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Using expert elicitation to define successful adaptation to climate change

Miguel de França Doria [a,*], *Emily Boyd* [b], *Emma L. Tompkins* [c], *W. Neil Adger* [d]

[a] *Division of Water Sciences, UNESCO, 1 rue Miollis, 75732 Paris cedex 15, France*
[b] *Oxford University Centre for the Environment, Dyson Perrins Building, South Parks Rd., Oxford, OX1 3QY, UK*
[c] *Sustainability Research Institute, University of Leeds, Leeds, LS2 9JT, UK*
[d] *Tyndall Centre for Climate Change Research, School of Environmental Sciences, University of East Anglia, Norwich, NR4 7TJ, UK*

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ABSTRACT

This paper develops definitions of adaptation and successful adaptation to climate change, with a view to evaluating adaptations. There is little consensus on the definition of adapting to climate change in existing debates or on the criteria by which adaptation actions can be deemed successful or sustainable. In this paper, a variant of the Delphi technique is used to elicit expert opinion on a definition of successful adaptation to climate change. Through an iterative process, expert respondents coalesced around a definition based on risk and vulnerability and agreed that a transparent and acceptable definition should reflect impacts on sustainability. According to the final definition, agreed by the Delphi panel, successful adaptation is any adjustment that reduces the risks associated with climate change, or vulnerability to climate change impacts, to a predetermined level, without compromising economic, social, and environmental sustainability.

1. Introduction

As knowledge about the science of climate change improves there is a growing realisation that adaptation by biological systems and by humans is already occurring (Rosenzweig et al., 2007) and that the scale of action required to adapt to future impacts of climate change may be very significant (Parry et al., 2008).

Despite initiatives promoting adaptation, such as the Article 4.1(e) and Article 4.4 of the United Nations Framework Convention on Climate Change, the UN Adaptation Policy Framework (Lim et al., 2005), and the Adaptation Policy Framework (DEFRA, 2005) in the case of the UK, there is still no consensus on the overall objective of adaptation, and hence little scope for defining the success or failure of adaptive actions. The goals of adaptation could be, for example, to maintain climate-related risks at present levels; to reduce risks from present levels if current risks are deemed to be unacceptable; to minimise exposure of the most vulnerable populations; or many others. Adger et al. (2009) argue that such lack of consensus is simply a reflection of diverse and contested values in society but that these diverse values represent a real barrier to adaptive action. The existing knowledge around observed adaptation and its impacts on sustainability, equity and resilience uses many criteria as their yardstick of success. Adger et al. (2005) postulate that a successful adaptation might be one that takes into account: cost-effectiveness, efficiency, the distribution of benefits, and the legitimacy of the adaptation. Other metrics include sustainability, global and intergeneration equity and the resonance of adaptation with cultural norms and collectively held community values (e.g. Hunt and Taylor, in press;

* *Corresponding author*. Tel.: +33 (0)145684181.
E-mail address: m.doria@unesco.org (M.F. Doria).
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O'Brien, in press; Ensor and Berger, 2009). Understanding what constitutes an adaptation and having a framework to evaluate success is necessary in an environment where there are limited resources available to address the complex, uncertain challenges of climate change.

There are a host of existing decision support tools that offer decision makers guidance on how to make decisions under risk and uncertainty (Keeney and Raiffa, 1993; Janssen, 1994; Zeckhauser et al., 1996), yet there is little evidence that these approaches are adequate to properly manage the complex issues associated with climate change (Webster, 2002; Wilby et al., 2002; Tol, 2003). As a point of good practice, Morgan et al. (1990) recommend (among their 'ten commandments of policy analysis') consulting with experts and users in finding solutions.

The Delphi approach and other expert elicitation tools which engage experts in an iterative process of problem definition and analysis have proven useful in eliciting opinions on complex climate issues, such as possible future changes in temperature and precipitation (Morgan and Keith, 1995); the impact of climate change on forest ecosystems (Morgan et al., 2001); the likelihood of rapid sea level rise following collapse of the West Antarctic Ice Sheet (Vaughan and Spouge, 2002); probability distributions of climate sensitivity (Mastrandrea and Schneider, 2004); the likelihood of different rates of future emissions of greenhouse gases (Webster et al., 2003); and the vulnerability of northern Europe to rapid climate change (Arnell et al., 2005). Keith (1996) has criticised the use of expert elicitation in explaining uncertainty, and he has gone as far as to suggest that rather than use expert elicitation in climate science we should re-think the way in which policy-makers use science. There has been little critical reflection of this nature on the appropriateness of expert elicitation to gain a better perspective of adaptation and this challenge is taken up here.

