







Interrogating ‘effectiveness’ in climate change adaptation: 11 guiding principles for adaptation research and practice

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ABSTRACT

The Paris Agreement articulates a global goal on adaptation, which aims to ensure an ‘adequate adaptation response’ to the ‘global temperature goal’, and requires countries to report progress through periodic global stocktakes. However, there remain conceptual and methodological challenges in defining an adaptation goal and mixed evidence on what effective adaptation looks like and how it can be enabled. In this review, we demonstrate how different normative views on adaptation outcomes, arising from different epistemological and disciplinary entry points, can lead to very different interpretations of adaptation effectiveness. We argue that how effectiveness is framed will significantly impact adaptation implementation and outcomes. This, furthermore, represents a way of exercising influence in adaptation decision-making. Eleven principles of effective adaptation are distilled as a way to pluralize guidance in international processes such as the Global Stocktake as well as national and sub-national exercises on tracking and monitoring adaptation.

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1. Introduction: why examine adaptation effectiveness?

Climate change adaptation has moved from understanding vulnerabilities to climate change, and therefore whether, where, and why adaptation is needed; to a post-Paris Agreement world with a ‘global goal on adaptation’ (UN 2015, Article 7.1). This goal aims to ensure an ‘adequate adaptation response’ to the ‘global temperature goal’, thereby enhancing adaptive capacity, strengthening resilience, and reducing vulnerability to climate change, ultimately contributing to sustainable development. The Paris Agreement further requires nations to contribute to periodic stock takes on progress towards the Paris Agreement goals, including reviewing the *adequacy* and *effectiveness* of adaptation and support provided for adaptation; as well as assessing overall progress made in achieving the global goal on adaptation (Craft & Fisher, 2018; Tompkins et al., 2018).

This begs the question: how should we define the effectiveness and adequacy of adaptation? Recent reviews (e.g. Berrang-Ford, 2019; Christiansen et al., 2018; Eriksen et al., 2021; Magnan et al., 2020; Milkoreit & Haapala, 2019; Möhner, 2018; Owen, 2020) highlight a complex mix of theory and practice, where effectiveness is interpreted differently at different scales and in different contexts (Dilling et al., 2019; Eriksen

et al. 2011; Ford et al., 2013; Preston et al., 2013). These complexities lead to tensions: some call for the need for a distinct, generalizable set of metrics that can help prioritize and allocate resources for adaptation, and assess the impact of these allocations; others argue that such top-down generalization will narrow the remit of what is considered to be adaptation, as well as exclude those who do not have sufficient access to data or resources to assess progress using externally-imposed metrics (Leiter, 2019).


Examining adaptation effectiveness is particularly cumbersome because adaptation measures are often difficult to delineate from development interventions, leading to difficulties in categorizing whether anything that builds adaptive capacity can be termed as adaptation (Eriksen & Brown, 2011b; Lemos et al., 2007; Owen, 2020; Schipper et al., 2020; Sherman, 2016). Further, there are no specific, commonly agreed upon metrics to measure adaptation (Christiansen et al., 2018; Dilling et al., 2019; Ford et al., 2013; Leiter, 2019; Morgan et al., 2019; Owen, 2020; UNEP, 2021) unlike in mitigation (e.g. tonnes of CO₂ removed or avoided) and the lack of a clear adaptation goal obfuscates tracking and monitoring progress towards it (Craft & Fisher, 2018; UNEP, 2021). Given the highly contextual nature of adaptation, a universal definition of what effective adaptation is particularly challenging

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(Morgan et al., 2019; Ngwadla & El-Bakri, 2016). Finally, setting the boundaries of effectiveness is difficult since what is effective today might not be tomorrow and adaptation interventions may have trade-offs across spatial scales (Dilling et al., 2019; Gajjar et al., 2019b; Magnan et al., 2020) that are not always apparent or measurable. Despite these challenges, tracking adaptation progress is critical to reducing vulnerability to climate change and informing adaptation funding and implementation priorities (Berrang-Ford, 2019; Morgan et al., 2019).

In this paper, we explore how different normative views on adaptation outcomes, arising from different epistemological and disciplinary entry points, can lead to very different interpretations of adaptation effectiveness. Section 2 details our methodological approach to do this and in Section 3, we discuss eleven frames used to understand and operationalize effectiveness in adaptation. We then illustrate these different views with empirical examples in Section 4, drawing on evidence from the Adaptation at Scale in Semi-Arid Regions (ASSAR) project (www.assar.uct.ac.za), which worked across nine semi-arid regions in Africa and Asia to understand the barriers and enablers of effective adaptation (EA). We end with eleven principles for EA, suggesting that opening up thinking about the purpose, processes, and outcomes of adaptation from different perspectives can lead to (1) better conceptualized and designed adaptation processes, which acknowledge the inherent biases and strengths of different effectiveness approaches, and (2) adaptation outcomes that are better aligned to the overarching SDG objective of 'leaving no one behind'.

2. Methodological approach

To examine how effectiveness is conceptualized and operationalized in the adaptation literature, we identify different frames used in the peer-reviewed ($n = 192$) and grey ($n = 51$) literature (a full list of papers assessed is given in Supplementary Material 1).

