Review

# Adaptation pathways: A review of approaches and a learning framework

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## ARTICLE INFO

## ABSTRACT

Adaptation pathways have experienced growing popularity as a decision-focussed approach in climate adaptation research and planning. Despite the increasing and broadening use of adaptation pathways reported in the literature, there has not yet been a systematic attempt to review, compare and contrast approaches to adaptation pathways design and their application. In this paper we address this gap through a literature review of conceptual and applied studies of adaptation pathways in the context of climate change. Adaptation pathways started to be conceptualised in 2010. They have become recognised as sequences of actions, which can be implemented progressively, depending on how the future unfolds and the development of knowledge. A difference between scholars is whether pathways are understood as alternative sequences of measures to realise a well-defined adaptation objective, or as broad directions of change for different strategic aims or outcomes. Analysis of case studies on adaptation pathways development showed three clusters of approaches: (a) performance-threshold oriented, (b) multi-stakeholder oriented, and (c) transformation oriented approaches. These broadly correspond to three desired outcomes of pathways development: (i) meeting short and long-term adaptation needs, (ii) promoting collaborative learning, adaptive planning and adaptive capacity, (iii) accounting for complexity and long-term change, including a potential need for transformation. Yet, as of now there is little evidence of the utility of different approaches for pathways development in different decision contexts. Scholars appear to be guided more by how they understand the adaptation problem and by what approaches are known to them, than by the context of the case. Attention is needed on who defines objectives and outcomes for pathway development. Based on the review, we present a learning framework to guide systematic reflection about why and how adaptation pathways are developed. Lessons learned by application of the framework will enable refinement of pathways approaches to make full use of the potential in different decision contexts.

## 1. Introduction

Sustainable development is pursued against a backdrop of climate change and uncertain future conditions. Given the complexity and the uncertain nature of social-environmental challenges, planning approaches that promote adaptability are required to accommodate changing conditions over time (Munene et al., 2018; Roy et al., 2018). 'Adaptation pathways' have been proposed as a promising decision-focused approach to incorporate flexibility into decision-making and account for future uncertainties (e.g. Haasnoot et al., 2013; Wise et al., 2014; Bosomworth et al., 2017). Adaptation pathways are broadly understood as sequences of actions, which can be implemented progressively, depending on future dynamics. In an adaptive plan, adaptation pathways capture the implementation process by specifying which measure(s) are to be taken now and which are planned to be implemented once certain conditions occur (Kwakkel et al., 2016). As such, adaptation pathways explicitly consider uncertainty and embed flexibility within planning. Other potential benefits are the ability to identify 'no or low regrets' interventions and to avoid lock-in, threshold effects, and maladaptive consequences (Butler et al.,

2016a; Reeder and Ranger, 2011).

Researchers and adaptation practitioners have recognised these potential opportunities and have begun experimenting with the development of adaptation pathways in different decision-making contexts, leading to substantial growth in application in recent years. Initially, adaptation pathways were designed in contexts where stakeholders' goals were assumed to be uncontested and constant over the planning horizon, with a clear mandate and agency for the decision-makers (e.g. Haasnoot et al., 2012; Ranger et al., 2013; Rosenzweig and Solecki, 2014). More recently they are being applied to uncertain and resource-constrained environments, where multiple decision-makers are involved and adaptation outcomes and goals are ambiguous (e.g. Butler et al., 2016b; Gajjar et al., 2018; Wise et al., 2014). Despite the growing use of adaptation pathways, there has been no systematic attempt to analyse and compare different rationales and approaches to their development. Indeed, while adaptation pathways are conceptually appealing and tractable, their utility remains unproven, especially for practice (Bloemen et al., 2018) and in contested, complex decision situations (Bosomworth et al., 2017). With the concept of adaptation pathways increasingly entering formal planning practice (e.g. BSI, 2020; Delta Commissioner, 2014; Lawrence et al., 2018; Siebentritt et al., 2014), and more people looking to apply them, understanding their utility in different decision-making contexts is all the more needed.

In this paper we aim to review the state of knowledge about adaptation pathways in the context of climate change to learn what approaches and methods are used in different case contexts. The review confirms a diversity in approaches with little evidence of what approaches are best suited to different case and decision contexts. To this end, we propose a learning framework with propositions on what contributes to the utility of adaptation pathways. We consider the framework can be used to inform the design and evaluation of adaptation pathways development processes in order to learn about how approaches affect intended outcomes and ultimately enhance decision-making for long-term sustainable development.

## 2. Methods

We systematically reviewed academic publications that apply and discuss the concept of adaptation pathways in the context of climate change. We followed Berrang-Ford et al. (2015) guidelines for systematic review in adaptation research, as applied by Tucker et al. (2015), and undertook the following four steps as detailed below:

1 Question-setting and scope;
2 Literature search and selection of documents;
3 Data extraction and analysis;
4 Reflexive learning.

**STEP 1 Setting the scope and questions of the review:** The review was guided by the specific research questions (i) what definitions and conceptualisations of adaptation pathways exist, (ii) what approaches are used for adaptation pathways development, and (iii) in what case contexts are different approaches applied?

The review was neither geographically nor temporally restricted. Topically, the review was limited to the domain of climate change adaptation, and to pathways planning as a response to future challenges. While recognising that an extensive literature exists relating to adaptation planning and decision-making under uncertainty that underlies adaptation pathways, for the scope of the study we considered only papers that were topically related to climate change adaptation, and where pathways were conceptualised as a planning response to future challenges. We did so because we feel that this literature is most representative of the current state of knowledge, and most likely to be consulted by scholars and adaptation decision-makers.

**STEP 2 Selecting the documents for review**: The literature was sourced from Web of Science and Scopus searches on Nov 5, 2018 (first

review) and Sept 28, 2020 (final review, reported hereafter) for the search terms: (1) "adaptation pathway*", AND (2) climate. In Web of Science the search was performed for the search option 'topic', and in Scopus for the options (TITLE-ABS-KEY). As per search rules, the specific phrase within speech marks (") will be found and any word that begins with the root/stem of the word truncated by the asterisk (*). This resulted in 232 publications since 2003 (198 in Web of Science and 193 in Scopus), with 159 papers mentioned in both libraries and with the number of papers increasing over time.

The titles and abstracts of these 232 papers were screened to identify papers for full analysis. Criteria for selection were (i) topical relation to climate change and adaptation planning, and (ii) the conceptualisation of pathways as a planning response to future challenges. To select the case studies a third criterion was added: (iii) explicit representation of the pathways as an output of the research.