Section 2 of this paper describes the Delphi approach adopted in this study. Section 3 describes the participants, the process undertaken, and the main findings of the study. Section 4 describes what the experts perceived as an acceptable definition of successful adaptation, and the challenges associated with defining, evaluating and measuring it. Section 4 reviews the usefulness and limitations of this study. We conclude that the Delphi-variant used in this study was useful in providing a clear and transparent means of exploring the complexities of adaptation. Specifically, the method highlighted the challenges in identifying the boundaries of an adaptation, who is benefiting and losing from the adaptation, impacts on sustainability and the minimum thresholds of danger. A more consensual definition can create a common working language, with clear practical benefits in this area. In addition, as limits to adaptation can result from different values and knowledge constructs (Adger et al., 2009), by examining the framework of interpretation of experts we can also learn about the limits to adaptation.

2. Research design

The Delphi method is a technique for structuring distributed expert group discussion in order to find solutions to complex problems (Linstone and Turoff, 1975). There are many variants of this method, which typically relate to the level of participants' anonymity, the consolidation and management of group views by a facilitator, and the potential of participants to review their judgments. The distributed nature of a Delphi survey helps to avoid problems of bias raised by group dynamics and provides experts enough time to reflect and present their judgments on the topic.

The most common Delphi approach starts with an initial questionnaire that leads to multiple interactions (rounds) between group members (expert panel) and the facilitator. Consensus is usually achieved after two to four rounds; a larger number of rounds generally leads to a considerable drop in the response rate (Keeney et al., 2001). In each round, participants are asked to judge the issues that were raised by the group on the previous round. This can lead to large questionnaires with long lists of issues, which are time consuming to review, hard to manage, and can complicate consensus (Hasson et al., 2000). In this study, in order to reach a consensus, the issues raised at each round were used by the facilitators to create new definitions of adaptation and successful adaptation. These definitions were refined in each round and re-presented to the group. The interactions ceased when the level of consensus reached a predetermined level of 80%. Hasson et al. (2000) suggest that consensus between 51% and 80% should be deemed acceptable.

Potential participants were invited to participate by e-mail and then telephoned. The invitation explained the purpose and methods of the study, and allowed potential participants to self-evaluate their expertise and suitability to the study (Dalkey et al., 1970). Three subsequent contacts were made by e-mail. Three questionnaires were used which included proposed definitions of successful adaptation to climate change. During the first round, some experts noted that adaptation should also be defined, and questionnaires two and three included definitions of adaptation to climate change. Questions regarding the participants' professional background and their views on the usefulness and limitations of this study were included in questionnaires one and three. Participants were given up to one month to reply to each questionnaire. Reminders were sent a few days before the deadlines. Replies were measured using 4-point Likert scales, from 'completely agree' (1) to 'completely disagree' (4), or from 'very useful' (1) to 'useless' (4). The data were analysed using frequencies (complemented where appropriated by means and standard deviations) and the Wilcoxon Mann–Whitney test for group differences.

Qualitative comments were categorised and independently coded by two of the authors, revealing an acceptable inter-coder reliability (Cohen's Kappa > 0.862) for the comments generated for each definition. The relevance of each comment was assessed by (1) the proportion of experts that raised that specific comment and (2) the level of agreement with the definition expressed by those who raised that comment. Higher priority was placed in addressing comments raised by a higher proportion of experts, and in those that were associated with higher disagreements. The purpose of this procedure was to minimise biases attributable to the facilitator during the process of improving the definitions.

The sampling procedure identified experts actively working with or studying climate change adaptations. We defined

experts as a group of informed individuals, specialists in a field, or those with knowledge about specific subjects (see Keeney et al., 2001). Potential participants were selected from academic publications databases, participation in scientific conferences, and professional networks. The group included experts from a variety of backgrounds, in order to ensure a heterogeneous range of opinions. A panel size within the range of 15–60 experts is considered appropriate for the application of the Delphi method (Hasson et al., 2000), and 38 experts were invited to this study. From this original group, 27 (71%) experts accepted to participate, 6 (16%) declined (due to lack of availability or inadequate expertise), and 5 (13%) could not be contacted (due to maternity leave, sabbatical, retirement, and career change). The first questionnaire was returned by 23 experts (i.e., a response rate of 85% of those who accepted to participate, and 61% of those who were originally invited), the second questionnaire was returned by 20 experts (i.e., 74% of those who accepted to participate, and 53% of those invited), and the third questionnaire was returned by 18 experts (67% of those who accepted to participate, and 47% of those invited). Of those who replied to any of the questionnaires, 73% were males and 27% were females. The majority (54%) described themselves as economists or environmental economists, 27% as environmental scientists, and 19% were in other occupations (e.g. sustainability advisory, engineering, zoology). We focussed on environmental economists as they are the main group who have published in the area of evaluating climate change adaptations. The data were collected between December 2005 and March 2006.