Frame analysis has been used to examine how different worldviews construct 'plausible, meaningful and socially relevant pathways' towards collective action (Fletcher, 2009) and how drivers of problems and their solutions are embedded

in particular narratives (Lindahl et al., 2016). In the adaptation literature, frame analysis has been used in various ways; e.g. to examine the emergence of different adaptation heuristics¹ (Preston et al., 2013), adaptation governance and policy approaches (Fünfgeld & McEvoy, 2014; Gonzales-Iwanciw et al., 2020; Vogel & Henstra, 2015), and how power mediates adaptation (Woroniecki, 2019a). 'Frames' encompass narrative devices through which issues, actions, policies, decisions, or events acquire meaning, or are strategically used to build support for different actions (Rein & Schön, 1996).

The process of identifying frames was done in three steps. First, we conducted a literature review to examine how adaptation effectiveness is discussed, which led to the identification of seven distinct frames.² Second, the literature review was discussed in two 5-day workshops where we tested the applicability of the seven frames in terms of real-world examples drawn from the ASSAR project (more on the project below), especially whether these seven frames adequately conveyed the ways in which adaptation actions were being conceived and debated by different actors. In doing so, we recognized that in practice, adaptation effectiveness is often signalled through normative *goals* (e.g. to avoid maladaptation) and enabling *processes* (e.g. community participation). Thus, by the end of the workshops, we expanded the number of framings that we perceive are being applied to understand and operationalize adaptation effectiveness to a total of eleven.

The eleven frames are: (1) maximizing economic benefits; (2) improved wellbeing; (3) vulnerability reduction or adaptive capacity enhancement; (4) enhanced resilience; (5) sustainable adaptation; (6) avoiding maladaptation; (7) ecosystem-based adaptation; (8) community-based adaptation; (9) adaptive governance; (10) ensuring equity and justice; (11) transformation.³ The frames fall into two broad categories: *normative frames* that use heuristics of adaptation 'goals'/desirable end points to track adaptation effectiveness against; and *process-based frames* that capture the 'means' of adaptation and highlight how the ways of prioritizing and implementing adaptation are key to delivering EA (Figure 1).

Though there are overlaps between the frames, each is sufficiently different to merit separate consideration, based

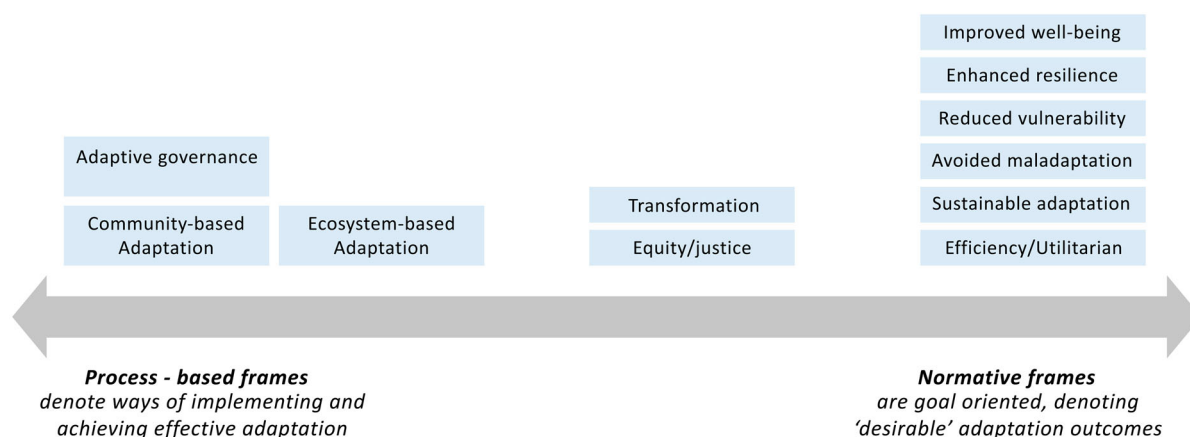


Figure 1. Frames to understand adaptation effectiveness range across a continuum of being process- or outcome-based. Source: authors, developed from the literature.

on the presence of distinct, well-developed literatures and perceptibly different implications for understanding and assessing EA. For example, the 'EA as transformation' frame has overlaps with 'EA as just and equitable adaptation' because both frames focus on how and to what end adaptation benefits are distributed in populations. However, the literature review highlights that the transformation frame's defining focus is on systemic change that moves beyond incremental adaptation and encompasses deep shifts in norms, values, and practices. Though its outcome goal might be similar, the justice frame expresses and operationalizes EA differently, through a focus on distributive, procedural, and recognition justice, and taking an explicitly rights-based approach to responding to climatic risks equitably.

For each frame, we reviewed the literature to answer four questions: (1) How does the frame define effective adaptation? (2) What are the metrics used to capture effectiveness? (3) What does the frame mean for the most vulnerable? (4) Are there reported examples that use this frame? Our enquiry explicitly focussed on vulnerable communities to capture how different frames can have negative or positive impacts on those most exposed to or least prepared for climatic risks.

