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Developing socio-ecological scenarios: A participatory process for engaging stakeholders

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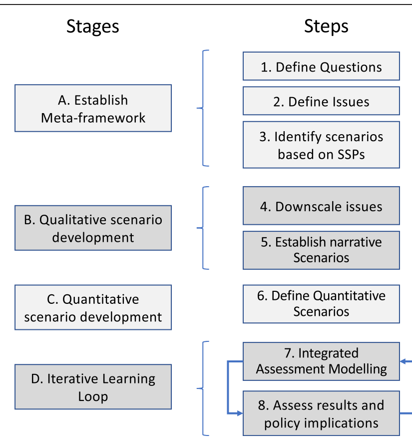
HIGHLIGHTS

- General 4-stage scenario development approach for integrated assessment
- Stakeholder-led development of extended SSPs to national and local level
- Qualitative and quantitative elements in multiples scales and sectors
- Application to climate change impacts in Bangladesh to 2050
- Novel incorporation of governance and implementation realities

GRAPHICAL ABSTRACT



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ABSTRACT

Deltas are experiencing profound demographic, economic and land use changes and human-induced catchment and climate change. Bangladesh exemplifies these difficulties through multiple climate risks including subsidence/sea-level rise, temperature rise, and changing precipitation patterns, as well as changing management of the Ganges and Brahmaputra catchments. There is a growing population and economy driving numerous more local changes, while dense rural population and poverty remain significant. Identifying appropriate policy and planning responses is extremely difficult in these circumstances. This paper adopts a participatory scenario development process incorporating both socio-economic and biophysical elements across multiple scales and sectors as part of an integrated assessment of ecosystem services and livelihoods in coastal Bangladesh. Rather than simply downscale global perspectives, the analysis was driven by a large and diverse stakeholder group who met with the researchers over four years as the assessment was designed, implemented and applied. There were four main stages: (A) establish meta-framework for the analysis; (B) develop qualitative scenarios of key trends; (C) translate these scenarios into quantitative form for the integrated assessment model analysis; and (D) a review of the model results, which raises new stakeholder insights (e.g., preferred adaptation and

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policy responses) and questions. Step D can be repeated leading to an iterative learning loop cycle, and the process can potentially be ongoing. The strong and structured process of stakeholder engagement gave strong local ownership of the scenarios and the wider process. This process can be generalised for widespread application across socio-ecological systems following the same four-stage approach. It demands sustained engagement with stakeholders and hence needs to be linked to a long-term research process. However, it facilitates a more credible foundation for planning especially where there are multiple interacting factors.

1. Introduction

1.1. Background

Scenarios are descriptions of possible futures that facilitate analysis for a variety of purposes. There are a number of different types of scenarios (Alcamo, 2001), often described as exploratory, predictive or normative, which can be applied in a variety of circumstances and purposes (Kok et al., 2019; Rothman, 2008). Scenario analysis can inform decision making in circumstances of uncertainty, and explore a range of plausible future states and their challenges (Shell International, 2003; European Environment Agency, 2009). In situations where the factors influencing the future, and their inter-relationship, are particularly complex, for example in the context of environmental and climate change, scenarios allow decision makers to consider a variety of plausible story lines of how the future might unfold (Carter et al., 2007; Jones et al., 2014; Wollenberg et al., 2000; Hickford et al., 2015). Effective involvement of stakeholders in scenario development can assist in enhancing both the acceptance and plausibility of the resulting scenarios (Alcamo, 2001; McBride et al., 2017). This is especially valuable where levels of complexity and uncertainty are high, such as strongly connected social and ecological systems (Berkes et al., 2003; Berkes and Folke, 1998; Bizikova et al., 2014). Attempting to describe how "*social systems in which some of the interdependent relationships among humans are mediated through interactions with biophysical and non-human biological units*" (Anderies et al., 2004) might develop in the future under various stresses only enhances this complexity.

Here we focus on scenarios of socio-ecological systems at national and smaller scales to support environmental management and development policy and planning, as opposed to global scale scenarios. Such scenarios are increasingly used to explore plausible futures across the high uncertainty in projections of the socioeconomic impacts of climate and other change (Mahmoud et al., 2009, Rounsevell and Metzger, 2010; Riahi et al., 2017; Kok et al., 2019). Planning strategies can be identified through the development of shared visions of future outcomes, as well as by assessing the effectiveness of different interventions in terms of performance against future uncertainties. One of the settings with the greatest exposure and vulnerability are low and mid-latitude deltas, with a global population of 500 million people (De Souza et al., 2015). Deltas are complex systems which are threatened by climate change and multiple human-induced changes such as enhanced subsidence due to groundwater withdrawal, and declining supplies of sediment linked to flood defences within the delta and upstream changes, especially existing and new dams (Syvitski et al., 2009; Dunn et al., 2019). At the same time, populated deltas are also a major focus for development and are seeing profound demographic, economic and land use changes (Nicholls et al., 2019). All these changes are exemplified in Bangladesh where the combined impacts of sea-level rise, changing precipitation patterns and upstream management of the Ganges and Brahmaputra rivers in particular, combine with poverty and dense rural population levels to produce high vulnerability and development needs (IPCC, 2014; Lázár et al., 2015; Nicholls et al., 2016, 2018; Alam and Collins, 2010; Huq et al., 1999; GED, 2018). The magnitude, complexity and uncertainty of the threat make it difficult for policy and decision makers to assess and plan appropriate responses. Scenario approaches can help to conceptualise and analyse these multiple drivers of risk in ways that render them more digestible by participants, facilitating dialogue and aiding the search for solutions. Bottom-up perspectives are essential to properly understand and contextualise our changing world, especially at sub-national scales (Conway et al., 2019), and by implication develop relevant scenarios. Participatory approaches allow stakeholders to contribute their knowledge to the assessment and build a shared understanding with experts. This makes the scenarios more relevant to analysing situations such as those in Bangladesh, including finding solutions.

This paper describes a participatory method for scenario development and wider stakeholder engagement to inform and engage with an integrated assessment process. It is illustrated by an analysis of the future of ecosystem services in south western coastal Bangladesh (Nicholls et al., 2016, 2018). It adopts a systems approach including biophysical and livelihood dimensions. The scenario development similarly incorporates both socio-economic and biophysical elements across multiple scales and sectors. Based on this experience the approach is generalised for wider application to complex socio-ecological systems in general.