3. Results: defining adaptation and successful adaptation

The study involved three rounds of questionnaires. Respondents were asked to answer questions and to provide qualitative feedback explaining their responses. We sought 80% agreement among participants for each component of the survey, i.e. the definition of adaptation, the definition of successful adaptation and the checklist of evaluation criteria.

The survey began with questionnaire one that provided a definition of successful adaptation based on the standard principles of welfare economics. Welfare economic analysis provides a well-established framework for policy evaluations based on aggregation of individual utility. The questionnaire provided the opportunity for participants to change the definition to whichever framework that they felt would be most appropriate. Therefore, in the first round questionnaire successful adaptation was defined as:

> ''Successful adaptation is that adaptation that generates net benefits for the adapting party, in both the short- and long-term, without causing net loss of welfare for the wider society.''

Of the 23 respondents who participated in round 1, the majority (65.2%) agreed or completely agreed with the definition (see Table 1). Participants made several comments on the definition and presented several suggestions on how to improve it. The main comments related to: ambiguous terminology; the need for a definition of adaptation before defining successful adaptation; relating the definition to climate change (or not); the importance of including *risk* and *uncertainty* in the definition; and the subjective nature of any definition of success (see Box 1).

Table 1 – Agreement (percentages) of respondents with the definition of *successful adaptation* to climate change.

Agreement	Round 1 (n = 23)	Round 2 (n = 20)	Round 3 (n = 18)
Completely agree	4.3	5.0	5.6
Agree	60.9	25.0	77.8
Disagree	30.4	45.0	11.1
Completely disagree	0.0	15.0	5.6
No reply	4.3	10.0	0.0
Mean (SD)	2.3 (.55)	2.8 (.81)	2.2(.61)

There was a clear criticism by many respondents (n = 11, mean agreement = 1.7) that the terms 'adapting party' and

Box 1. Selected first round comments from participants critiquing on the first definition.

Ambiguous terminology

- Wider society is also a very vague definition–does this mean that you would define something that causes a great loss to some and benefits to some as successful adaptation? Perhaps the definition of pareto efficiency and pareto improvement may be if use.
- Strategic adaptation should be required to pass an ex-ante cost benefit test from the perspective of society as a whole. Autonomous adaptation may well involve actions that benefit some agents but that impose a net cost of society as a whole.
- It is worth considering the issue of society. The definition is useful for society as a whole, but individual entities may consider that they have successfully adapted themselves regardless of the consequences–are they wrong? Who governs society's welfare in adaptation?

Difficulty in defining net benefits and losses

- Net benefit, as a term, is general enough to keep the academic community arguing over the definition for years to come. You could generate a net benefit without having successfully adapted to a climate-related threat.
- The practical usefulness of a definition expressed in terms of 'net benefits' can be questioned–i.e. what exactly are these and can different types of benefit and disbenefit be aggregated?

- Another issue with cost benefit analysis is that the difficulty with valuation of some categories of climate change impacts directly translates to the task of assessing net damage costs under different assumptions on adaptations.
- If risks > opportunities, surely some kind of net loss to the wider society is inevitable–in most cases you can't adapt for free. So you are implying that opportunities > risks, which I would dispute. What about the kind of adaptation where we accept that loss is inevitable, given the high cost of avoiding it (e.g. loss of coastline through sea level rise and erosion). In this case, there is no net benefit to anyone. You could argue that this is not adaptation at all . . . but it must be part of a successful adaptation strategy, otherwise adaptation will be unaffordable.

Need to define adaptation first

- It also needs to refer to what adaptation actually is, e.g. adjustments in environmental, social or economic systems in response to actual or expected climatic stimuli and their effects or impacts.
- I would probably feel the need for a clear definition of adaptation before establishing any success criterion. I would prefer a broad definition of adaptation, which includes both autonomous adaptation and strategic, or policy-driven adaptation.

Incorporating long time horizons and adaptive processes into the definition

- This definition seems to apply to a single adaptation action; it does not apply to the state of adaptation. It addresses the option appraisal stage, but not the difficult question ''Are we successfully adapted?'' To express the same point in a different way, it is important to decide if this definition is to be used before adaptation occurs (Is this the right thing to do?) or afterwards (Have we done the right things?); i.e. is the definition for decision-making or for evaluation?
- ''in both the short- and long-term'' implies that the path of benefits must be always be positive through time. Some adaptation will involve short-term costs in return for long-term gains. This would appear to be excluded.
- Also, your definition says nothing about whether benefits are spread over time and whether the cost or investment is incurred just at the beginning or not.