To contextualize the eleven frames, we draw on empirical evidence from five case studies in the Adaptation at Scale in Semi-Arid Regions (ASSAR) project (www.assar.uct.ac.za). The ASSAR project, on which all the authors worked, was a five-year long project spread across nine semi-arid regions in Africa and Asia. It aimed to understand the barriers and enablers of effective adaptation, focussing on most vulnerable populations and livelihoods. The empirical examples (discussed in Table 1) were chosen to portray different livelihood systems and dynamics (pastoralism, smallholder agriculture, rural-urban migration) as well as varied socio-ecological contexts (India, Mali, Namibia, Kenya). The ASSAR examples are used as an illustrative device to showcase how applying different metrics to assess effectiveness highlight different aspects of how successful a particular measure was.

3. How is 'effective adaptation' framed?

How adaptation is understood matters. The underlying concepts used to construct that understanding shape priorities about what is done, for what purpose, by who, for whom, and with what outcome. The very act of including or excluding certain perspectives in the conceptualization of adaptation approaches is a reflection of dominant knowledge and institutions (Nalau & Verrall, 2021). This, in turn, determines who will benefit or, in some cases, who will be made worse off by adaptation actions (Dilling et al., 2019; Eriksen et al., 2021; Gear & Dehm, 2020; Vink et al., 2013).

Adaptation effectiveness has been directly or indirectly examined in various literatures (Christiansen et al., 2018; Dupuis & Biesbroek, 2013; Owen, 2020), from economic analyses of costs and benefits associated with specific adaptation interventions to equity-based framings focussed on who is included and excluded from adaptation processes, decision-making, and outcomes. From the practice domain, attempts at conceptualizing and implementing EA have called for more community-based processes and more dynamic

monitoring and evaluation frameworks. Based on an extensive review of the research and practice literatures, we summarize these different articulations of adaptation effectiveness and their implicit assumptions.

3.1. Efficiency or utilitarian frame

Adaptation should minimise costs and maximise benefits.

A utilitarian approach to effectiveness emphasizes that any investment in adaptation should maximize benefits of the intervention and minimize its costs. The original rationale for this framing arose from cost-benefit analyses to capture trade-offs between mitigation and damage (and associated cost of adaptation) to ultimately understand what comprises 'dangerous climate change' (Stern, 2006). Once the need for adaptation was accepted, efficiency became an important consideration in deciding between different adaptation interventions, largely from a financial perspective, but also – and increasingly – from a social cost perspective (Downing, 2012). A utilitarian approach defines adaptation effectiveness by principles of efficiency such as optimization (Cartwright et al., 2013), parsimony (generating desired benefits for the minimum investment, Pelling, 2010), and utilitarianism (Cartwright et al., 2013; Möhner, 2018).

This utilitarian frame assumes that the benefits of adaptation can be estimated or calculated and tends to define benefits in financial terms, showing benefits as strongly affected by discount rates uses. This focus poorly captures non-economic impacts (e.g. as losses to quality of life or cultural heritage) (Tschakert et al., 2017). How adaptation effectiveness is defined in the utilitarian framing strongly depends on how and for whom efficiency is framed. If it is targeted at vulnerable groups, it might focus investments on benefitting the most vulnerable, if it is framed around economic damage reduction then those with greater assets might preferentially benefit. Utilitarian framings have been critiqued for their inadequate acknowledgement of the 'multiple dimensions of human well-being and the plural forms of value articulation' (Wegner & Pascual, 2011, p. 492).

The metrics used to assess effectiveness are typically quantifications of adaptation investments (costs), positive gains in risk averted, and adaptive capacity built (benefits). Some examples using this framing are (1) cost-benefit analyses – investment costs versus financial benefits which may include contingent valuation for non-economic benefits (e.g. Gray & Srinidhi, 2013 assess costs benefit ratios of integrated watershed management in India); (2) multi-criteria analysis – such as ease of implementation, cultural and/or political barriers, as well as non-economic benefits, co-benefits with mitigation or SDGs (Cartwright et al., 2013); and more recently, (3) benefits in terms of numbers of people benefitting (e.g. Möhner, 2018). Overall, there is little on what an effective investment means and no systematic reviews of existing adaptation projects benchmark the range of cost-benefit estimates.

3.2. Effective adaptation as improved wellbeing

Adaptation should support achievement of material, subjective, and relational wellbeing goals.

EA framed as improved wellbeing has its roots in the capabilities approach (Sen, 2000). At its broadest, the wellbeing approach covers three facets of wellbeing: material (assets, standards of living), relational (social relations, cultural associations), and subjective (perceptions of quality of life, mental health, cultural values) (McGregor & Sumner, 2010; White, 2010). Unlike the reducing vulnerability frame, which predominantly takes a deprivational approach, the wellbeing frame combines deprivational and aspirational approaches by focusing on subjective wellbeing (Camfield, 2006) and emphasizing the agency of actors in determining their wellbeing.

