/wellbeing of the greatest number of people possible (even if a minority suffer losses)

What do we need to do to get to a state of successful adaptation in 2050?

_____

_____

_____

_____

_____

Of the criteria in this table, please rank your top five from most important (1) to least important (5)

Criteria of successful adaptation	Rank
The majority of men and women experience an improvement in their income level	
The majority of people gain improved access to health services	
The majority of people have improved access to education (primary, secondary and tertiary)	
The majority of people have improved access to clean water for personal use	
The majority of people have access to a more reliable and more nutritious source of food	

The livelihoods of the majority of people are less vulnerable to damage from climate hazards	
No one is forced to migrate because their livelihoods have become untenable	
Marginalised groups (e.g. women, those of lower castes, and the elderly) are less vulnerable	
The adaptation measures implemented are sustainable in the context of long-term anticipated climate change	
The adaptation measures implemented can be managed and maintained by local knowledge and labour	
The adaptation measures are consistent with a low-carbon future (i.e. they do not increase greenhouse gas emissions)	
Marginalised groups are able to make real choices about their livelihoods	
Marginalised groups have access to equal pay and job opportunities	
The rates of maternal mortality fall to levels comparable with Europe	
All members of the community have access to good advice on how to protect livelihoods from natural hazards	
Employment levels increase across the delta	
The capacity of local institutions to manage hazards and changes improves	
All adaptation policies implemented have a net economic benefit (compared to the present)	
Traditional knowledge is effectively used and integrated into local decision making	
All vulnerable citizens have access to a shelter to protect them from natural hazards	
All citizens have access to some form of insurance/risk sharing mechanism in the event of an extreme event	

Have we missed any important criteria? Please tell us below

Criteria	Rank

Thank you very much for completing this survey. We will be using the results to help us evaluate the success of different adaptation pathways for your delta, and we will be feeding the results back to you.

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