The benefits of participatory scenario development approaches have been shown to include increased ability on the part of stakeholders to address uncertainty and complexity, and improved understanding of the impacts of global change across scales and disciplines (Tompkins et al., 2008; Oteros-Rozas et al., 2015; Strasser et al., 2019). They also create the opportunity for structured engagement with stakeholders in ways that allow contact with groups with differing levels of expertise and interest (Bizikova et al., 2014). Methods for describing the relevance of the Shared Socio-Economic Pathways (SSP) narratives at smaller geographical and political scales are developing (Ebi et al., 2014; O'Neill et al., 2017; Frame et al., 2018; Cradock-Henry et al., 2018; Rohat et al., 2018). Stakeholder involvement in this process is recommended as illustrated by Nilsson et al. (2017) for the far north of Europe and Palazzo et al. (2017) for agriculture in West Africa.

The value of participatory approaches has been highlighted by the gaps in existing modelling capacity and its ability to integrate across sectors and disciplines. Identifying trends in socio-economic processes with multiple interactions and dependencies is severely limited by the current capacity to understand and represent these processes, particularly in a quantitative way (Strasser et al., 2019; Berkhout et al., 2002, Swart et al., 2004). This is further compounded by the range of scales considered, from international cooperation and macroeconomic issues through to individual and household behaviour. Despite an increasing number of studies adopting interdisciplinary scenario development down to the regional scale, the majority of these studies remain focused on a sub-set of future changes, such as flood risk (Hall et al., 2005), water resources (Soboll et al., 2011) and land use change (Baker et al., 2004; Rounsevell et al., 2005; Audsley et al., 2006), with only a few addressing the full extent of biophysical and socio-economic changes considered in this research (Harrison et al., 2016; Holman et al., 2017; Harrison et al., 2019). In particular, there is limited evaluation of socio-economic scenarios focusing on human well-being and poverty (Lázár et al., 2015).

1.2. Participatory climate scenarios in Bangladesh and integrated assessment

Application of participatory scenario techniques in Bangladesh has been comparatively limited, although the application of scenario approaches has increased rapidly in the context of climate change (e.g., Nishat and Mukherjee, 2013; Kniveton et al., 2013). Scenarios have been incorporated to some extent into planning processes in Bangladesh (GED, 2012), although longer term planning has been somewhat inhibited by the five year planning cycle (GED, 2015). Various research initiatives have sought to integrate scenarios within the five-year planning window, notably the Climate Change, Agriculture and Food Security (CCAFS) programme.[4] In addition, the Government of Bangladesh Planning Commission has been a key actor in efforts over the past few years to extend the use of scenarios, including within the Bangladesh Delta Plan 2100 (BDP2100). This provides a long-term adaptive and integrative planning framework over many decades up to 2100 (GED, 2018; GED, 2015, 2018; Oteros-Rozas et al., 2015) and makes explicit reference to the generalised process described below (GED, 2018 at 709).

1.3. Paper novelty, aims and structure

Building on these challenges, this paper sets out a novel participatory method for multi-sectoral scenario development to aid policy makers in planning for the impacts of climate change over the medium term. The explicit aim of the scenarios was to inform an integrated assessment of ecosystem services and human well-being in coastal Bangladesh (Lázár et al., 2018). As such it took global visions of the future derived from the Shared Socioeconomic Pathways (SSPs) and downscaled them via an inclusive stakeholder process.

The scenario process operated in parallel with the BDP2100 development and helped to inform it so policy impact was an explicit goal. The approach adopted here is built on a process of deep stakeholder involvement necessitating the planning of a multi-step engagement process from the outset. It adopts elements of the 'story and simulation' approach (Alcamo, 2001). The process described below took almost four years, demonstrating one of the potential costs of participatory scenario development processes (Oteros-Rozas et al., 2015), but equally it offers huge benefits compared to one-off stakeholder engagement as presented below. In the first instance, stakeholders establish the frame of reference for the work, then led the detailed elucidation of detailed socio-economic scenarios at national/subnational levels in the form of detailed narratives, before engaging in the process to translate these narratives into forms suitable for quantitative modelling. The process described here was used to directly inform some of the boundary conditions used in the multi-sectoral integrated assessment modelling (Lázár et al., 2018), thereby minimising questions of transparency that potentially undermine integrated assessment models (Schneider, 1997). The application of the integrated assessment, dynamically representing coupled systems (Forster et al., 2018), is described more fully in Rahman et al. (2019b).

This paper is structured as follows. Section 2 describes the four-stage participatory method adopted. The results are set out in Sections 3–5: Section 3 elaborates on and applies Stage A, establishing the meta-framework. Section 4 addresses Stage B, producing qualitative scenarios tailored for the Bangladeshi delta context. Stage C, the process of quantifying these qualitative scenarios, is then described in Section 5. Section 6 discusses and synthesises the results, providing a link with Stage D of the approach, and Section 7 concludes with lessons for more general application.

2. Method

A participatory approach was developed in order to engage and integrate stakeholder views into a broader system level and model-focused assessment in a way that did not require high levels of technical expertise.[5] This was designed to enhance the credibility of the final project results because the assumptions underpinning this modelling work would be aligned with those of a cross-section of national stakeholders. Further, it allowed local knowledge to be incorporated throughout the model development and application process. This included for example: (1) understanding contemporary policy implementation; (2) expectations of trajectories and trends over the next few decades; and (3) understanding the main areas of concern for the future. Our approach used a series of meetings which informed the integrated assessment from its formulation through preliminary results and ultimately policy analysis. This gave the stakeholders a strong sense of ownership of the process moving towards co-production in ways that are rarely achieved in practice. In this paper, 'local' should be interpreted as 'national', this being relatively local in the context of global scenarios. A general schematic of the method is shown in Fig. 1 comprising four stages which are further broken down into eight steps.

The research also considers the influence of governance on outcomes. Assessment of infrastructural or management interventions usually assumes perfect implementation, but the outcome depends on the quality of legal and institutional frameworks (Rogers and Hall, 2003). This raises the question as to the extent to which policy objectives can be achieved in the absence of perfect governance (Grindle, 2004): this could inform donor decisions. Although the mapping of law (as one aspect of governance) has been theorised to some extent (von Benda-Beckmann et al., 2009), connecting the impact of governance quality more broadly with the success of management interventions has not yet been satisfactorily achieved. Hence, governance quality was explicitly considered within the scenario development process as one way of reflecting its consequences on the natural and social environment over the longer term (Gardner et al., 2014).