The wellbeing frame tends to focus on the individual (Sointu, 2005; White, 2010), assuming that improving individual material and subjective wellbeing can aggregate to community, regional, national, and global scales. Thus, while a wellbeing approach to effectiveness can help evaluate adaptation strategies as improving or hindering individual wellbeing, trade-offs at higher scales can be missed. Recent empirical research in semi-arid regions show significant gender and generational trade-offs in individual and household wellbeing even as women exercise agency to achieve the best outcomes for their families (Rao, 2020).

Well-being approaches tend to use a range of metrics. For example, the Tracking Adaptation and Measuring Development (TAMD) exercise uses household surveys and participatory well-being rankings to track and measure adaptation effectiveness (Brooks et al., 2013). This approach is not explicitly focused on the most vulnerable, but the focus on subjective wellbeing in addition to material and relational wellbeing gives agency to those being studied. Behavioural measures that enable changing work hours to avoid heat stress have significant impact on the well-being of informal workers (Day et al., 2019).

3.3. Effective adaptation as reduced vulnerability or increased adaptive capacity

Adaptation should reduce vulnerability and/or increase adaptive capacity, especially of the most vulnerable and those most at risk to climate change.

This frame considers adaptation to be effective when vulnerability is reduced or adaptive capacity is enhanced, with a particular focus on the most vulnerable. We discuss reducing vulnerability and enhancing adaptive capacity together because they signify two sides of the same coin (Gallopín, 2006). A strong emphasis is placed on enhancing capacities to adapt to, avoid, reduce, or capitalize on risk and assessing adaptive capacity usually serves as a proxy for actual adaptation (Mortreux & Barnett, 2017).⁴

A key assumption in this framing is that enhancing adaptive capacity will reduce vulnerability (Fritzsche et al., 2014; Gallopín, 2006) and, thus, EA should address the root causes of inability to sustain livelihoods and manage risks (Ribot, 2014). A prerequisite is thus identifying not only *who* is vulnerable and who has the capacity to adapt but also *why* people are vulnerable and why they hold differential adaptive capacities (Ribot, 2014; Thomas, 2019).

Here, EA can be assessed either through direct, outcome-based approaches such as reduced risk following adaptation,

or indirectly through proxy measures of vulnerability reduction (Ford et al., 2013). Indicator-based vulnerability assessment methods or participatory approaches, serve as metrics to monitor vulnerability reduction over time (e.g. before and after an adaptation intervention or action) and at different scales (Ford et al., 2018). While there is no single method to assess adaptive capacity, the sustainable livelihoods framework's five capitals (natural, physical, financial, social and human) have been used most commonly. However, asset-based approaches have shown to be insufficient to explain or anticipate adaptation and there has been a shift from asset enumeration to identifying factors that mobilize capacity for change (Mortreux & Barnett, 2017).

A focus on reducing vulnerability is criticized for depriving the most vulnerable of agency over their adaptation choices. This is countered by a focus on capacity as a positive but variable trait, and one that contributes to a state of resilience (Miller, 2010). Despite these theoretical debates, vulnerability reduction and adaptive capacity enhancement dominate the adaptation implementation landscape.

3.4. Effective adaptation as enhanced resilience

Adaptation should increase resilience by building functional persistence over long timescales so that systems have the ability to bounce back from climatic shocks.

The resilience framing originates from the ecological sciences, which acknowledges ecological limits to adaptation (Dow et al., 2013) but demonstrates that resilient systems have the ability to 'bounce back' from shocks and stressors (Folke, 2006). While this approach has overlaps with the sustainable adaptation frame, there are several points of departure. The sustainable adaptation frame has vulnerability reduction at its core, while resilience is often understood as the opposite of vulnerability (Pelling, 2010).⁵ Others argue that resilience and vulnerability are linked through adaptive capacity, where greater the adaptive capacity of the system, higher the resilience to climate stress (Engle, 2011). The three fundamental constituents of resilience within socio-ecological systems theory are functional persistence, self-organization, and adaptation (Pelling, 2010) and the spatio-temporal scales under consideration are much longer and larger than in other approaches (Miller, 2010).

The frame tends to assume that there are trade-offs between adaptiveness and resilience (Nelson et al., 2007) and that reducing vulnerability in a particular context and time may create/increase vulnerability in another context and time. Critiques of the 'tyranny of resilience' argue that its positivist epistemology tends to privilege phenomena that can be objectively defined and measured, without adequate attention to non-material and subjective aspects of resilience (Béné et al., 2012; Miller, 2010) with a bias towards technical responses (Bahadur & Tanner, 2014).

Resilience framings measure EA in terms of stability, self-organization, and learning, with emphasis on defining the system and its bounds as well as the (typically external) disturbance being considered. Examples include work in biodiversity conservation where EA has been defined in terms of specific goals such as preventing species extinctions;

maintaining intact and functional ecosystems; sustaining key ecosystem services (Stein & Shaw, 2013).