These selection criteria resulted in 76 relevant publications for full-text analysis, of which 32 were conceptual or review papers and 44 were practical applications. Further practical cases were identified from reference lists in this initial set and from expert elicitation. In particular, the authors organised dedicated sessions at the European Climate Change Adaptation Conference (ECCA) in 2017 and the Adaptation Futures Conference in 2018. During these sessions, early findings of the review were discussed, and additional cases were identified. These sessions yielded an additional three practical cases for which we allowed public, non-peer reviewed reports, bringing the number of applied papers to 47. Also, to achieve a more detailed understanding of methods used in pathways development, we included in the review three non-peer-reviewed guidance documents (Bosomworth et al., 2015; Siebentritt and Stafford Smith, 2016; Wise and Capon, 2016), and the Adaptation Pathways wiki and Pathways Generator[1] .

Focussing on the application of adaptation pathways in adaptation planning, we applied the following exclusion criteria. We did not select cases that used pathways as a way to conceptualise and map past decision-making (e.g. Burnham et al., 2018; Fischer, 2018; Gajjar et al., 2018). We also did not select cases outside the context of climate adaptation such as those applied to climate mitigation (e.g. Foxon et al., 2010; Rosenbloom, 2017), sustainable development (e.g. Winkler and Dubash, 2016) or socio-technical transitions (e.g. Geels and Schot, 2007). We did, however, review these conceptualisations in our overview of pathway definitions (Section 3.1) to understand the different contexts in which pathways approaches have been framed.

**STEP 3 Data Extraction and Analysis:** The full texts of the 47 practical case papers identified in Step 2 were reviewed. Document characteristics and information relating to the research questions were extracted and recorded for analysis in a simple table form. Headings for the data extraction were as follows: (i) the *definition* of adaptation pathways, (ii) the *decision context* for adaptation pathways development, (iii) the *method* used for developing pathways, and (iv) the *representation and visualisation of the output* of pathways development. From these 47 case papers, 19 distinct cases and approaches were identified that we report on in Section 3.2.

**STEP 4 Reflexive learning from adaptation pathways development:** In dedicated sessions at the ECCA Conference in 2017 and the Adaptation Futures Conference in 2018, we brought together adaptation pathways researchers and practitioners to reflect on the review, the outcomes of pathways development, and what they considered preconditions of 'successful' adaptation pathways development, and what factors contributed to this success. Session participants included individuals with pathways experience from various geographic and institutional contexts, including Australia, Bangladesh, India, Mali, Nepal, the Netherlands, Pakistan, Papua New Guinea, Peru, Portugal, Senegal, and the USA. We used these sessions, together with lessons

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[1] publicwiki.deltares.nl/display/AP/Adaptation+Pathways, accessed 2 November 2018.

from the literature review, to frame a set of desired outcomes and propositions for reflexive learning and evidence-based action in adaptation pathways development (c.f. Nagoda et al., 2017; Walker et al., 2006; Weber et al., 2018). We provide justification for each proposition, and suggest learning questions to guide the learning and evaluation on how the propositions contribute to outcomes of adaptation pathways development.

## 3. Review of adaptation pathways

### 3.1. Definitions and conceptualisations of adaptation pathways

In this section, we report on the emergence and conceptualisation of adaptation pathways in the context of climate change (Table 1). The term emerged in the climate change discourse around 2010, with neither explicit conceptualisation nor definition (e.g. Lowe et al., 2009; Pelling, 2011; Stafford Smith et al., 2011). Downing (2012) reports the use of the term to signify a shift in the understanding of climate change adaptation from predicting impacts and providing adaptation options to understanding dynamic decision processes and adaptive management. At the time, analytical tools were only beginning to appear (Downing, 2012).

The subsequent literature acknowledges that pathways thinking itself is not new, nor is it confined to the climate sciences, as reflected in, for example, Impact Pathways developed for a Theory of Change (Maru et al., 2018; Omore et al., 2019) or in 'Pathways to Sustainability' (Leach et al., 2007). The basic notion of pathways is that decisions and measures are sequenced in time to achieve future goals. Conceptualisations (Table 1) agree in referring to adaptation pathways as adaptation responses that consider path dependency, decision sequencing, and timeframes (c.f. Colloff et al., 2016). Authors have emphasized that uncertain and changing conditions require more adaptive planning which enables flexibility in decision-making over time to account for changing conditions. However, the conceptualisations differ in the extent to which pathways are understood as alternative sequences of discrete actions to realise a well-defined adaptation need (e.g. Haasnoot et al., 2013; Sadr et al., 2020), or as a metaphor for broad directions of change and transformation (e.g. Colloff et al., 2016; Wise et al., 2014). Monitoring and evaluation is seen by all authors as necessary to inform pathways implementation, revision and adaptive learning, yet details and examples are still underrepresented in the literature (Hermans et al., 2017).

In recent years, adaptation pathways approaches have gained prominence in dealing with path-dependency resulting from past decisions and the need to achieve sustainable development and climate adaptation together (e.g. Gajjar et al., 2018). This is also reflected in the positioning of climate resilient development pathways by the IPCC, which goes beyond the adaptation literature to include action on mitigation, sustainable development, and transformation (Denton et al., 2014). As we focus on the application of pathways in climate adaptation planning, these examples are not dealt with in later sections. However, we did include these conceptualisations here to understand the development in how pathways approaches are framed (Table 1).

Conceptualisations of pathway development in the context of climate change in chronological order

### 3.2. Approaches to adaptation pathways development

Table 2 presents the nineteen case examples, characterised by (i) decision context, (ii) method, and (iii) representation or visualisation of the output, along with references to cases that were found to follow the same approach.