The approach is aligned with the scenario approach adopted under the Intergovernmental Panel on Climate Change (IPCC) 5th and forthcoming 6th Assessment Reports, whereby climate emissions and socio-economic change are considered separately through Representative Concentration Pathways (RCPs) and Shared Socioeconomic Pathways (SSPs) (Moss et al., 2010; Kriegler et al., 2012; IPCC, 2014). In addition, Shared climate Policy Assumptions (SPAs) (Kriegler et al., 2014) have been developed that connect policy choice to the RCPs in particular. As already noted, this global framework is not intended to

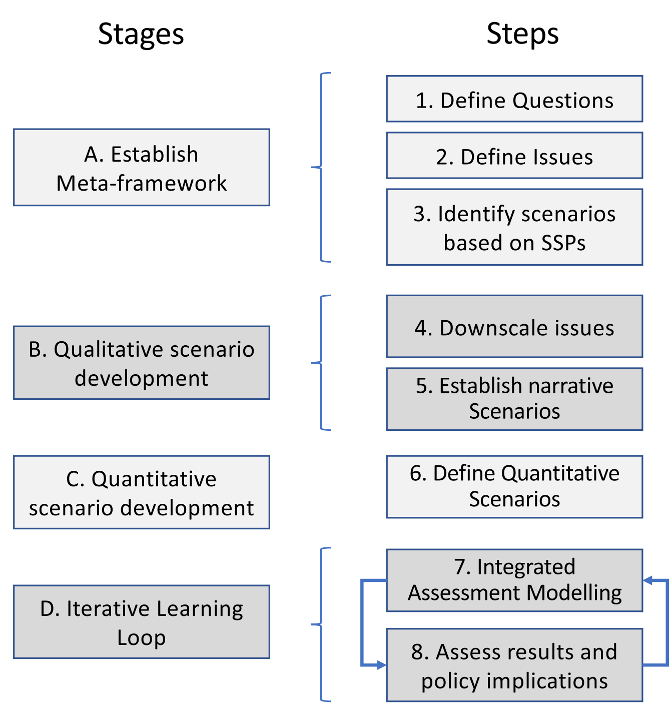

Fig. 1. Graphical representation of the participatory scenario development method.

[4] https://ccafs.cgiar.org.

[5] The work took place in the context of the ESPA Deltas Project which aimed to provide policy makers with the knowledge and tools to enable them to evaluate the effects of policy decisions on ecosystem services and people's livelihoods.

be applied directly at national or subnational level (O'Neill et al., 2017), requiring further elaboration and refinement in order to make it applicable for national decision makers (see for example Rohat et al., 2018; van Ruijven et al., 2014; Yao et al., 2016). Therefore it requires downscaling and modification to reflect the issues of specific relevance to the stakeholders and decision makers in the relevant location. This creates rich and detailed socio-economic scenarios at a higher level of detail than has typically been achieved in this context. In coastal Bangladesh, a matrix of three climate change scenarios combined with three socio-economic scenarios were used to describe a range of plausible socio-ecological futures for coastal Bangladesh to 2050 and 2100 (Barbour et al., 2018, at 166). The climate change scenario always considered similar high-end emissions, as explained below. The combination of these nine scenarios sought to identify a range of possible future change and ultimately to investigate the effectiveness of different management interventions. The application of the SPAs has not been addressed as the focus of the work was on adaptation rather than mitigation (Kriegler et al., 2014; Kebede et al., 2018).

The scenario development process adopted here integrated stakeholder views with an interdisciplinary approach that covered key elements of the biophysical environment along with changes in livelihoods, education, economics and governance both nationally and internationally. The approach involved close collaboration with stakeholders and the project team, with a view to developing both qualitative narratives (Stage B) followed by quantitative scenarios (Stage C) for the evaluation of management interventions at the integrated assessment stage (Fig. 2).

In line with project objectives of informing future policy choices and modelling plausible futures, and to consider restrictions on time and resources, stakeholders were presented with a limited set of choices of possible futures. Given the relative constraints placed on stakeholders with respect to the choice of scenarios. It was decided that they would consider all elements that they thought were relevant, and the project would then identify from this subset those that were capable of being analysed in models. These were validated with stakeholders in later workshops.

As set out in Fig. 1, the process involved three initial stages comprising of six principal steps: Stage A: (1) determining the questions to which answers were sought; (2) identifying key issues of concern to stakeholders in relation to longer-term livelihood and environmental protection in the Ganges-Brahmaputra-Meghna (GBM) delta; (3) identifying the number of scenarios to be applied; Stage B: (4) taking the issues identified in step 2 and breaking these down in order to determine a baseline and indication of how much change might be expected at the local level; (5) integrating the results to qualitatively describe what the future might look like at the scenario time horizon using narratives/storylines; and Stage C: (6) translating these qualitative descriptions into quantitative form for the integrated assessment. These steps were conducted as part of an iterative process of interviews and six national level stakeholder workshops held over the period from early 2012 to May 2016. The process was used throughout to facilitate cross-sectoral discussions and breakdown sectoral boundaries so coastal Bangladesh was considered as a whole. This then supported the development of an integrated modelling tool (the Delta Dynamic Integrated Emulator Model) which was applied to investigate development trajectories, including possible management and development interventions across the scenarios (Nicholls et al., 2016). Stage D, incorporating steps 7 and 8, provides ongoing engagement with stakeholders and the opportunity to comment on and progressively refine management and policy interventions in the light of modelled simulations through an iterative learning loop (Nicholls et al., 2016). This is a critical part of its application to policy analysis and formulation but will not be examined in this paper as it is fully set out in Rahman et al. (2019a, 2019b). Converting these processes to embedded policy analysis could see steps 7 and 8 followed many times.

Sections 3 to 5 below explain the results of this method.

3. Results: establish the meta-framework (Stage A)

3.1. Define questions and issues: steps 1 and 2

For step 1, fundamentally the principal question at the heart of the research derived from the principle project objective: to assess the present and future status of ecosystem service provision and human well-being in the study area. For step 2, a series of thirty unstructured interviews were held during 2012 and 2013 with stakeholders in order to determine the key issues of concern in relation to long-term livelihood and environmental protection in coastal Bangladesh. These stakeholders comprised of representatives from relevant institutions, primarily at the national level, following a detailed stakeholder mapping (described in Allan et al., 2018). They were chosen because of their