Depending on the scale and scope of the system being considered, the resilience framing helps focus on (1) temporal trade-offs (Nelson et al., 2007); (2) spatial trade-offs (Bahadur & Tanner, 2014); and (3) trade-offs between objectives (e.g. human well-being vs. environmental services) (Cumming et al., 2013; Nelson et al., 2007; Rodríguez et al., 2006).

3.5. Effective adaptation as sustainable adaptation

Adaptation should be economically, ecologically, and socially sustainable, explicitly looking at longer-term, cross-generational viability of adaptation actions.

The sustainable adaptation framing⁶ articulates EA as that which adheres to the principles of sustainable development, moving towards goals of social equity and environmental integrity (Eriksen & Brown, 2011) with a strong focus on temporality (through aspects of intergenerational sustainability) (Santhia et al., 2018). Eriksen et al. (2011) propose four normative principles that guide sustainable adaptation responses to climate change: adaptation planning should (1) recognize the multi-dimensional stressors that maintain vulnerability; (2) acknowledge the contribution of diverse values and interests in adaptation outcomes, particularly of the most vulnerable; (3) integrate local knowledge into adaptation responses; and (4) consider cross-talk between local and global processes.

Simply, sustainable development aims to address issues of poverty while sustainable adaptation focusses on climate change vulnerability and gaps in adaptive capacity. However, vulnerability and poverty do not always map onto one another; there are poor populations that are not vulnerable to climate change and vulnerable populations that are not poor (Nelson et al., 2016). The interface where vulnerability reduction and poverty reduction measures intersect can be considered sustainable adaptation measures (Eriksen & Brown, 2011; Eriksen & O'Brien, 2007; Eriksen et al. 2011). The sustainable adaptation framing draws from sustainability studies but might sometimes conflate vulnerability with poverty. A critique has been unclear demarcation between what is adaptation and what general development (Eakin et al., 2014; Kuchimanchi et al., 2021; Schipper et al., 2020; Singh et al., 2019), making it unclear whether sustainable adaptation is sustainable development plus climate change or something more.

There are no clear metrics to assess sustainable adaptation, but they tend to borrow from climate change vulnerability research and development studies (e.g. livelihoods research Scoones, 2009). For example, sustainable adaptation can be measured through 'measures that reduce vulnerability and promote long-term resilience in a changing climate' (Leichenko & O'Brien, 2008, p. 31). Eriksen et al. (2011) also emphasize distributive aspects of sustainable adaptation by using the metric of 'does the action contribute to social justice and environmental integrity?' This framing places a significant importance on vulnerable communities and intergenerational aspects of vulnerability, which is often missing from other framings (except maladaptation and justice frames, to some extent).

3.6. Effective adaptation as avoiding maladaptation

Adaptation should take into account unintended negative consequences and explicitly look at the cross-scalar, long-term impacts of adaptation actions.

Maladaptation is defined as, 'action taken ostensibly to avoid or reduce vulnerability to climate change that impacts adversely on, or increases the vulnerability of other systems, sectors or social groups' (Barnett & O'Neill, 2010, p. 211). In this frame, adaptation is considered effective if the risk of maladaptation can be avoided. Barnett and O'Neill (2010) identify different types or pathways of maladaptation: increasing GHG emissions; disproportionately burdening the most vulnerable; entering interventions with high opportunity costs; reducing incentives to adapt and creating lock-ins and path dependency that limit future choices. Juhola et al. (2016) further suggest a typology of maladaptation that is based on the *outcomes* of adaptation – rebounding vulnerability, shifting vulnerability, and eroding sustainable development. Maladaptation studies highlight that starting with *the intention to avoid mistakes* and not locking in detrimental effects of adaptation-labelled initiatives is a key step of EA (Magnan, 2016, 2020).

One of the critiques of this framing is that it assumes that adaptation actions are underway; this tends to ignore how development interventions can narrow the space to adapt, thereby leading to maladaptation in the future (Gajjar et al., 2019b). Also, given that the impacts of climate change are dynamic and may not be fully realized in the short-term, tracking adaptation and anticipating maladaptation is fraught with methodological challenges (Berrang-Ford, 2019; Ford et al., 2013). On the positive, a maladaptation framing calls for thinking of the most vulnerable and not inadvertently exacerbating/shifting their vulnerability, in the present and future (Schipper, 2020). The metrics to assess EA as avoided maladaptation remain few and untested through empirical research (Magnan et al., 2020). This remains a key knowledge gap.

3.7. Effective adaptation as ecosystem-based adaptation

Adaptation should invest in ecosystem conservation, management and restoration to enhance ecosystem services, and subsequently reduce impacts of climate change on social and ecological systems.

Ecosystem-based adaptation (EbA) highlights that human wellbeing and adaptive capacities are deeply dependent on biodiversity and functioning ecosystem services (Reid et al., 2017). EbA addresses the crucial links between climate change, biodiversity, and sustainable resource management by preserving and enhancing ecosystems and thereby enabling human systems to mitigate and adapt to climate change (Munang et al., 2013). The frame tends to focus on EA as staying with ecological limits and sustainable use of natural resources (Vignola et al., 2015).