Overview of adaptation pathways cases and papers considered in the review, presented chronologically by publication year

All cases were found to be from the domain of land and water management. Synthesising from the analysis, three clusters of approaches emerge, each of which offers different yet complementary

**Table 1**

Conceptualisations of pathway development in the context of climate change in chronological order.

| Terminology, definition(s) and reference(s) | Characteristics |
| --- | --- |
| *The route-map (or decision pathways) approach* (Ranger et al., 2013; Reeder and Ranger, 2011) is a method of designing robustness to climate change uncertainties into the adaptation strategy by encouraging decision-makers to postulate 'what if' outcomes and take a more flexible approach. | Primarily aims to ensure that whatever short- to medium-term plan is adopted, it is set in a framework that will not be maladaptive if climate change unfolds differently than predicted. |
| In the context of adaptation economics, an *adaptation pathway analysis* (Downing, 2012) links the lower and upper bounds of economic costs estimates of adaptation, enabling a shift in strategy as challenges increase; with the lower bound being a conservative estimate of easy to achieve adaptation and the upper bound the costs of more adverse climate impacts. | The author observes a shift in the literature and practice from framing climate change adaptation as vulnerability–impacts to adaptation pathways. Adaptation is viewed as a socio-institutional pathway based on concepts of resilience and adaptive management. |
| *Dynamic adaptive policy pathways* (Haasnoot et al., 2013) provides an analytical approach for exploring and sequencing a set of possible actions based on alternative external developments over time. Central to adaptation pathways are adaptation tipping points: the conditions under which an action no longer meets clearly specified objectives. The timing of an adaptation tipping point is scenario-dependent. | Pathways are designed to address future adaptation needs. Possible actions are sequenced in the form of adaptation decision trees or a 'roadmap', dictated by adaptation tipping points. Any given route through the tree is an adaptation pathway. The analysis of pathways provides insight into potential lock-ins and path dependency. |
| *Adaptation as part of pathways of change and response* (Wise et al., 2014) sees pathways as a process rather than an outcome. The aim is to identify responses yielding benefits under any future condition, to be implemented over time, informed by an understanding of interactions between changes and responses to avoid maladaptation and facilitate necessary societal transitions and transformations. | Considers pathways as components of dynamic, multi-scale, social-ecological systems. Recognises multiple stakeholders and their competing values, goals, and knowledge. Combines incremental adaptation strategies to address proximate causes or symptoms of vulnerability, and transformative strategies to tackle systemic causes. |
| *Adaptation pathways* as possible approaches to adaptation with different strategic aims or outcomes. Pathways result in alternative states of the system of interest (e.g. Colloff et al., 2016; Garcia-Webb et al., 2017). | Stresses that implementation of adaptation needs to include the social-ecological context under which adaptation decisions are made. To this end, assessment includes societal values, governance rules and systems knowledge for transformation. |
| *Climate-resilient development pathways* (IPCC, 2014, Section 20.6.2) defined as development trajectories that combine adaptation and mitigation to realize the goal of sustainable development. Pathways are seen as sets of decisions and actions that consider both short and long-term time horizons. | Calls for strategies and actions that lead up to resilient pathways that help improve livelihoods, social and economic well-being, and responsible environmental management. May involve substantial transformation. |
| *Development pathways* are used as a metaphor to trace 'trajectories of change' (cumulative decisions and actions) and to diagnose how past decisions determine chances of future (mal)adaptation (Burnham et al., 2018; Fischer, 2018; Gajjar et al., 2018). | Adaptation is conceptualised as dynamic and continually unfolding pathways. The approach takes a historical perspective to identify lock-ins. It is not designed to target a specific adaptation decision or create future pathways. |

**Table 2**

Overview of adaptation pathways cases and papers considered in the review, presented chronologically by publication year.