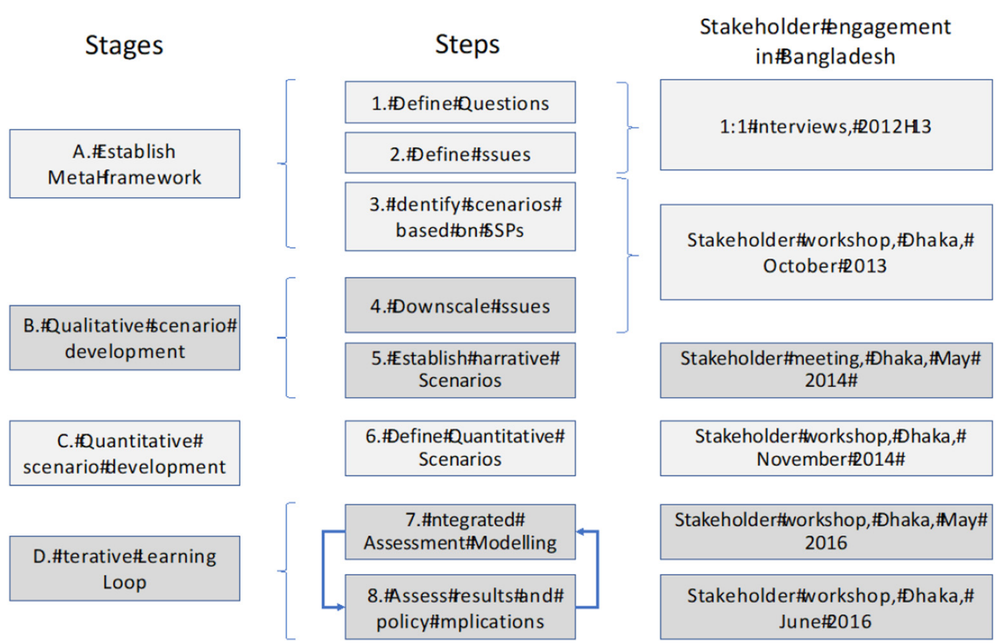

Fig. 2. Integration of stakeholder engagement with the participatory scenario development method.

relevance to ecosystem services and poverty and the scale at which they operated within Bangladesh. These included:

- National government officials across a range of Ministries and agencies related to ecosystem services and human well-being (e.g. Planning Commission; Ministry of Agriculture; Water Development Board; the Water Resources Planning Organisation (WARPO));
- Relevant non- and inter-Governmental Organisations at the international level (e.g. International Union for Conservation of Nature (IUCN); International Organisation for Migration; Global Water Partnership; Care)
- UN organisations, multi- and bi-lateral donor agencies (e.g. the United Nations Development Program (UNDP); the Food and Agriculture Organisation (FAO); World Health Organisation (WHO); World Food Program (WFP); World Bank; Asian Development Bank; and the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ))
- National non-governmental organisations (NGOs), research groups and subject experts, including representatives from academic institutions (e.g. BRAC and BRAC University; WildTeam; Bangladesh Agricultural Research Institute (BARI); and Bangladesh Rice Research Institute (BRRI)).

The results of these interviews, combined with a literature review, revealed the breadth of the issues of concern to stakeholders in relation to longer-term livelihood and environmental protection in the GBM delta. These findings were synthesised and categorised into key issues (Allan et al., 2018). These key issues reflect those areas where stakeholder opinion overlapped with the literature review: issues identified in the literature that were not seen as priorities by stakeholders were omitted (Allan et al., 2013). This completed steps 1 and 2 of the process.

3.2. Identify scenarios based on SSPs: step 3

As already noted, the scenario development process was inspired by the SSPs as set out by Arnell et al. (2011); O'Neill et al. (2012) and O'Neill et al. (2017). These pathways describe different development scenarios, ranging from Sustainability (SSP1), to Middle of the Road (SSP2), Fragmentation (SSP3), Inequality (SS4) and Conventional Development (SSP5). Each is characterised by the extent to which it will be able to meet the socioeconomic challenges of adaptation and mitigation respectively (O'Neill et al., 2012).

The scenario elaboration approach applied in Bangladesh effectively produces what are termed 'extended SSPs' (Arnell et al., 2011; Ebi et al., 2014). This takes a global approach unsuited to direct application at lower scales, and adds more nationally relevant characteristics, facilitating to some extent the downscaling of the SSPs (Absar and Preston, 2015; van Ruijven et al., 2014; Yao et al., 2016; Frame et al., 2018).

In order to complete step 3, the five SSPs were reduced to three future socio-economic scenarios in consultation with Bangladeshi partners at a meeting in Dhaka in October 2013. As the project research was neither focused on nor addressing the mitigation of greenhouse gas emissions, we chose to exclude SSP5 from the outset, leaving four outline scenarios in principle. After further debate in the light of a more detailed reading of the SSP narratives, project partners decided that there would be too much overlap between the Fragmentation and Unequal SSPs when applied in Bangladesh, and a decision was therefore taken to combine SSPs 3 and 4. The resulting three scenarios adopted were: Business As Usual (BAU); and two variants termed Less Sustainable (LS); and More Sustainable (MS). Fig. 3 demonstrates how these results correspond with the original axes from O'Neill et al. (2012).

BAU was defined as the situation that might exist if existing policies and development trajectories continue along similar lines to the previous 30 years, *irrespective* of whether or not this in itself is sustainable. It provided a scenario linked directly to the stakeholder's experience. LS and MS are alternatives that are broadly less or more sustainable than BAU. This allowed us to take the issues raised in step 2 and project

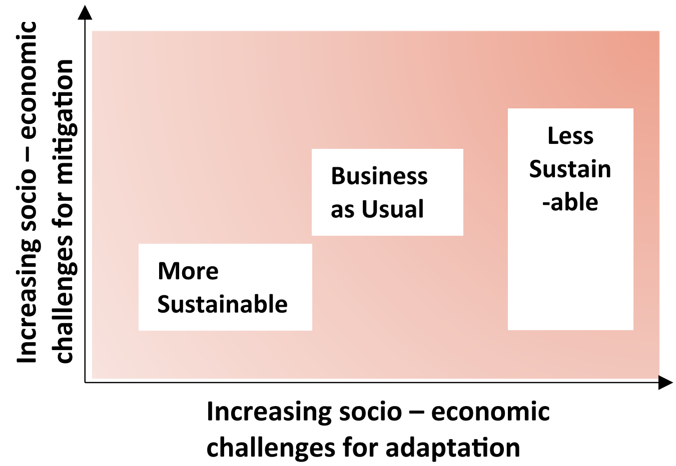

Fig. 3. The Shared Socioeconomic Pathways and the degree of respective challenge for climate change mitigation and adaptation.
(After Arnell et al. (2011).)

how they might look in 2050, on the basis of regional climate projections (Caesar et al., 2015; Caesar and Janes, 2018). The BAU scenario is broadly comparable to SSP2 in the SSP framework, the MS scenario with SSP1, and the LS scenario a combination of SSP3 and SSP4. This mapping is subject to the caveat that the MS and LS scenarios were developed in relation to BAU, and no objective measure of sustainability was used in the three resulting scenarios. Therefore, there is no suggestion that the More Sustainable future would actually achieve the levels of sustainability that Bangladesh needs for its long term survival. This concluded step 3.