EbA is underpinned by the assumption that ecosystem-based solutions can have co-benefits for climate change, disaster management, and sustainability (Munang et al., 2013; Scarano, 2017). However, EbA has been criticized for paying insufficient attention to issues of empowerment and agency

with limited evidence on the social benefits associated with primarily biophysical interventions (Woroniecki et al., 2019b).

The EbA literature has a rich diversity in metrics to assess adaptation outcomes ranging from quantification of ecological limits to indicator-based assessments of how adaptation strategies are benefiting/eroding ecosystem services. Doswald (2014) review how EbA assessments treat effectiveness and find that most studies use changes in ecological parameters (e.g. biomass productivity, biodiversity coverage) to assess adaptation outcomes while other metrics include cost-benefit analyses (on social, environmental, economic aspects) and the absence/presence of institutional support for EbA. There have also been international efforts to systematize EbA metrics such as the IUCN-led EbA effectiveness quality standards (IUCN, 2017) and voluntary guidelines released by the Convention on Biodiversity (CBD, 2019) and the More recently, Donatti et al. (2020) reviewed 58 EbA projects implemented globally and identified 13 adaptation outcomes and seven indicators to monitor the effectiveness of EbA in achieving adaptation outcomes.

3.8. Effective adaptation as community-based adaptation

Adaptation prioritisation, implementation, and monitoring should be co-produced with communities to ensure inclusive and sustainable adaptation.

Community-based adaptation (CbA) is a bottom-up approach that focuses on increasing the participation and agency of vulnerable communities in adaptation prioritization and implementation (Dodman & Mitlin, 2013; Faulkner et al., 2015; Reid & Huq, 2014). It views EA as a community-led process that co-produces adaptation strategies, ensures participation of multiple stakeholders, and enables devolution of decision-making authority and administrative control.

This framing challenges top-down and bottom-up binaries, arguing that co-producing adaptation solutions can facilitate more EA. In doing so, it presents an opportunity to learn from potential failures of top-down, 'one size fits all' approaches to development, as well as 'hard', impact-led approaches to adaptation (Reid & Huq, 2014). CbA explicitly focusses on mainstreaming community priorities, needs, knowledge, and capacities into adaptation thereby aiming to empower people to adapt more effectively (Kirkby et al., 2018; Reid & Huq, 2014).

The large literature on CbA covers a range of metrics to assess effectiveness with most studies converging to suggest metrics of community participation in adaptation prioritization, implementation, and monitoring and evaluation (Faulkner et al., 2015). For example, participatory vulnerability assessment tools before and after adaptation interventions are often used for evidence-based adaptation planning and tracking adaptation outcomes (D'Souza et al., 2018).

3.9. Effective adaptation as adaptive governance

Adaptation should be oriented towards achieving transparency, accountability and representation in governance through multi-scalar, participatory, and inclusive processes.

The adaptive governance frame draws from research on managing complex, dynamic social-ecological systems (Folke et al., 2005; Tompkins & Adger, 2006) to argue for institutions that are flexible and forward-looking, have the capacity to prepare for uncertainty, and explicitly address current climate change impacts, while planning for future risks. It also draws on the construct of 'good governance', which signifies transparency and accountability; participation and inclusion; and fiscal, political, and administrative decentralization. A key assumption of this framing is that unequal power structures can be balanced by greater participation and inclusion, both within and across scales and that multi-scalar governance for adaptation can be strengthened by decentralization (Ziervogel et al., 2019).

The links between governance goals and EA are most visible in the adaptive governance literature, which argues for participatory management, decentralized governance, cross-sectoral learning and implementation, open and shared information, integration between science and policy making and learning, recognition of fluid or unorganized forms of power, and integration of marginalized groups in adaptation decision-making (Pahl-wostl et al., 2007; Plummer et al., 2017; Vink et al., 2013). While policy learning is seen to be important in the multi-level governance literature, social learning is identified as critical in the adaptation literature (Gonzales-Iwanciw et al., 2020). Other aspects of governance such as political leadership, technology sharing, and funding are identified as important for effective national-level adaptation (Ford et al., 2013).

Metrics to capture adaptive governance include degree of decentralization and autonomy, transparency and accountability, responsiveness and flexibility, and participation and inclusion (Tanner et al., 2009). Further, the literature on barriers and enablers to adaptation highlights how inadequate authority and co-operation, legal barriers, and contradictory organizational missions can constrain EA (Ekstrom & Moser, 2014). There are a few monitoring and evaluation tools and frameworks which incorporate governance into their measurements, such as the Environment Friendly Local Governance Framework in Nepal, with indicators at household, community, and local government levels (Government of Nepal, 2013).

3.10. Effective adaptation as just and equitable

Adaptation should be oriented toward socially just and equitable processes and outcomes.