| Name of case study and reference | Context | Method | Output / visualisation |
|---|---|---|---|
| 1. Climate uncertainty in the Thames Estuary 2100 Project (Ranger et al., 2013; Reeder and Ranger, 2011) | Planning long-lived infrastructure under the Thames Estuary 2100 Project, London | Identifies and discusses sets of options for lowering risk under different climate conditions | Maps what measures satisfy performance criteria under rising sea levels |
| 2. Dynamic adaptive policy pathways. A method for crafting robust decisions for a deeply uncertain world. (Haasnoot et al., 2013) [i] | Planning for long-term water safety in the Dutch Delta Programme (Delta Commissioner, 2013). | Connects actions to achieve goals under climate uncertainties. Discusses no regret actions, lock-ins and stakeholder preferences | A route-map illustrating actions to be taken with increasing impact over time |
| 3. A local coastal adaptation pathway. (Barnett et al., 2014) [ii] | Exploring adaptation for a coastal community in Australia | Assesses 'things of value' at risk of sea-level rise and associated adaptations. Next constructs pathways in workshops with residents | Geographical map overlaid with a timeline, thresholds and trigger points for actions |
| 4. Hurricane Sandy and adaptation pathways in New York: Lessons from a first-responder city. (Rosenzweig and Solecki, 2014) | New York City Climate Action Strategy after Hurricane Sandy | Reviews measures triggered by perceived risk levels. Qualitative evaluation of future plans | Timeline of selected measures and risk levels |
| 5. Regional climate change adaptation plan for the Eyre Peninsula. (Siebentritt et al., 2014) [iii] | Adaptation planning for the Eyre Peninsula in South-Western Australia for eight areas of decision making | Regional planning process involving conversations and workshops with key regional leaders and influencers | Graphics of best current practices and transformational options over time with decision switch points |
| 6. Vulnerability and resilience for adaptation pathways in remote disadvantaged communities. (Maru et al., 2014) | Responding to increasing stressors (flooding and heat waves) in remote disadvantaged regions | Puts together vulnerability and resilience narratives in linked system diagrams and pathways | Sketches short-term responses and longer-term actions under stressors |
| 7. Adaptation pathways of global wheat production (Tanaka et al., 2015) | Wheat yields in nine major wheat-producing countries | Models intensity and timing of adaptation to maintain yields for two adaptation options (irrigation, change crop variety) | Graphs of timing and intensity of adaptations necessary to maintain current wheat yields |
| 8. Adaptation services and pathways for the management of temperate montane forests under transformational climate change (Colloff et al., 2016) [iv] | Managing changes in fire events caused by a warming, drying climate in montane forests in south-eastern Australia | Constructs pathways from 1) ecosystem adaptation services, 2) decision points between ecosystem states, 3) values, knowledge, rules to reframe decision context | Qualitatively visualises alternative states and decision points to switch between states over time |
| 9. Mapping options and trade-offs for London's water resources (Kingsborough et al., 2016) [v] | Adaptation planning for London's urban water supply system, to link current risk-based planning with long-term pathways | Risk assessment, with a quantification of risk of water shortages under different pathways and population and climate scenarios through to 2100 | Timeline of measures against 1) volume of water saved / gained; 2) probability of water shortage |
| 10. Scenario planning to leapfrog the Sustainable Development Goals: An adaptation pathways approach. (Butler et al., 2016a, 2014). | Poverty alleviation under climate change in developing countries, Indonesia case. | Uses a normative back-casting process to identify pathways towards an aspirational future vision, with emphasis on building adaptive capacity | Abstract representation of scenario lines (what could be) and a vision (what should be) over time |
| 11. Flexible adaptation planning: Cockburn sound coastal alliance experience. (Garcia-Webb et al., 2017) | Addressing coastal vulnerability along Cockburn Sound, Perth, Australia. | Defines and appraises pathways for different strategic aims | Decision trigger points on risk / time axis |
| 12. Development and valuation of adaptation pathways for storm water management infrastructure (Manocha and Babovic, 2017) [vi] | Design of urban storm water management infrastructure, based on Kent Ridge catchment, Singapore | Cost-benefit analysis of pathways, generated as incremental combinations of three pre-defined solutions | Maps adaptation actions and tipping points with respect to increase in annual rainfall |
| 13. Climate adaptation pathways in multi-use woodland landscapes (Prober et al., 2017) | Management of grassy eucalypt woodland landscapes, south-eastern Australia | Outlines pathways for three future landscapes. Discusses decision context and implementation constraints, using the values-rules-knowledge framework | Sketches decision points and resulting trajectory in (mal)adaptation space |
| 14. Pathways to resilience: adapting to sea level rise in Los Angeles (Aerts et al., 2018; Ruig et al., 2019) | Reduction flood risk and damage from sea level rise in Los Angeles County, US | Analyses combinations of measures with respect to flood risk and damage costs | Tree diagram with measures and switch points at different stages of sea level rise |
| 15. Water Resource Planning in the Cauvery River Basin, Karnataka, India (Bhave et al., 2018) | Planning under climate and socioeconomic uncertainties in the Cauvery River Basin, India. | Iterates climate and socio-economic scenario assessment, appraisal of measures with stakeholders, and modelling | Timeline of measures as proposed by four stakeholder groups |
| 16. Adaptation pathways for conservation law and policy (McDonald et al., 2019) | Managing climate-induced change with Australian conservation law and policy | Outlines three possible pathways for changes in law with the legal mechanisms needed | Sketches pathways for expanding the focus of conservation law |
| 17. Paving the way to coastal adaptation pathways (Rocle et al., 2020) | Adaptation to sea level rise in French coastal areas | Constructs pathway narratives for coastal archetypes from under two scenarios of sea level rise | Narratives built from change variables, including governance |
| 18. Designing adaptation pathways for flood-affected households in Bangladesh (Roy et al., 2020) | Building livelihood resilience in north-west Bangladesh | Adaptation options are identified from correlation to resilience indicators and ordered from the short-term to long-term options | Visualisation as in Case 5, with respect to a general trend of flooding |
| 19. Strategic planning of the integrated urban wastewater system using adaptation pathways (Sadr et al., 2020) | Management of a semihypothetical urban wastewater system | Multi-criteria approach to evaluate strategies for i) compliance with adaptation thresholds and ii) levels of regret under transient scenarios | Compliance and regrets for strategies over time, for decision makers to select pathways |
| SYNTHESIS of characteristics of the cases | • *Goal and target decision*: ranging from targeting a specific planning process to exploring decision pathways with and for different actors | • *Creator*: ranging from participatory community-based to expert-driven<br>• *Model use*: ranging from quantitative model based to qualitative narrative based | • *Delineation*: ranging from quantified well-defined measures to transformational directions of change<br>• *Number*: ranging from exploratory (mapping many possible pathways) to |

**Table 2** (*continued*)

| Name of case study and reference | Context | Method | Output / visualisation |
|---|---|---|---|
| | • *Drivers of change*: ranging from targeting a specific climate impact to addressing vulnerabilities more broadly<br>• *Setting*: ranging from developed to developing, from rural to urban, and from local to regional | • *Interaction*: ranging from anticipatory forecasting to back-casting from a (shared) vision | reflecting the output of a stakeholder process (visualising selected pathway(s)) |

Notes:

i) A growing number of studies follows the approach presented in Case 2. Studies include the city of Dordrecht, the Netherlands (Gersonius et al., 2014), the Rhine Delta (Kwakkel et al., 2016), Shanghai (Ke et al., 2016), Ho Chi Minh City (Scussolini et al., 2017), Kingston Beach, Tasmania (Ramm et al., 2018) and London (Kapetas and Fenner, 2020). van der Wiel et al. (2017) illustrate its application in asset management, and Radhakrishnan et al. (2018a; Radhakrishnan et al., 2018b; 2018c) elaborate a multiple drivers setting in Can Tho, Vietnam and in Melbourne, Australia. Other authors experiment with pathways of actions at fixed times (Knott et al., 2019) or impact levels (Hall et al., 2019). Carstens et al. (2019) organise stakeholder workhops, following the logic of Case 2, to construct pathways for three municipalities in Sweden; which brings their study close to the method of case 3.

ii) The method of Case 3 has been applied in combination with visualisation of Case 2, e.g. by Campos et al. (2016) for Portugal, and Hossain et al. (2018) for coastal Bangladesh.

iii) The method of Case 5 was used for adaptation planning in Hawke's Bay, New Zealand (Cradock-Henry et al., 2020).

iv) Lavorel et al. (Lavorel et al., 2019) adapt the method of Case 8 to pathways for mountain social-ecological systems.

v) The method of Case 9 was applied by Kingsborough et al. (2017) to a case of managing urban heat.

vi) The method of Case 12 has been extended by Buurman and Babovic (2016) with Real Options Analysis, by Manocha and Babovic (2018) with multi-objective genetic algorithms to automate the development of pathways, by Gilroy and Jeuken (2018) with integrated pathways and economic analysis for Central Cebu, Philippines. It was used for urban drainage systems in the Cranbrook catchment (Babovic and Mijic, 2019a) and their economic evaluation (Babovic and Mijic, 2019b). Haasnoot et al. (2020) add an economic evaluation framework, which includes transfer costs to other options.

insights for adaptation planning. These clusters are not mutually exclusive, and some papers include elements of more than one cluster.