4. Results: qualitative scenario development (Stage B)

4.1. Downscale issues: step 4

Moving from Stage A to Stage B, step 4 necessitated the integration of the issues identified in step 2 with the narrative scenarios to be produced in step 5, in effect extending the SSPs to the national level. It was brought about by categorising the issues into four broad groups: (1) Natural resource management; (2) food security; (3) health, livelihood and poverty; and (4) governance. These were further divided into constituent elements by the attendees at the first stakeholder meeting held in October 2013. Participants represented 14 institutions across a wide range of areas of expertise, interests and scales (Allan and Hutton, 2013). Discussions were conducted in plenary, with decisions reflected on white boards. Once consensus or majority agreement was reached on the breakdown of each of the issues and categories, attendees were asked to assess the expected trend over time, using a three point positive and negative scale for improvement or deterioration from "+" (or "−") to "+++" (or "−−−"), with "+/−" being slight and "+++/−−−" being strong (and with 'no change' comprising the seventh middle element of the scale). Votes were taken where full consensus proved elusive, but such instances were rare.

To frame discussions at this meeting, outline climate projections and credible boundary conditions based on conservative interpretations of their impacts were developed using the related biophysical research. This prevented discussions at the meeting being dominated by issues that could not be addressed, and focused the stakeholders on the project's results. More detailed climate change projections were developed in parallel with this work, but the results were not available at this point (Caesar et al., 2015). A time horizon of 2050 was selected for scenario development as this aligned best with existing longer-term planning processes in Bangladesh (notably projections within the BDP2100 process) and with climate change projections. The result of the meeting was a detailed, and internally consistent matrix of the participant's views on Bangladesh in 2050, given:

a) maintenance of existing policy direction within Bangladesh;
b) previous trends from (roughly) 1980 to 2015 (35 years);
c) factors influencing the likelihood of these trends continuing for the next 35 years;
d) externally imposed boundary conditions:
   a. Temperature: +1 °C (later amended to 1.5 °C in the light of more detailed downscaling)
   b. Sea level rise: +0.25 m
   c. Peak river flow into Bangladesh: +10%
   d. Uncertainty in arrival of monsoon: +10%
   e. Frequency and intensity of storms: +10%

e) relevant international and global influences.

The completed matrix for BAU, representing the consensus of attendees is shown in Table 1 to illustrate the outputs.

It was found that only the BAU scenario could be elaborated in a one-day workshop as the level of detail and the complexity of maintaining internal consistency for all three scenarios was simply too challenging in the time available. However, the list of issues for the BAU scenario was elaborated in great detail and effectively downscaled the BAU scenario to the GBM context. The considerable effort required to elucidate each of the 100 or so elements, coupled with the degree of consensus achieved, produced an extension of the global SSP approach to a national context in a way that was considered credible by the cross-sectoral group of stakeholders present. To determine the More Sustainable and Less Sustainable, experts interpreted the BAU outputs in Table 1 and these were validated with stakeholders at the next meeting.

4.2. Establish narrative scenarios: step 5

In order to translate the rough quantifications that emerged in the BAU matrix from the first stakeholder meeting into a form suitable to support the integrated assessment, they were first converted into a credible and representative narrative that could draw each element together in a consistent format – Step 5 in Fig. 1. Three extended narratives were prepared, one for the BAU based on the completed matrix, and one each for MS and LS based on appropriate changes to the matrix elements, including variations in governance quality and assumptions about the correlative effects of those disparities. These detailed narratives (set out in full in Allan et al., 2018, chapter 10 appendix), each written in the present tense and around 1600 words in length, were a crucial element in efforts to enable stakeholders to consider possible futures holistically across multiple sectors and scales, and to coherently synthesise the diverse findings from the first workshop in October 2013. The narratives were presented to stakeholders at a further, larger scale workshop co-organised by Bangladesh University of Engineering and Technology (BUET) and the Government of Bangladesh Planning Commission's General Economic Division in Dhaka in May 2014. The main objective of the workshop, was to critically assess the narratives, including their credibility and consistency, both internally and between narratives, as only the BAU narrative was based on stakeholder-derived information. Attendees were identified using the same stakeholder mapping exercise that determined participation in the first stakeholder meeting in order to ensure consistency.

The initial categories of issues identified at the first meeting (natural resource management; food security; health, livelihood and poverty; and governance) did not lend themselves to narrative disaggregation due to overlap and potential duplication. Therefore, the narratives were reframed into six categories that could link to the integrated assessment:

- Land use
- Water
- International cooperation
- Disaster management
- Environmental management
- Quality of life and livelihoods.

This created a coherent story combining local, regional and global drivers, and highlighted their impact for Bangladesh. This typology also allowed for the incorporation of elements of governance into the narratives such that its quality could directly inform each of the six categories above. For example, in the context of water and international cooperation, it was possible to differentiate between a more effective international context for the management of the Ganges and Brahmaputra rivers in the MS narrative at one end of the spectrum, in contrast to the effects of a non-existent framework in the LS scenario. Attendees at the meeting in May 2014 interrogated each of the scenarios and the resulting comments were integrated into the revised version of the narratives.

4.3. Incorporation of governance

Governance and its implementation emerged as a key issue of concern at the first stakeholder workshop, with eight broad components identified by stakeholders (Table 2) and further divided into multiple sub-components (see Table 1 for the full list), highlighting a recognition of poor governance as an area of concern. There was a clear awareness of the potential impact of governance quality across each of the other groups of issues (i.e. natural resource management; food security; and health, livelihood and poverty).

The stakeholders had a positive outlook for governance within Bangladesh based on current trends, projecting declining levels of inter-sectoral conflict over water use for example, rising levels of transparency and accountability coupled with improved levels of participation and implementation of policy objectives and legal frameworks. In contrast, relations with the main upstream riparian states were considered to be deteriorating. No conclusions were reached regarding the relationship between these, so it is unclear if the improvement in Bangladeshi governance could be seen as an adaptive response to upstream instability, or the logical result of existing national trends (which could themselves be a response to more general basin conditions).