'wider society' were ambiguous as stated and needed to be defined. The mere absence of net loss for the wider society includes situations where large groups have small gains at the expense of great losses from small groups. It also includes cases where a small group experience great gains and large groups suffer small losses. While it is important to consider society as a whole, the individual level should be considered, particularly with regards to those experiencing the downstream effects of the adaptation. Furthermore, nine people commented (with a mean agreement = 2.1) that net benefits and losses are ambiguous terms and hence difficult to define. For instance, the different kinds of benefits and losses would need to be evaluated and comparable in order to assess the net result. Moreover, in many cases adaptation may necessarily imply losses, even if minor than those that would occur in its absence. Experts also highlighted that the integration of time into the definition may be difficult. Several respondents noted that the terms *short-term* and *long-term* were ambiguous and do not take into account the continuous process of adaptation ($n = 5$; mean agreement = 2.0). Adaptation is not restricted to a single isolated action but to a process where adaptation has stages with different states. Also of relevance, the inclusion of short- and long-term considerations does not take into account the temporal distribution of costs and benefits, excluding for instance short-term investments (costs) done to achieve long-term benefits. There were also suggestions that risk and uncertainty should be included in the definition ($n = 3$; mean agreement = 2.3). The inclusion of risk (which implies chance) can emphasize the probabilistic rather than deterministic nature of losses.

Five experts noted that a*daptation* should be defined, before defining successful adaptation (with mean agreement = 1.6). In this context, some expressed a preference for a broad definition that would encompass both autonomous and planned adaptation targeting environmental, social and economic systems. There were some comments that the scope and purpose of adaptation also needs to be addressed ($n = 3$; mean agreement = 1.3). Ideally, the definition would be used to inform both decision-making ('how can we adapt?') and appraisal ('how successful was the adaptation?') stages. However, for this purpose, adaptation should be considered as a continuous process rather than a single action. Finally, it was also noted that any definition that can be envisaged/established will only be one possible definition among several potential ones; it is always subjective and depends on who picks the criteria (n = 2; mean agreement = 2.0).

Having considered the experts' comments on defining successful adaptation, a second questionnaire was produced and was sent out to the same participants. Following on from the comments made in the first round, the second questionnaire was used to elicit opinions on both a definition of adaptation and a revised definition of successful adaptation. As a result, the second round questionnaire was slightly longer than the first. Successful adaptation was defined in the second questionnaire as:

> ''A successful adaptation is one that counterpoises reductions in risk and vulnerability, with the temporal and spatial distribution of adaptation impacts on sustainability (economic, social and environmental).''

Only 20 participants responded to the second round questionnaire. Of these, only 30% agreed or completely agreed with the definition of successful adaptation (see Table 1). Although the level of agreement decreased in quantitative terms, participants' comments show that the components of the definition were improved, and the disagreement was largely due to the grammatical structure and vocabulary used in the definition ($n = 14$; mean agreement = 2.9). Participants comments regarding the second definition of successful adaptation related to: poor grammatical structure and vocabulary (especially use of the word counterpoises); questions about how the definition would be used; the importance of stating success in terms of achieving a certain target level (see Box 2).

Six of the experts (with mean agreement = 3.5) attempted to redefine successful adaptation themselves, see Box 3. Each of these definitions is using different language to make the same point, i.e. 'balancing' is not enough, success relates to achievement of an optimum level or crossing a threshold, not just relative improvement.

In addition to reviewing the definition of 'successful adaptation', participants were asked to evaluate a definition of 'adaptation' itself, following earlier comments that such definition should be considered. The initial (first) and final

Box 2. Selected second round comments from participants critiquing on the second definition.

Confusing language

- I have problems with the wording and also with the clarity of the definition. It is unclear ''counterpoises reductions in risk?'' (corrects/offsets/counterbalances reductions in risks?).

Problems with using opaque terms

- The first definition we saw was based on a concept of net welfare improvement. I said that as an economist I tended to endorse this perspective, though I also mentioned I could see problems with a cost benefit approach in relation to accounting for the full range of climate change impacts that adaptation can help reduce, particularly non-market & environmental impacts. There may also be issues of social justice in relation to different adaptation strategies (e.g., are less vocal communities or specific groups of people being unduly affected?). So I would not disagree with moving towards a definition of successful adaptation that explicitly mentions the different dimensions of sustainable development... I wonder whether a more specific criterion could refer to the different forms of capital (economic, environmental and social) that a successful adaptation action should preserve in the face of climate change.

Box 3. Experts suggested alternative definitions of successful adaptation.