*Firstly, **performance-threshold oriented pathways development*** informs adaptation planning by providing alternative sequences of discrete adaptation measures in response to different future scenarios. It is designed to address future adaptation needs in a well-defined system of interest. Actions are quantified with respect to a specific performance metric in support of an existing value set. These approaches started in a data-rich context where the goals can be quantified, and are little contested, with a clear mandate and agency of the decision makers. Example cases are the Dutch Rhine Delta (Haasnoot et al., 2013), and London, United Kingdom (Kingsborough et al., 2016). In these cases, the adaptation goal is clearly defined, and the results are policy and government-actor oriented. Importantly, these cases assume that the performance of the current system is satisfactory. Adaptation is motivated by system performance dropping below a decisive level. This condition is called an adaptation tipping point. Measures are organised incrementally into pathways to maintain performance under different climate scenarios. Pathways are evaluated quantitatively. Pathways are represented in a "route-map", which exemplifies the necessary actions for sustaining system performance (See Fig. 1).

This form of pathways development is usually expert-driven. Kwakkel et al. (2016) offer an overview of the typical iterative assessment steps: (i) the decision context, (ii) the vulnerabilities and opportunities, (iii) the identification and analysis of actions, (iv) the development and evaluation of pathways, and finally (v) the design of an adaptive plan. The additional steps (vi) implementation and (vii) monitoring are usually outside research lifetime and not reported in case papers. Researchers and practitioners apply the performance-threshold orientated pathways approach in a multitude of adaptation contexts, including in developing countries (see Cases 2, 7, and 12 in Table 2). Other cases in this group put more emphasis on exploration and designing robustness to climate change uncertainties into adaptation strategies, rather than identifying a specific pathway for each specified scenario. Yet, like the previous cases, in the final representation of pathways, the decision context is reduced to a single climate metric against which the performances of clearly identified (controlling) measures are quantified. Examples are the Thames estuary flood risk management planning (Ranger et al., 2013; Reeder and Ranger, 2011), adaptation planning for London's water supply system (Kingsborough et al., 2016) and adaptation to sea level rise in Los Angeles (Aerts et al., 2018; de Ruig et al., 2019).

*Secondly, **multi-stakeholder-oriented pathways development*** stress the social and institutional components of pathways development. It starts by acknowledging that adaptation plays out in a multi-stakeholder setting. Pathways methods attempt to include multiple drivers and multiple stakeholders with conflicting goals, interests, and contested values. For example, Barnett et al. (2014) investigated whether an adaptation pathways approach can support or enable consideration of contested options in local-scale long-term coastal planning. Instead of using changes in environmental conditions as thresholds, they identify thresholds that are important for local people. In this case, the adaptation pathways approach is framed as the necessary management of risks for achieving societal goals and collective values. A method to deal with different stakeholder opinions is presented by Bhave et al. (2018), where each pathway represents the preferences of a particular stakeholder group in the Cauvery River Basin in Karnataka (India).

These cases differ from the previous examples in their use of participatory methods, and attention to multi-stakeholder interests, ambiguity and to the process of pathways development (see also Bosomworth and Gaillard, 2019). Their approach to knowledge development is designed to provide space for recognition and inclusion of non-scientific knowledge. As such, they aim to promote collaborative learning and to build capacity for adaptive planning. Pathways maps reflect the output of a stakeholder process and qualitatively visualise selected pathways (See Fig. 2).

*Thirdly, **transformation-oriented pathways development*** views pathways as a metaphor for broad directions of change that represent different strategic aims. Whereas pathways generated in the earlier reported approaches can also result in substantial change, those pathways are still in support of the existing value set. The approaches in this cluster do not assume current system performance to be satisfactory. Rather, on the contrary, from the outset these approaches intentionally address a potential need to transform values and governance arrangements to enable adaptation. The term transformation is used because there is recognition of need for transformation, although these approaches do not necessarily cover all aspects of fundamental change (c.f. Scoones et al., 2020). The justification for these approaches is that other pathways approaches had not focused on the 'root' causes of vulnerabilities and barriers to more transformational change (Wise et al., 2014). Examples here are a dialogue about adaptive co-management in Indonesia (Butler et al., 2016a), a more science-driven exploration of
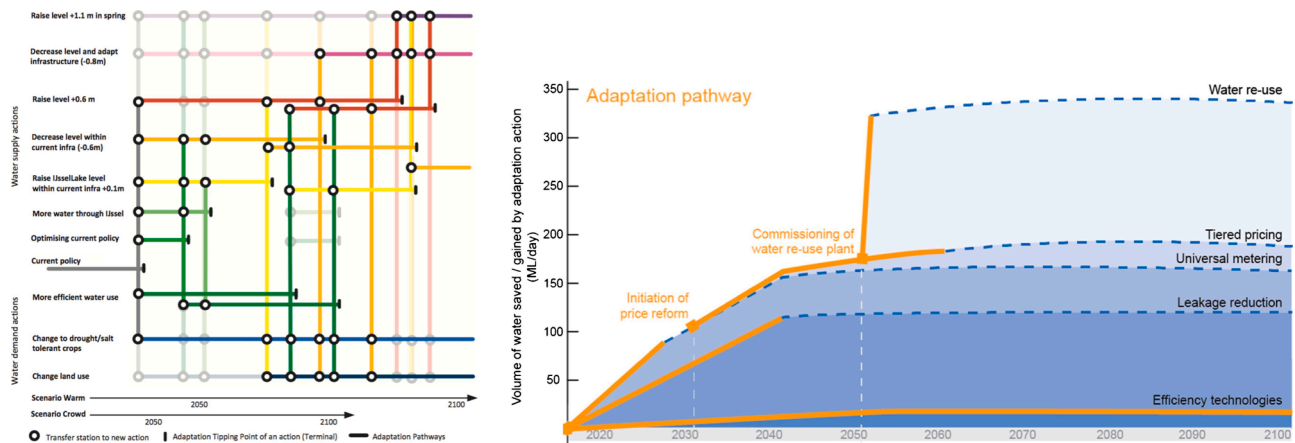
**Fig. 1.** Examples of performance-threshold oriented adaptation pathways (Source: Haasnoot et al., 2013 (left), and Kingsborough et al., 2016 (right)).

decision points in ecosystem transition pathways (Colloff et al., 2016; Prober et al., 2017) and narratives of decisions timeframes for transformative adaptation of mountain social-ecological systems (Lavorel et al., 2019).