5. Results: quantitative scenario development (Stage C)

Step 6, the quantification of the narratives, had two main goals: (1) to improve the sectoral model inputs and hence credibility; and (2) to facilitate discussion and co-learning. Stakeholders had previously given an indication of the ways in which they thought trends might go and the extent of expected change, but had not quantified these trends in ways that could be used by quantitative models (Section 4.1). To use the scenario narratives described above with biophysical modelling informed by climate projections, the socio-economic and biophysical/climate views had to be integrated, including consideration of the RCPs. The downscaled climate modelling used in the project is based on the earlier SRES framework (Nakicenovic, 2000), not the RCPs, as the project relied on the HadRM3P model for the A1B GHG emissions scenario. These projections sit somewhere between RCP6.0 and RCP8.5 in terms of global emissions and global temperature response (Caesar et al., 2015).

5.1. Define quantitative scenarios: step 6

Elicitation of model inputs included the initial identification of plausible assumptions among the project team. A series of postulations with associated questions were sent to stakeholders who had indicated their willingness to attend a workshop to be held in Dhaka in November 2014, dedicated to the quantification of the key assumptions that would be used to inform the biophysical modelling. These ranged across a variety of factors influencing sectoral model inputs, including

Table 1
Downscaled scoring matrix from October 2013 stakeholder meeting.

Natural resource management	Food security	Health, livelihoods/and poverty	Governance

Salinity/freshwater
- Freshwater ↓ +++
- Ingress salinity ↑
- Mangrove ↓ +
 	
Flow dynamics/riverbank erosion and sedimentation
- Mech: Accretion ↑ +
- Erosion ↑ +
- Water logging ↑ ++ and flooding ↑ ++
 	
Land-use
- Land-use change rate ↑ ++
- Rice production ↓ +
- Shrimp production ↑ +
- Floodplain fisheries ↓ +++
 	
Coastal defence
- Infrastructure ↑ +
- Maintenance/rehabilitation ↑ +
- Mangrove/forest ↓ +
 	
Impact of extreme weather events
- Asset damage ↑ ++
- Loss of life ↓ +++
 	
Conservation effort ↑ +
- Biodiversity ↓ +
 	
Management (local involvement) ↑ +
	Availability and access
	- Rice (area) ↓ +
	- Rice (yield) ↑ +
	- Others (area) ↑ +
	- Others (yield) ↑ +
	- Storage ↑ ++
	- Household storage ↑ +
	- Market access ↑ +
	- Farmer knowledge ↑ +
	
	Water security
	- Freshwater:
	  - Quality ↓ ++
	  - Quantity ↓ ++
	  - Predictability ↓ +++
	  - Accessibility ↑ +
	
	Nutrition
	- Food habit ↑ +
	- Pricing (% income) ↓+
	- Protein ↑
	
	Agriculture production systems/R&D
	- Efficient fertilizer use ↑ +
	- R&D/technology ↑ ++
	- Crop diversification ↑+
	- Subsidies ↑ +
	- Wheat production ↑ +
	
	Household equity
	- Intra- ↑ +
	- Inter- ↓ +
	
	Market dynamics
	- Role of intermediaries ↓ +
	- Information technology (price information e.g. mobile phones) ↑ ++
	
	Seasonality
	- Shift in traditional practices
		Migration
		- Net migration (urban: rural ratio) ↑++
		- Outmigration from project area ↑ ++
		- Push ↑++
		- Pull ↑+++
		
		Remoteness/communication/infrastructure
		- Infrastructure ↑ +
		- Communication ↑ ++
		
		W.A.S.H.
		- Community ↑ +
		- Urban (formal) ↑ ++
		- Urban (informal/slum) ↑ +
		- Water: Sanitation ↑ +
		
		Changes in livelihoods
		- Diversification ↑ ++
		
		Utilization of ecosystem services
		- Availability
		- Access
		- ↑Private Sector:
		  - Community ↓ ++ (access ratio)
		  - Ag
		  - Private/community ↓ ++
		
		Disease
		- Non-communicable ↑ +
		- Water borne ↑ +
		- Vector borne ↑ +
		- Zoonotic ↑ +
		
		Gender balance
		- Influence on disaster management ↑ +
		- Disaster risk reduction +
		- Climate change adaptation ↑ ++
		- Access to natural resources/ecosystem services ↑ +
			Coordination & collaboration (sectoral and geographical)
			- Sectoral ↑ +
			- Geographical:
			  - Transboundary ↔
			  - Bangladesh ↑ +
			
			Power structure/conflict
			Conflict ↓
			Intersectoral (e.g. fisherman vs. farmers) ↓ +
			Intra-sectoral ↓ ++
			Power structure ↔
			Human & financial capacity/Awareness/extension agents
			- Human and financial capacity ↑ + (likely to have most impact on pollution, NRM ↑ +)
			- Awareness ↑ ++
			- Local government empowerment ↑ +
			- Implementation and enforcement ↑ +
			- Law & order/security (dakoits/pirates)
			- Fisheries ↑ ++
			- Unauthorised inputs (pesticides, fertilizer etc.) ↓ +
			- Piracy ↔
			
			Lack of participation and marginalization of the poor
			- Participation ↑ ++
			- Marginalization ↓ ++
			
			Role of NGOs/Civil Society/Private sector/farmers' assn, public organisations
			- NGOs/CSO ↑ +
			- Private/corporate/entrepreneurs ↑ ++
			
			Transparency/access to information/accountability
			- Transparency ↑ +
			- Access to information ↑ ++
			- Accountability ↑ +
			
			Land management/zoning and distribution
			Land management ↑ +
			Zoning ↑ +
			Distribution ↔
			Transboundary (India, China)
			- Water ↓ ++
			- Trade ↓ +
			
			Planning
			- Central ↑ +
			- Local ↑ +
			
			Effectiveness of local justice
			- Maintenance of existing infrastructure ↑ +
			- Rules & regulations ↑ +
			- local level policy ↑ +
			- local courts ↔
			- Service delivery efficiency ↑ +

upstream conditions for water quantity and quality (for example, in the light of proposed Indian Interlinking Rivers Project and expectations regarding dam construction); fisheries and aquaculture; delta modelling (e.g. dike height around polders); and land use and land cover (e.g. mangroves and agriculture), and market access. They were derived from either estimates from experts within the project team or from available datasets. For each set of assumptions, stakeholders were presented with a series of options for consideration that had been predetermined by project partners. Participants at the workshop (numbering more than 20) were primarily identified by local project partners as well as through connections formed as part of earlier stakeholder interviews and workshops.

Table 2
Governance categories linked to issues of concern as identified by stakeholders at the first stakeholder meeting.