A justice and equity frame is a normative, people-centred approach that explicitly focusses on winners and losers from both climate change impacts and adaptation action. It frames EA as redressing imbalances in order to achieve more equitable adaptation and reduce socially unjust outcomes. It makes the case for ensuring that the most vulnerable are shielded from climate impacts and that their well-being is not compromised further through actions taken to respond to climate change (Byskov, 2021; Marino & Ribot, 2012; Schlosberg et al., 2017; Shackleton et al., 2015; Tschakert & Machado, 2012; Ziervogel, 2017). Justice and equity framings also draw attention to the asymmetries of structure and

power that shape differential vulnerability and adaptive capacity, and argue that these can ultimately undermine inclusive adaptation (Malloy & Ashcraft, 2020). The act of including or excluding knowledge from marginalized stakeholders can also mediate the effectiveness of adaptation efforts (Byskov, 2021; Morchain, 2018).

In the environmental justice literature (Bulkeley et al., 2013; Forsyth, 2014; Sikor et al., 2013; Walker, 2012), principles of social justice are commonly articulated in terms of three dimensions:

- ‘distributive justice’ – distribution of burdens and allocation of benefits across society (i.e. who suffers from climate risks, who benefits from adaptation responses?);
- ‘procedural justice’ – processes of representation and participation in decision-making (i.e. how are adaptation actions prioritized?);
- ‘recognition justice’ – who is recognized as a legitimate actor and how are their needs and interests acknowledged and included (i.e. whose concerns matter?).

The framing assumes that socially just outcomes should be a priority if adaptation is to be fair, inclusive, and sustainable, and suggests that adaptation rooted in equity and justice principles can have an ‘intrinsic’ value (a goal in itself) and an ‘instrumental’ value (in achieving wider goals) (Ziervogel, 2017).

Closely related to this framing is the focus on gender equity and empowerment as a key aspect of just adaptation (e.g. Rao, 2020; Ravera et al., 2016; Tschakert & Machado, 2012). Rooted in feminist studies and highlighting intersectional axes of inequity, a gender frame adds to an equity/justice lens by focussing on differential vulnerability and adaptive capacities of men and women.

We did not find explicit assessment metrics for this framing. Of the four dimensions of ‘successful’ adaptation discussed in Adger et al. (2005), two, ‘equity’ and ‘legitimacy’, correspond closely to this framing. Pointers toward assessment approaches and indicators may come from wider literature, especially from advances in Social Impact Assessment (SIA) methods (e.g. Esteves et al., 2012 who point toward internationally-emerging concepts within ‘human rights’, ‘free, prior and informed consent’ and ‘social performance standards’ as potential sources of assessment criteria).

3.11. Effective adaptation as transformation

Adaptation should be a process that fundamentally changes human thinking and practices in the face of climate change and overtly challenges the power structures that generate vulnerability.

The transformation framing generally assumes that climate change brings risks that are beyond society’s ability to manage through ‘business-as-usual’ (or incremental) approaches to adaptation, and that fundamental change is both feasible and desirable (Schipper et al., 2020). Transformation in relation to climate change has recently been the subject of much discussion (Hadarits et al., 2017; Mapfumo, 2017; Rippke, 2016; Vermeulen et al., 2018). Few et al. (2017) suggest this can be distilled into two main interpretations. The first, normally

referred to as ‘transformational adaptation’, argues that ‘incremental’ adaptation that seeks to modify existing human-environment relations will be insufficient for society to manage the consequences of climate change (e.g. de Coninck, 2018; Dilling et al., 2015; Kates et al., 2012; Klein et al., 2014). It argues instead that to avoid catastrophic impacts, fundamental changes in how we utilize and manage resources, where and how people live, what systemic limitations are imposed on people’s agency, and how we interact with nature are required.

The second interpretation, ‘transformative adaptation’, argues that adaptation requires, and presents an opportunity for society to fundamentally challenge and change the relations of social power and the socio-structural constraints that deepen vulnerability (Eriksen et al., 2015; Gillard et al., 2016; O’Brien, 2012; Tschakert et al., 2013) while at the same time reducing the negative consequences of climate change impacts (Few et al., 2017). The focus tends to be on vulnerability of those more marginalized from power and with least secure access to resources, and assumes that radical social changes are required if adaptation is to be effective for all. As such, transformation pursues justice through the righting of a fundamental social wrong in design as well as in action – in the shape of alternative pathways for development.

The differing conceptualizations of transformation (see e.g. Scoones et al., 2020) makes metrics difficult to develop. Further, the idea of measuring progress in transformation might be seen as contrary to the very idea of it; as transformation, while it may be clear in its intended outcomes, can often be led by exploration rather than certainty in its means. Notwithstanding, one approach is to interrogate an adaptation action and characterize different aspects of transformation in terms of mechanisms of change, target outcomes, and the object of transformation (Few et al., 2017).

Transformation can be argued to be essential and urgent in order to protect the most vulnerable, but one of the critiques of transformation as imperative is that it can fail to account for the differing priorities and needs of those already experiencing heightened vulnerability (Blythe et al., 2018; Gajjar et al., 2019a). While the transformative framing is centrally concerned with reducing marginalization and strengthening capacities of the most vulnerable, it can go both ways: the most vulnerable can arguably be most fearful of the potential instability and uncertainty associated with challenges to power structures inherent in transformation (Pelling et al., 2012).