Whereas the approaches in the first cluster (e.g. Rhine Delta (Haasnoot et al., 2013)) start from the present situation and develop pathways to adapt to increasing climate change impact(s), transformation-oriented pathways approaches develop pathways for a future goal (e.g. one desirable future vision (Butler et al., 2016a), or alternative future states (Colloff et al., 2016; Prober et al., 2017) or visions (Lavorel et al., 2019)). This is illustrated by the scenario planning and back-casting in Butler et al. (2016a), where pathways were constructed following three steps: identification of drivers of change; participatory development of an aspirational vision and future scenarios of what could be; and a normative back-casting process to identify and explore no-regrets strategies. This cluster of approaches is also the most diverse in terms of methods applied. Prober et al. (2017), for example, adopt the 'values-rules-knowledge' framework (Gorddard et al., 2016) to assess the multiple-drivers and identify potential constraints to implementing pathways. Whereas, Maru et al. (2014) propose a method which combines (i) short-term measures that address current disadvantages reflecting the vulnerability of communities, and (ii) long-term responses that focus on the resilience of the community.

In sum, this cluster differs from the previous cases in its focus on the need for transformation and the use of visioning and back-casting methods. It is argued that these methods are appropriate in dynamic multi-driver contexts where an implementation deficit and the potential need for transformational change have been identified. The output of pathways development is visualised as broad transformational directions of change (See Fig. 3).

## 4. A learning framework for adaptation pathways development

Section 3 presented cases of adaptation pathways development and discussed three clusters of approaches. While there are guidelines for adaptation pathways design and development (notably, Bosomworth et al., 2015; Siebentritt and Stafford Smith, 2016; Wise and Capon, 2016; and the Adaptation Pathways wiki (publicwiki.deltares.nl/display/AP/Adaptation + Pathways, accessed 2 November 2018)) no guidance exists on which of the varied approaches are best-suited to different decision-making contexts. Our review has exposed the need for reflexive learning efforts to identify what approaches have utility in what decision contexts and for what outcomes. To this end, we present a learning framework which consists of propositions on what contributes to the utility of adaptation pathways. We distinguish three outcomes for adaptation pathway development that guide the learning framework. These outcomes are interconnected and motivated by the case studies reviewed:
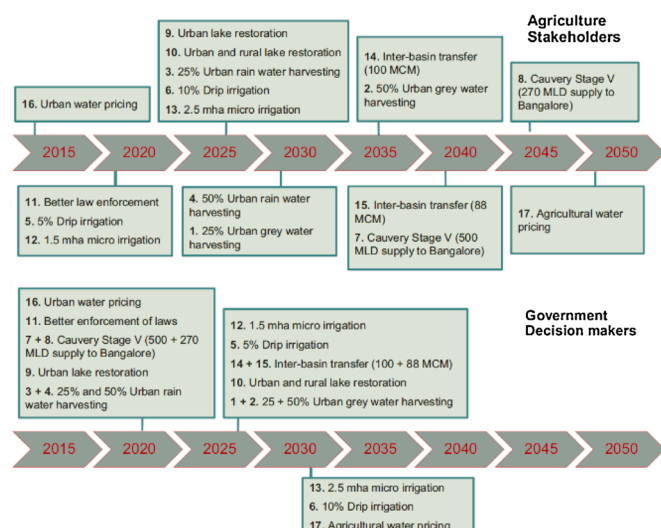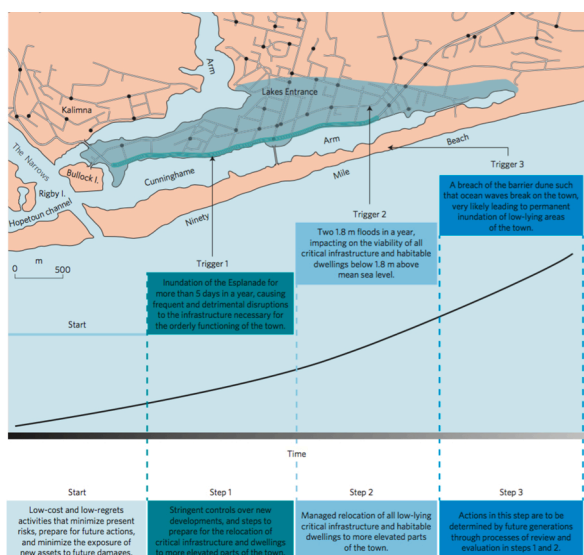


**Fig. 2.** Examples of multi-stakeholder-oriented pathways development (Source: Barnett et al., 2014 (left), and Bhave et al., 2018 (right)).

- Outcome 1: Meet short and long-term adaptation needs;
- Outcome 2: Promote collaborative learning, adaptive planning and adaptive capacity;
- Outcome 3: Account for complexity and long-term change, including a potential need for transformation

The learning framework is suggested as a guide on what needs consideration in approaches to pathways design, as well as providing a structure for reflection on how approaches affect intended outcomes of adaptation pathways development (Fig. 4). We use the term proposition, after Walker et al. (2006), to indicate that the propositions are tentative, they can be true or false, and they need testing. Whilst the propositions reflect what the literature suggests so far might be important for successful pathways development, their relative importance and the potential trade-offs between them may be explored through the application of the framework. For each proposition we also propose several learning questions to orient project teams and researchers towards their intended outcomes.

**Proposition 1.** Adaptation pathways development target specific decisions or decision-makers to meet short and long-term adaptation needs

It is suggested that adaptation planning and pathways development are most effective if they are focussed on the concerns and needs of decision-makers and / or specific policy goals (Kwakkel et al., 2016; Werners et al., 2013). The success of pathways development is found to depend on a consensus about the adaptation needs to be addressed, including the objective thresholds, what constitutes unwanted change, and uncertain future changes (Abel et al., 2016; Zandvoort et al., 2017). Development processes cannot be effective when proposed in isolation from local reality, and therefore it is important for analysts to make sense of the decision context or a particular category of stakeholders. Relevant dimensions of this include the identification of a geographic scale, sectors to be included, generation and delineation of adaptation options, and performance metrics to be used in the assessment (Zandvoort et al., 2017).

*Learning questions:* How can objectives be selected in such a way that short and long-term adaptation needs are met? In what way does the identification and selection of decision makers(s) and their goals affect whether adaptation needs are met?