- ''A successful adaptation must reduce risk and vulnerability without disproportionately reducing economic, social and environmental sustainability.''
- ''A successful adaptation is one in which the resulting reductions in risk and vulnerability are perceived to outweigh any adverse economic, social and environmental impacts, now and in the future, which the adaptation may cause.''
- ''A necessary condition for successful adaptation is that it should provide net benefits to society in terms of reduced risk and vulnerability to climate change (including climate variability). Furthermore, these benefits should be sustainable on economic, social and environmental dimensions.''
- ''A successful adaptation is one whose benefits outweigh its costs over time, i.e. where (1) benefits are reductions in risk and vulnerability, and (2) costs are economic social and environmental impacts, over time and wherever the impacts are experienced.
- ''A successful adaptation is one that reduces risk and vulnerability without causing unduly high economic, social and environmental impacts now and in the future, on- and off-adaptation site.'' (Note: both this and the previous definitions were provided by the same participant).
- ''Successful adaptation is adaptation which is effective over the short and long-term for both the direct beneficiary of the adaptation and wider society, and which maximises benefit in relation to the effects of adaptation on the economy, society and environment.''
- ''Adaptation is anything that reduces the risks associated with climate change, and vulnerability to climate change impacts.'' [I think some of the definitions of adaptation would be more appropriate as part of the definition of successful adaptation e.g. elements of timescale (short-/long-term) and direct beneficiary/wider society. Also, I do not think the definition goes far enough with the word ''counterpoise''; successful adaptation should strive to maximise/reach a certain level of adaptation while minimising side-effects.]
- ''A successful adaptation is one that reduces risk and/or vulnerability and leads to a sustainable outcome.''

(second) definitions of adaptation can be seen in Box 4. Agreement with these definitions is presented on Table 2. In the final round, two definitions of adaptation were evaluated, one incorporating climate change mitigation as part of adaptation, and the other explicitly excluding mitigation from adaptation; a third version (presented in Box 4) ignored the role of mitigation. The large majority of respondents (88.9%) agreed or completely agreed with either one or the other definition but there was no consensus regarding the inclusion or exclusion of mitigation (due to the sample size and agreement levels, it is not possible to state that one definition was significantly preferred over the other Wilcoxon Signed Ranks Test $Z = -1.291$; $p = .197$).

There were significant differences in the backgrounds of those who thought that the adaptation definition should include mitigation ($Z = -2.026$; $p = .043$). While only 50% of economists agreed with this definition, 80% of environmental scientists agreed (or completely agreed) with this definition, and the proportion of agreement was 100% among those with other backgrounds. No differences of agreement were found between respondents from different backgrounds with regards to the definition that excluded mitigation ($Z = -.290$; $p = .772$).

Based on these and other comments from the experts, a third questionnaire was developed and circulated, which contained the third and final definition of successful adaptation:

> "Successful[1] adaptation is any adjustment that reduces the risks associated with climate change, or vulnerability to climate change impacts, to a predetermined level[2], without compromising economic, social, and environmental sustainability[3]."

In this third and final round of feedback and comments, the target level of consensus was achieved, when 83.4% agreed or completely agreed with the definition (see Table 1). The majority of comments related to how the predetermined level is decided and how to manage the concept of sustainability. Five experts suggested that the *predetermined level* is vague. They also questioned who should determine it and how? (mean agreement = 2.2). The comments about sustainability were about whether it should or should not be included, and/or further explained and clarified ($n = 3$; mean agreement = 2.6). There were further comments on whether mitigation should be included in the definition. Three experts said that it was not clear whether mitigation is included or excluded from this definition. It was thought that mitigation can be easily excluded from the definition, if it refers to *the occurrence of climate change*, instead of just referring to *climate change* ($n = 3$; mean agreement = 2.0). Other comments on the definition referred to its potential use as a tool for policy-makers, and specifically whether it had any policy applicability.

Based on the final definition of successful adaptation, a preliminary checklist of evaluation criteria was inferred:

Box 4. Defining 'adaptation'.

Definition 1: Adaptation is anything that reduces the risks[1] associated with climate change[2], and vulnerability[3] to climate change impacts, in both the short- and long-term, for both the direct beneficiary of the adaptation and the wider society[4].

[1] *Risk* can be defined as "the chance, in quantitative terms, of a defined hazard occurring", and *hazard* can be defined as "the potential for adverse consequences of some primary event, sequence of events or combination of circumstances". (Warner, 1992).

[2] Climate change encompasses climate variability.

[3] Vulnerability can be defined as "the state of being vulnerable, i.e. exposed to suffering, needs or threats while lacking abilities and/or resources to cope with these. Vulnerability means … exposure and defencelessness. It has two sides: the external side of exposure to shocks, stress and risk; and the internal side of defencelessness, meaning a lack of means to cope without damaging loss" (Chambers, 1989).

[4] Wider society refers to those experiencing the downstream effects of the adaptation.