Governance categories identified by stakeholders at first stakeholder meeting
1. Coordination & collaboration (sectoral and geographical)
2. Power structure/conflict
3. Human & financial capacity/awareness/extension agents
4. Role of NGOs/civil society/private sector/farmers' assn, public organisations
5. Transparency/access to information/accountability
6. Land management/zoning and distribution
7. Transboundary (India, China)
8. Planning

For example, Table 3 lays out some scenario assumptions prepared by project partners for consideration by stakeholders in relation to the Indian Interlinking Rivers Project. Of the six responses received, four people agreed and two disagreed, with one questioning why Chinese diversions were not included. Further questions and opportunities for providing comments, along with the addition of assumptions from the project team where necessary, resulted in Table 4.

The scenario results were used to establish boundary conditions for the relevant sectoral models that were then fed into the integrated assessment modelling efforts using the Delta Dynamic Integrated Emulator Model (see Lázár et al., 2018). This constituted steps 7 and 8 in the approach, providing informed inputs for multi-sectoral modelling efforts, the results of which could then be reconsidered by stakeholders and subsequently modified in order to evaluate the impacts of a variety of policy and management interventions (Rahman et al., 2019b).

Participants, when asked to comment on values previously estimated within the project team, generally agreed or proposed only minor modifications. Where participants were asked to provide new values for different assumptions, they mainly agreed on the overall direction and magnitude of change, but with the specific value of change varying between responses. Despite requesting individual responses, it was evident that some participants conferred during the event. In general, group responses reflected some elements of the individual responses, while in a few cases the group discussion introduced additional perspectives or changed the majority view of individuals.

The ultimate outputs of the quantification exercise informed the integration process to combine all of the sectoral models (Lázár et al., 2018). It is however impossible at this point to disaggregate the results in order to better understand the precise importance of each sectoral input or the relative significance of the climate scenarios and the more socio-economic scenarios developed in the process described above. Further analysis of model outputs is required.

The outcome of this process was largely successful in terms of engaging representatives from different institutions and disciplines to discuss future changes across a range of key issues. Informal participant feedback indicated the process was interesting, useful and informative, although a number of participants found the questions challenging. Fourteen participants completed a formal feedback form, of which the large majority indicated that the workshop had contributed to their wider understanding of ecosystem services at least to some extent, through the quantification of real conditions and assumptions, the use of narratives, assumptions and scenarios and discussion with economists about economic valuation of ecosystem services.

5.2. Quantifying governance

Of the list of governance issues identified by stakeholders in step 2, few could be represented in the integrated modelling work, even in general terms. Teasing out a causal or even an associative relationship between a governance intervention of any sort and a change in an indicator of biophysical or human wellbeing from the multitude of other relevant factors in such a broad arena as ecosystem services and livelihoods is extremely difficult, making modelling challenging (Primmer et al., 2015).

Identifying appropriate governance datasets that could be directly applicable to the circumstances of the project was challenging. The definition of 'governance' differs across disciplines, and while there are a significant number of governance indicator systems now in existence, there is no agreement on definitions between them (Arndt and Oman, 2006). In addition, governance datasets are restricted in their applicability by temporal and scale issues.

Despite these challenges, it was possible to incorporate a number of direct links between particular aspects of governance and quantification for modelling purposes. For example, Bangladesh is broadly entitled under the Farakka Treaty (Farakka Agreement, 1996) to an average of 35,000 cusecs from the Ganges river over 10 day periods between 1 January and 31 May every year. This agreement is due to be renegotiated in 2026 so it is impossible to predict what the respective entitlements of each riparian state will be between 2026 and the scenario time horizon of 2050, but it is possible to make projections based on a business as usual basis – i.e. maintenance of the current situation. Freshwater flows incoming to Bangladesh (from the Ganges, Brahmaputra and Meghna rivers) were projected in step 4 to fall quite significantly (Allan et al., 2018). The process of quantification allowed stakeholders to determine what levels of constant flows they might expect under the renegotiated Farakka agreement under LS and MS scenarios (30,000 and 40,000 cusecs, respectively).

6. Discussion

The following discussion sets out the lessons from creating participatory scenarios for integrated assessment of the future of ecosystem services in coastal Bangladesh. It also considers how the process outlined in Fig. 1 can be applied more widely for scenario development of coupled human-environmental systems.

The approach presented here demonstrates how the global SSP projections (or any similar global socio-economic scenarios) can be refined, downscaled and quantified at national and sub-national levels, to inform policy processes across multiple sectors. Given the increasing prevalence and importance of complex integrated assessment modelling techniques especially in the context of climate change, the approach adopted here provides a framework template that can be used by others to enhance the credibility of their model inputs. The process facilitates the progressive incorporation of biophysical elements with the socioeconomic and governance considerations built up in steps 1-5, but crucially does this in a way that is most likely to accord with stakeholder views.

A number of key challenges are evident however (as set out below), but with an appropriate investment of time, stakeholders were able to directly inform the integrated assessment over an extended period.

Table 3
Scenario choices of water transfer under the Indian Interlinking Rivers Project.

Scenario	Time period		
	(i) Present	(ii) 2041-2060	(iii) 2080-2099
Less sustainable	No transfers	1. Brahmaputra to Ganges starting 2050 2. Sarda to Yamuna to Rajasthan starting 2050	1. Brahmaputra to Ganges starting 2050 2. Sarda to Yamuna to Rajasthan starting 2050
BaU	No transfers	No transfers	No transfers
More sustainable	No transfers	No transfers	No transfers

Table 4
Final stakeholder scenarios on inter-basin transfers as part of the Interlinking Rivers Project.

	Brahmaputra to Ganges		Sarda to Rajasthan		Kosi-Ganga		Gandak-Ganga	
	Flow reduction	Time	Flow reduction	Time	Flow reduction	Time	Flow reduction	Time
LS	5% 30%	Wet season Dry season	10%	Wet season	10%	Wet season	10%	Wet season
BaU	5%	Wet season	10%	Wet season	5%	Wet season	5%	Wet season
MS	No transfers							

This complements other existing planning and infrastructural initiatives in Bangladesh, but the quantification process described above is innovative in this context. Involving stakeholders was critical to the success of the scenario process, and the integrated assessment it supports, and creating widespread ownership of the process within Bangladesh and support for its subsequent application (Rahman et al., 2019b). As such, the programme of scenario workshops and meetings (Fig. 2) were a key component of the stakeholder engagement with the research, though the events set out in Fig. 2 should not be seen as prescriptive. The resulting trust and ownership that developed between the Bangladesh policy community and the research effort, more deeply embedded the research in Bangladesh, promoting moves towards action and impact. In fact, the process also created linkages within Bangladesh as our scenario workshops brought together people who did not often meet and exchange ideas in such a broad way.