**Proposition 2.** Adaptation pathways development sequence actions to meet short and long-term adaptation needs under uncertainty

Zandvoort et al. (2017) argue that, next to the specific adaptation problem, uncertainty regarding drivers of change needs to guide adaptation pathways development. Uncertainty means that it is rarely useful to set fixed implementation dates, but it is useful to set decision criteria that show when the circumstances are right for implementation (Abel et al., 2016). Adaptation pathways planning enables actors to prepare for future risks and uncertainties by specifying which measure(s) are to
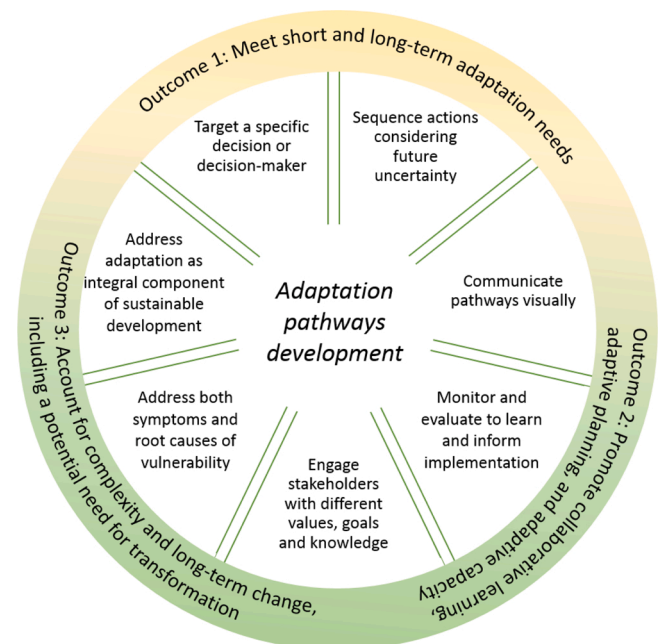


**Fig. 4.** Propositions and outcomes in the learning framework on adaptation pathways development.

be taken now, and which are planned for the future, to be implemented once specific (scenario) conditions are evident. Lempert and Groves (2010) argue that adaptation pathways development should aim to take into account the extent to which measures are flexible, reversible, 'low regrets', or robust (i.e., perform satisfactorily under a range of future conditions).

*Learning questions:* How can measures be sequenced into pathways that meet short and long-term adaptation needs under uncertainty? What role can lead-time, trade-offs, interdependencies, flexibility, reversibility, and robustness play in the sequencing of activities and interventions?

**Proposition 3.** Visual communication of adaptation pathways promotes collaborative learning on the adaptation process

A visual representation of pathways helps communicate outputs from the adaptation planning process (Ranger et al., 2013) and assists the decision-makers to imagine a dynamic response to changing conditions, and navigate the adaptation process (Wise et al., 2014). Pathways diagrams can visualise the way in which future adaptation needs are coupled with adaptation actions (Kingsborough et al., 2016). Visually representing policy decisions as a sequence of several smaller decisions over time can enable decision-makers to overcome some of the barriers
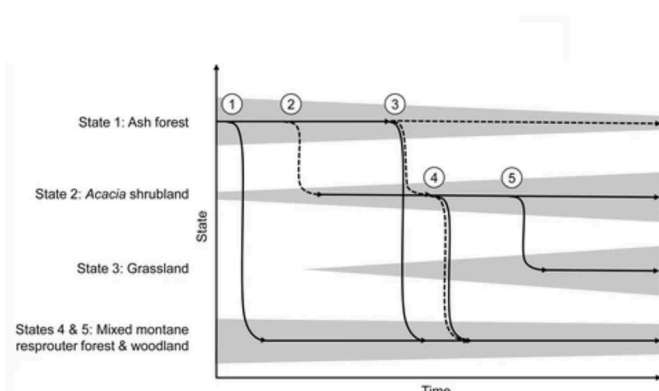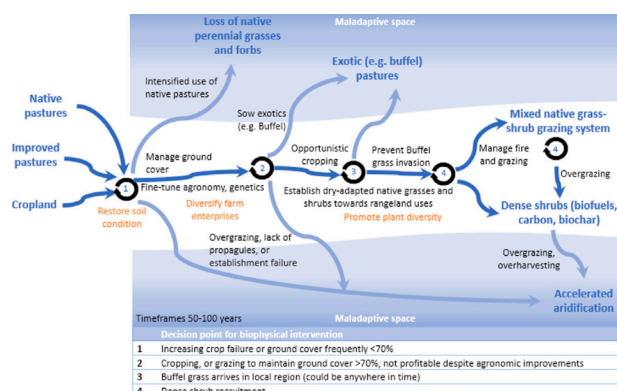


**Fig. 3.** Examples of transformation-oriented pathways (Source: Prober et al., 2017 (left), and Colloff et al., 2016 (right)).

associated with making long-term climate adaptation decisions (Hermans et al., 2017; Wise et al., 2014).

*Learning questions:* Can diagrams of pathways and of future goal(s) effectively synthesise actions required to meet adaptation needs? Does visualisation of pathways promote collaborative learning and adaptive capacity?

**Proposition 4.** Monitoring and evaluation enables learning from and informing pathways implementation

Adaptation pathways development and implementation is monitored and evaluated to learn from experiences, inform on-going decision-making, and trigger follow-up activities as required (Hermans et al., 2017; Jeuken et al., 2015; Wise et al., 2014). The use of adaptation pathways implies the explicit intention to adaptively learn about the system (Butler et al., 2014) and a systematic monitoring effort to inform implementation and future adaptation decisions (Abel et al., 2016; Bloemen et al., 2018; Hermans et al., 2017; Kingsborough et al., 2016). Butler et al. (2016b) draw attention to the importance of considering who is engaged in monitoring and evaluation of pathways design and implementation.

*Learning questions:* Was 'learning practice' established to promote collaborative learning, adaptive planning, and adaptive capacity? How is monitoring and evaluation of the effect of actions designed to inform their re-adjustment and / or follow-up interventions and activities?

**Proposition 5.** Engaging stakeholders with different values, goals, and knowledge across levels and sectors facilitates collaborative learning on the potential need for transformation

Responding equitably to global change (including climate change) might consider: (1) stakeholders' differing assumptions, values and goals associated with the present and future; (2) their different views (perceptions, expectations, attitudes) about the nature of change and how to achieve future goals; and (3) how their history and knowledge can guide future possibilities (Bosomworth et al., 2015, 2017; Fazey et al., 2016; Leonard et al., 2013; Wise et al., 2014). The integration of diverse expertise and knowledge has the potential to enhance the quality of decisions, due to more comprehensive and inclusive information inputs (Butler et al., 2014). Stakeholders can play an active role in identifying decision-critical performance metrics (Bhave et al., 2018), and in so doing, the approach can support the planning agenda to focus on 'real' communities' issues (Vogel et al., 2007). Furthermore, Zandvoort et al. (2017) found that planning cultures and the institutional contexts can lead to pathways that support lock-in on the already chosen development path, instead of highlighting lock-ins to adjust and respond to options accordingly.