Definition 2: Adaptation is any adjustment that reduces either the risks[1] associated with climate change[2] or vulnerability[3] to climate change impacts.

[1] Risk can be defined as the chance, in quantitative terms, of a defined hazard occurring, and hazard can be defined as a primary event, sequence of events or combination of circumstances that can potentially have adverse consequences (Warner, 1992). The concept of chance incorporates elements of uncertainty.

[2] Climate change encompasses climate variability.

[3] Vulnerability can be defined as "the state of being vulnerable, i.e. exposed to suffering, needs or threats while lacking abilities and/or resources to cope with these. Vulnerability means … exposure and defencelessness. It has two sides: the external side of exposure to shocks, stress and risk; and the internal side of defencelessness, meaning a lack of means to cope without damaging loss" (Chambers, 1989).

[1] Success is a subjective concept.

[2] The predetermined level will vary for every adaptation and will depend as much on actual level of risk as perceived levels of danger, among other factors. The predetermined level will be selected by the person/people evaluating the adaptation using any decision appraisal method they choose.

[3] Sustainability is deliberately left undefined and can refer to either strong or weak sustainability.

Table 2 – Agreement (percentages) of respondents with the definition of *adaptation* to climate change, with the inclusion or exclusion of mitigation (M) or by ignoring the role of mitigation.

Agreement	Round 1	Round 2 (M included)*	Round 2 (M excluded)*	Round 2 (M ignored)*
Completely agree	20.0	11.1	27.8	38.9
Agree	55.0	55.6	50.0	50.0
Disagree	20.0	27.8	22.2	11.1
Completely disagree	5.0	5.6	0.0	0.0
Mean (SD)	2.1 (.79)	2.3 (.75)	1.9 (.72)	–

* For M included, mitigation was included in the definition; for M excluded, mitigations was excluded from the definition; and for M ignored, the role of mitigation was ignored in the analysis.

a. reducing the probability of a hazard from climate change occurring.
b. reducing the magnitude of the hazard.
c. reducing the intensity of the hazard
d. reducing levels of exposure to the hazard.
e. reducing the sensitivity of the adaptor to the hazard.
f. increasing the adaptive capacity of the adaptor to the hazard.
g. reducing the sensitivity of society to the hazard.
h. increasing the adaptive capacity of society to the hazard.
i. reducing the sensitivity of future generations to the hazard
j. increasing the adaptive capacity of future generations to the hazard.
k. reducing the impact on economic sustainability.
l. reducing the impact on social sustainability.
m. reducing the impact on environmental sustainability.

This checklist was presented to the panel of experts, who were asked to comment on it, to evaluate its usefulness, and to rate the relative importance of each criterion by attributing a weight from 1 (''not important at all'') to 10 (''extremely important''). The majority (83.3%) of participants considered the checklist very useful or somewhat useful (Table 3). However, most participants suggested modifying and simplifying the checklist.

Suggested changes included adding or removing criteria. Ambiguous terms need clarifying, for example 'sustainability' needed to be explained in more detail—to explain whether it includes distribution and equity issues, also 'the adaptor'—does this refer to an individual, society or even future generations? Other complex terms such as 'sensitivity' and 'adaptive capacity' require explanation. Specific criteria such as damage costs are needed, where it was suggested that 'potential damage' could be estimated by the frequency of event x intensity of event x the sum of the impacts over time (social, environmental and economic). It should be also noted that the first four criteria refer to mitigation and to its potential but contentious inclusion in the adaptation concept, as discussed above.

Table 3 – Usefulness of the checklist.

Usefulness	Criteria checklist
Very useful	27.8
Somewhat useful	55.6
Of limited use	16.7
Useless	0.0

By continuously refining draft definitions of successful adaptation, it was possible to reach an agreement of the majority of the experts that composed our panel. The final definition received a high level of consensus although comments by respondents suggest that some aspects of the definition remain problematic. The main issues left unresolved relate to: the definition of sustainability; whether mitigation should be included in the definition of adaptation; the exclusion of the benefits that could be exploited under climate change and estimates of these; identifying the predetermined level of success; and how this should be used by governance institutions to make decisions.