The extension of the global SSP-inspired narratives through the detailed disaggregation of impacts in south western Bangladesh necessitated extensive discussion, though consensus was achievable despite the fact that the participating stakeholders represented a variety of sectors with opposing interests in many cases. Development of both qualitative and quantitative scenarios across a diverse range of biophysical and socio-economic issues facilitated cross-disciplinary discussion and learning. The process has assisted in promoting dialogue about the complex dynamics influencing changes in the natural and human environment, breaking down barriers and improving understanding between experts with different expertise. Adopting a systems-based approach at this scale and with this breadth of sectoral coverage is challenging, but provides new and relevant information for the management of coastal Bangladesh. In particular, these types of scenarios are appropriate to support existing and future government plans, including the Five Year Plans and the Delta Plan 2100 (Kebede et al., 2018).

One aspect of the downscaling work that proved problematic for some participants was the scenario nomenclature: it was felt that the term ‘More Sustainable’ implied a degree of sustainability when there was no objective basis upon which to assess this. In the light of this, an alternative, potentially less value-loaded nomenclature would be to use the terms BAU, BAU+ and BAU−, which emphasises that the reference is the present situation and trajectory, wherever that is. This approach was supported by Kebede et al. (2018).

While stakeholders recognised it as an important issue, the incorporation of governance issues into the scenarios proved problematic, reflecting the difficulties in quantifying the impacts of governance quality on the biophysical (and social) environment. While the inclusion of certain elements of governance in the scenario development process was desirable from a stakeholder perspective, quantification is extremely challenging. While the quantitative effects of legal and policy commitments can be projected (e.g. the operation of the Farakka Treaty), more difficult-to-measure aspects of governance including institutional coordination, stakeholder participation in decision making, and transparency, are more difficult to assess. However, the development of the scenario narratives allows for cross-sectoral integration to an extent, such that pervasive issues such as governance can be effectively reflected across multiple categories. This allows the scenarios to consider the possible impacts of differing legal and institutional frameworks in a way that aligned with stakeholder views. This approach may offer a realistic way to encourage policy makers to address governance quality, pending greater understanding of the causal or associative relationships between governance and the achievement of policy objectives. Experimentation with steps 7 and 8 in the iterative learning loop provide opportunities for stakeholders to examine the consequences of specific governance and management interventions.

The scenario process we applied here could be applied to other long-term integrated assessment and planning efforts where there is time to hold workshops which build on each other. The costs of such a process are high but so are the benefits in terms of genuine co-creation and building an engaged practitioner community. The needs for climate adaptation and the wider agenda of sustainable development suggest widespread application of these approaches would be beneficial.

7. Conclusions

The process of stakeholder engagement over such a lengthy period is unusual but provided a unique opportunity to build on this dialogue. There was great value in conducting the meetings from the perspective of developing the scenarios and ensuring the assessments incorporated stakeholder knowledge. Further this created stakeholder ownership of the whole process. Stakeholders were often pleasantly surprised to be able to maintain their involvement through the interviews and then on to the workshops. This continuity demonstrated to them that the project was committed to considering their views. Over the duration of the project, it became clear that the credibility of project outputs was increased significantly by the fact that stakeholder views and inputs had been integral to each successive step from the identification of the key issues right through to the integrated assessment.

The varying, and often low levels of response in the quantification process was unfortunate though hindsight might suggest this was unsurprising, given the wide range of subjects covered by the questionnaire in step 6 and the level of detail requested. While this is a limitation in not showing a full spread of individual perceptions prior to the group session, the generation of discussion about such topics is still a positive outcome. In combination, this makes it difficult to clearly attribute quantified conclusions to individual stakeholders rather than project-led contributions.

What also became clear was that the time budget must be carefully managed in order to ensure that stakeholders can digest complex scenario narratives and model assumptions. The downscaling process requires a considerable commitment on the part of stakeholders (see also Fancourt, 2016), who derive no other benefit from the process than the opportunity to discuss issues in a forum with others from outside their immediate sphere of contact, and the hope that they might acquire a greater understanding through the project outputs. Multiple workshops and repeated engagement are critical for building trust between stakeholders and researchers. Alternative approaches may also be considered in future applications of this approach – for example, by establishing a standing stakeholder cross-sectoral expert group who could comment on technical detail, perhaps in return for a fee reflecting the degree of commitment needed. It was also apparent that reaching agreement across multiple sectors, levels of seniority and disciplinary background, becomes progressively more difficult as the level of detail increases. Further if the integrated assessment becomes embedded in the policy process, continued regular stakeholder engagement is essential – the iterative learning loop in steps 7 and 8 relies on ongoing analysis and modification by stakeholders.

Although we are unable to track the value of stakeholder input from project initiation to the modelled results, we can demonstrate that stakeholders contributed at every step and that they influenced how subsequent steps progressed. Extensive efforts have been made since the completion of the ESPA Deltas project to continue the participatory approach. As part of Stage D, stakeholders have been using the model to project the impact of interventions of their choice on the delta, using the results to inform, for example, the scale and location of infrastructural developments in the GBM basin (e.g., Rahman et al., 2019a, 2019b). The scenarios have therefore created a foundation for planning, enabling decision makers to better understand the effects of policy choices across the social and biophysical environments.

More broadly, the process provides strong evidence that making the global SSPs relevant to national governments, especially across multiple sectors, is a significant undertaking demanding sustained engagement with stakeholders. The application of the generalised process especially in the extension sections of Stage B, along with basic scoring system, provides a much higher level of detail than would generally be achieved, providing a valuable resource for decision makers, with the potential for incorporation of the SPA dimension where appropriate (see Kebede et al., 2018). It also flags the importance of future governance quality as an element in the process, highlighting to decision makers the need to relate policy implementation to wider governance effectiveness. The method described has broad potential for application to many situations where an understanding of the possible interactions of the physical and social environments under climate change over the medium term is needed.

CRediT authorship contribution statement

Andrew Allan: Conceptualization, Methodology, Investigation, Writing – original draft, Writing – review & editing. **Emily Barbour:** Methodology, Investigation, Writing – review & editing. **Robert J. Nicholls:** Writing – review & editing, Supervision, Funding acquisition. **Craig Hutton:** Methodology, Investigation, Conceptualization, Writing – review & editing. **Michelle Lim:** Methodology, Investigation, Writing – review & editing. **Mashfiqus Salehin:** Conceptualization, Methodology, Project administration. **Md. Munsur Rahman:** Conceptualization, Methodology, Project administration.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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