*Learning questions:* What kind of stakeholder engagement processes promote collaborative learning about climate change, a common agenda for the future, and adaptive and transformational planning? How can stakeholder involvement in adaptation pathways support dealing with ambiguity and uncertainty?

**Proposition 6.** By addressing both symptoms and root causes of vulnerability, adaptation pathways can account for complexity and a need for transformation

The literature suggests that adaptation is most effective when it considers both the causes and symptoms of vulnerability, especially in situations where goals and practices need to change because they are no longer desirable or feasible under climate change, and transformational adaptation is necessary (Butler et al., 2016b; Lemos et al., 2007). Examples of root causes include governance misfits (e.g. between risk ownership and mandates in adaptation planning) and political barriers (e.g. powerful vested interests maintaining the status quo), cultural barriers (e.g. gender imbalances), or constrained resource access resulting from long-established rules and norms (e.g. familial endowments and entitlements). When cognisant of societal values, governance rules, and systems knowledge, adaptation pathways can allow

identification of whether adaptation decisions will be effective or maladaptive (Colloff et al., 2016; Prober et al., 2017; Rocle et al., 2020). From a systems perspective, this is understood as addressing controlling variables and feedbacks, which dominate system behaviour and stability domains (Abel et al., 2016).

*Learning questions:* What diagnostic approaches can effectively map root causes of vulnerability and controlling variables, particularly across scales? How can activities ranging from physical interventions to capacity-building and governance arrangements be combined in pathways to generate and sustain the transformational changes needed?

**Proposition 7.** Adaptation pathways are a necessary integral component of long-term sustainable development

It is recognised that adaptation should not be addressed in isolation, but rather should be an integral component of broader development planning and sustainability goals (e.g. integrated in the SDGs) (Butler et al., 2016a; Eriksen et al., 2011; Fazey et al., 2016; Lemos et al., 2007). An integrated approach can illuminate an improved understanding of how adaptation practices at different scales interact and how contradictions and synergies shape adaptation pathways and outcomes (Juhola et al., 2011). Implementation of adaptation needs to include the broader social-ecological context under which adaptation decisions are made (Colloff et al., 2016). In complex developing country contexts, the uncertainties associated with rapid socioeconomic development and future climate change are interlinked and so it is important to consider them together (Bhave et al., 2018).

*Learning questions:* In what way does development change the context for adaptation? How can sustainable development targets be integrated within adaptation to account for complexity, uncertainty, and long-term change? How can adaptation pathways warrant the long-term sustainability of development choices? How can approaches be harmonised to promote coherent responses for long-term sustainable development?

## 5. Discussion and conclusion

In this paper we have reviewed the state of knowledge on adaptation pathways development to identify and compare approaches to pathways development in different decision contexts. The review is based on a search of WoS and Scopus from 2003 to 2020, and expert input at ECCA 2017 and Adaptation Futures 2018. Our inclusion criteria for the review are that a paper is topically related to climate change adaptation, and that adaptation pathways are conceptualised as a planning response to future challenges.

Adaptation pathways are framed in the reviewed literature as sequences of actions that can be implemented progressively, depending on how the future unfolds, and on the development of knowledge and stakeholder preferences. A key difference between scholars is the extent to which pathways are understood as alternative sequences of discrete measures to realise a well-defined adaptation objective, or as broad directions of change for different strategic aims or values. We identified three non-exclusive clusters of approaches for adaptation pathways development: performance-threshold oriented, multi-stakeholder oriented, and transformation-oriented. Importantly, these differ in how adaptation needs are understood and assessed. The first cluster corresponds with understanding the adaptation challenge as one of addressing well defined future impacts, while the latter understands the current situation as requiring transformational adaptation. Multi-stakeholder approaches emphasise the process of pathways development as a tool to explore short and longer-term decisions as part of collaborative learning and planning, rather than an end product. From such process perspective, adaptation pathways map the exploration of measures needed for achieving objectives under uncertainty. Together with monitoring and evaluation, making pathways can guide adaptive learning decision cycles over time.

In the literature, we found little evidence of the utility of different approaches for pathways development in different decision contexts (c.f.

Bloemen et al., 2018; Bosomworth and Gaillard, 2019; Carstens et al., 2019). Method selection in pathway development seems to correlate more with the experience of the researchers and how they understand and assess the adaptation problem within an approach known to them, than the case and decision context. As a consequence, adaptation pathways development is often framed within the context of a pre-selected method.

To faciliate more structured learning about the utility of pathways approaches in different decision contexts, we have proposed a learning framework with seven propositions. We distinguished three outcomes for adaptation pathway development that motivate the learning framework: (1) Meet short and long-term adaptation needs, (2) Promote collaborative learning, adaptive planning and adaptive capacity, (3) Account for complexity and long-term change including, a potential need for transformational change. The propositions reflect what the literature suggests so far might be important to provide these outcomes. Thus positioned, the learning framework helps pathways development processes to reflect on and improve existing approaches. It is our intention that the learning framework will provide a foundation for the conceptual and methodological advancement of adaptation pathways. The framework itself will also benefit from iterative testing. With greater evidence, there will also be potential to address three currently perceived challenges: 1) how complex co-evolutionary dynamics across scales can be accounted for in adaptation pathways (cf. Bassett and Fogelman, 2013; Fazey et al., 2010); 2) how deliberative, reflexive learning can be integrated in pathways approaches, representing the diversity of knowledge types, governance regimes and decision hierarchies (c.f. Bosomworth and Gaillard, 2019; Butler et al., 2014; Skrimizea and Parra, 2020; Vervoort et al., 2014); and 3) how to help shift (transform at various scales) current development patterns onto long-term climate-resilient development pathways (Field et al., 2014; Nelson, 2010; Pahl-Wostl et al., 2009; Park et al., 2012; Pelling et al., 2012; Scoones et al., 2020; Stafford Smith et al., 2011).

We trust that reflexive learning from adaptation pathways development – guided by the learning framework presented here – will help researchers and practitioners uncover what works, when, where and why. In closing, we invite researchers and practitioners to apply the learning framework to guide their design and evaluation of adaptation pathways development processes, and thus to enhance the concept's utility for planning under increasingly uncertain futures.

## 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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