First, it is not entirely clear if the maintenance of sustainability can provide a definable threshold to evaluate successful adaptations. As noted in the definition, sustainability is deliberately left undefined and can refer to sustainability that allows transfer of natural capital into financial capital. Therefore, the adopted definition of sustainability can significantly impact the practical meaning of the definition of successful adaptation and this is underlain by different values (Adger et al., 2009). Second, it was not possible to reach an agreement with regards to the inclusion of mitigation as part of adaptation to climate change. While several experts felt that mitigation is a form of adaptation, others thought that it is important to address mitigation as a separate concept. As noted above on the definition of adaptation, there was no consensus on its inclusion or clear exclusion. This lack of consensus seems to be partially explained by the different backgrounds of respondents, with economists expressing a lower preference for its inclusion than those of other backgrounds, particularly environmental sciences. Mitigation can be considered an adjustment that reduces the risks associated with climate change on a large scale and as such some regard it should be also considered in successful adaptations. In addition, mitigation is sometimes referred in the literature as an action to remedy impacts, in this case considering adaptation as part of mitigation. For instance, Glasson et al. (2005, p. 4) consider that ''mitigation involves the introduction of measures to avoid, reduce, remedy or compensate for any significant adverse impacts''. However, mitigation also affects both potential benefits indiscriminately, and is markedly different from most adaptation processes in terms of scale and policy tools. The motivation for excluding mitigation was mostly due to practical concerns, as mitigation is most often addressed at the national scale, and adaptation at the local

one, and mitigation is often regarded as a public good whereas adaptation is more often a private one. As a result different sets of incentives or penalties are needed to encourage people to act. Third, the final definition does not specifically mention seizing potential benefits that may emerge with climate change. Climate change could bring new opportunities, and an adaptation that profits from these could be regarded as successful on its own right. Finally, other issues left unresolved pertain to the need to identify a predetermined level of adaptation that can be regarded as successful. This threshold for success is undefined, and there is no recommendation about who should determine it or how this level is established. From prior experience with thresholds for environmental risks (e.g. for potentially hazardous substances in water and air), the level may best be defined by policy-makers and stakeholders together with public support and acceptability. It is not clear how flexible this level should be. It should allow revisions and accommodate lessons learned from experience, but some rigidity would be beneficial to avoid *post hoc* adjustments that would enable the categorisation of failures as successes.

4. Implications and methodological considerations

Is the Delphi technique a useful approach for identifying subjective concepts, such as success and for identifying evaluation criteria? The challenges of using expert elicitation methods were brought out clearly in this study. The majority of respondents regarded it as very or somewhat useful (60.8%) for generating a definition of successful adaptation (see Table 4).

Respondents who were familiar with the expert elicitation method tended to regard the definition of successful adaptation as more useful than those who were unfamiliar with the method ($\chi^2(3) = 8.604$; $p = .035$). 15 (65.2%) respondents were familiar with the expert elicitation method (e.g. participated or designed it), 8 (34.8%) were unfamiliar with it. A greater proportion (78.3%) considered that defining successful adaptation was a very useful or somewhat useful activity (see Table 4; mean agreement = 1.9; SD = .83).

Participants made several comments regarding the usefulness of the first definition. Of particular concern was the use of the definition, four experts believed that a poor definition may create more problems than solutions (mean agreement = 2.5). Specifically, if the definition is to be used as a basis for policy, the specific elements of the definition are important. If the definition is to promote awareness of adaptation a broader definition might be useful. The difficulties in predicting the future, coupled with the uncertainties and subjectivity associated with the concept of adaptation make it complicated or even impossible to define adaptation ($n = 4$; mean agreement = 2.5). Nonetheless, it was felt that a common language, which facilitates communication and consensus was needed ($n = 3$; mean agreement = 2.3), and an appropriate definition was needed in order to identify criteria by which to evaluate adaptation ($n = 3$; mean agreement = 2.0). To tackle the problem of defining adaptation from a different angle led some to suggest that defining unsuccessful adaptation, or even mal-adaptation, may be more useful ($n = 2$; mean agreement = 3.0). Finally, one expert suggested that these definitions needed to be tested empirically to identify their utility.

Although all participants agreed that the checklist criteria should be weighted, most refused to attribute weights, for various reasons. Many participants considered that the relative importance of specific criteria depends on the particular case to which the criteria are applied. Others felt that their weights are not relevant in practice, suggesting that the checklist should be rated by policy-makers and stakeholders, not by experts. Many felt that the weights they would allocate would vary according to the type of hazard and would also depend on the circumstances or the context in which the decision is being made. For these reasons, only 41.2% considered that experts' weights were very useful or somewhat useful (Table 4).

Overall, respondents suggested that expert elicitation is less useful for assessing subjective concepts and more useful to reduce uncertainty associated with specific values where boundaries are fuzzy (e.g. sea level rise, temperature increase). In the specific case of adaptation to climate change, it might be the case that success is best evaluated by those adapting or affected by adaptation measures, and not by external thresholds defined by experts. Individuals experiencing climate change may be best able to identify whether they feel better protected or better adapted and it may also be the case that different values underpin different goals of adaptation (Adger et al., 2009).

Table 4 – Perceived usefulness of (a) the expert elicitation method for generating a definition of successful adaptation, (b) defining successful adaptation, and (c) establishing experts weights.

Usefulness	Expert elicitation method	Defining successful adaptation	Experts weights
Very useful	38.9	36.4	17.6
Somewhat useful	38.9	45.5	23.5
Of limited use	22.2	13.6	47.1
Useless	0.0	4.5	11.8

5. Discussion and conclusions

Given the difficulties of finding consensus around criteria to assess the success of climate change adaptation, finding a workable definition of successful adaptation is always going to be contested (Adger et al., 2005). This paper described the process based on the Delphi method to gather consensus around a definition of successful adaptation to climate change with a view to finding criteria by which to evaluate adaptation decisions. The definition that reached the predetermined level of consensus (>80%) is: ''Successful adaptation is any adjustment that reduces the risks associated with climate change, or vulnerability to climate change impacts, to a predetermined level, without compromising economic, social, and environmental sustainability.''

The Delphi method was a useful tool both to better approach the nuances of adaptation, as well as to highlight the complexities in evaluating adaptation. However, the conclusion from the Delphi survey is that while a definition can be produced it is unlikely that there will be full agreement on it. Even among a group of predominately environmental economists there was disagreement over various issues. The first disagreement related to the selection of the appropriate framework to describe adaptation: i.e. is a risk-based approach more appropriate than welfare economic or vulnerability framework? Some differences between the participants remained throughout the research process.

The second disagreement related to the whether mitigation should be included in any definition of adaptation. A third disagreement related to how sustainability could be included in such a definition and, if included, whether it made the definition of success unusable. These issues were not resolved and remain at the heart of the challenge to assess the success of adaptation to climate change. In addition, the question of how time should be included in any evaluation of climate change adaptation was not resolved, specifically the question ''over what time period should an adaptation be evaluated?'' remains central to evaluating success. Yet this question also remains unanswered. To begin to answer it, more work is required which considers trade-offs between the costs and benefits of the adaptation to current and future generations. At present, a lack of work in this area is limiting our ability to answer this question.

In conclusion, the expert elicitation method has produced a concerted definition of successful climate change that could be used as a useful standard against which to develop evaluation criteria, although the limitations and strengths of the method need to be acknowledged. Future research on the objectives of adaptation will have to reflect further on the role of thresholds which affects the risk framing of adaptation decisions and objectives. In addition, consideration has to be given to the scale at which adaptation is happening to assess whether the generic definition and checklist are adequate to actually enable measurement at different scales, such as national and community levels. The definition and checklist can be tested empirically to illustrate their application in practice and to fully assess their applicability and utility. One way of doing so is to use the definition and checklist to study randomly selected example cases of various types of adaptation (e.g. anticipatory, autonomous and planned adaptation) at different stages (decision process, mid-project review, assessment) and geographical scales. While taking into account its limitations, the checklist may be weighted by policy-makers and stakeholders and used in conjunction with the definition as a tool to inform the planning of adaptation strategies and to guide the evaluation of these strategies.

Finally, we conclude that the challenge of assessing the impacts of climate change responses (adaptations and mitigative actions) over time remains as much a challenge today as it has been for researchers in all areas of social science who have been considering issues associated with intergenerational equity and justice. Ultimately, adaptation will progress at multiple scales that relate specifically to the environmental change experienced and to the range of beneficiaries and losers, whether in the present or in the future. Thus adaptation to climate change, in common with many areas of complex trade-offs and long-term dynamics, involves context and value specific judgements concerning the ultimate objectives and sustainability of actions and investments. As noted by the participants, successful adaptation to climate change may be best evaluated by those adapting or affected by the adaptation measures. In this case, the role of experts is to assist this process by ensuring that adaptation is well understood and that all relevant factors are considered.

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Miguel F Doria is an officer of the secretariat of the International Hydrological Programme (IHP) of UNESCO and is IHP's focal point for the United Nations of Education for Sustainable Development. He also serves as deputy officer for IHP activities on the water and energy nexus. Before joining UNESCO, he was a researcher at the Tyndall Centre for Climate Change Research and at the Centre for Environmental Risk, University of East Anglia.

Emily Boyd is a social scientist with a background in development, complemented with a degree in forestry and land use change, and a PhD in climate change and development from the University of East Anglia Norwich. Emily is currently a Research Fellow at ECI Oxford University and a member of the Stockholm Resilience Centre.

Emma Tompkins is a Senior Lecturer at the University of Leeds. She has a bachelors degree in Economics, a Masters degree in Environmental Economics, and a PhD in environmental management. Her research interests lie in understanding how societies can and should adapt to climate change.

Neil Adger is Professor of Environmental Economics in the School of Environmental Sciences at the University of East Anglia, Norwich, UK. He has led the research programme on adaptation in the Tyndall Centre for Climate Change Research since its inception in 2000.