4. Effectiveness in action: empirical examples from semi-arid regions

The eleven frames of EA distilled from the literature provide lenses to examine adaptation priorities and outcomes. Using empirical data from cases across Africa and Asia, we now ‘apply’ these framings to examine the outcomes of different adaptation interventions studied under the Adaptation at Scale in Semi-arid Regions or ASSAR project. The ASSAR project’s overarching objective was to draw on multi-scalar, interdisciplinary research to improve the understanding of the barriers, enablers and limits to effective, sustained, and widespread adaptation. Working across five years (2014–2018) in

Table 1. Assessment of select adaptation strategies in semi-arid Asia and Africa using different framings of effective adaptation.

Adaptation strategy	Description of the strategy and outcomes	How adaptation effectiveness was examined
Farm ponds for rainwater harvesting and drought-proofing in Maharashtra, India	Ahmednagar District in Maharashtra faces severe water scarcity. Increasing rainfall variability has led to water insecurity and associated impacts on agriculture and allied livelihoods. The state government is promoting farm ponds to collect and store rainwater to provide protective irrigation during periods of water scarcity. It also projects farm ponds as a way to recharge local groundwater through percolation.	<i>Sustainability, equity:</i> Primary research shows that instead of using farm ponds as water harvesting and storage structures, farmers extract groundwater and fill the ponds, exacerbating water scarcity. Thus, the farm ponds have driven more groundwater extraction and increased competition amongst farmers to further extract groundwater (Kale, 2017). Such farm ponds are also owned by richer farmers leading to equity issues and competition for water resources. <i>Maladaptation:</i> Plastic lining of the ponds has negated efforts to improve groundwater recharge through percolation making the intervention potentially maladaptive and unsustainable, especially at system scale (Kale, 2017; Thomas & Duraisamy, 2018). <i>Economic costs and benefits:</i> A cost-benefit study of farm ponds found that costs of water lost due to evaporation and opportunity costs associated with the farmland converted to farm ponds outweighed the benefits from the intervention.
Rural to urban migration in Karnataka, India	In Gulbarga and Kolar districts in Karnataka, recurrent drought and rainfall variability have made agricultural livelihoods precarious, driving out-migration to cities. This migration is often a risk reduction and risk spreading strategy driven by climatic and non-climatic risks.	<i>Wellbeing:</i> While material wellbeing of migrants increases due to migration (Michael et al., 2019; Singh et al., 2018), subjective wellbeing decreases (especially for women within migrant households) (Singh & Basu, 2020). <i>Reduced vulnerability/increased adaptive capacity:</i> Vulnerability assessments of migrants before and after moving found that while migration reduces certain agriculture-related vulnerabilities (e.g. lower dependence on a good monsoon for income) and increases adaptive capacities for some (e.g. through remittances), it can also exacerbate vulnerability (e.g. for those who enter precarious livelihoods in cities) and reduce adaptive capacity (e.g. poor social capital in new settlements in the city) (Singh & Basu, 2020). <i>Equity and justice:</i> Migration into cities also highlights how structural vulnerabilities of migrants (e.g. based on caste, religion, or gender) can follow them into the cities they migrate to, exacerbating existing inequities and vulnerabilities (Michael et al., 2019).
Drought management in Onesi constituency, northern Namibia	Namibia suffered from a devastating drought in 1992/3, after which a drought policy was developed to enable drought risk reduction and better responses during drought. The policy supports rural agricultural livelihoods by reducing the vulnerability of small-scale farmers and providing relief during drought events (Sweet, 1998).	<i>Wellbeing:</i> Drought interventions aim to address material wellbeing through access to improved information, seeds and equipment and social grants for support during drought. For many, small wellbeing improvements have occurred, but drought continues to have a negative impact of psycho-social wellbeing (Spear & Chappel, 2018; Spear et al. 2018). <i>Equity and justice:</i> Ethnic groups, as well as female- and male-headed households, within the constituency have differing experiences in benefiting from the drought policy - those who are minorities or not as well connected to traditional authorities and government agencies are less able to access drought interventions and support as easily (Spear & Chappel, 2018). <i>Transformation:</i> The drought policy has largely been implemented as a vulnerability reduction mechanism. While it aimed to transform livelihoods by reducing poverty and making household livelihoods more sustainable, it has not had this effect, but rather managed to avoid the worst deprivations of drought (Spear et al. 2018; Davies et al., 2019).
Pastoral land zonation in Kenya	In the drylands of Kenya interventions are instituting or reinstating systems of land zonation that set rules of access to pasture/water on different stretches of land, including land set aside for seasonal access and 'reserve' lands set aside for times of drought. Initiatives to support or re-establish traditional systems of communal land management have been implemented.	<i>Community-based adaptation:</i> It is argued by intervention agencies that strengthened land zonation can reduce vulnerability through better options for sustainable resource management, and enhance community-based management. <i>Equity and justice:</i> Such management systems have the potential to enable distributive (access to pasture/land), procedural (participation/decision-making) and recognition justice (pastoralists as adaptation agents). <i>Adaptive governance:</i> However, distributive/equity claims can be partly contested and effective decision-making may require regulation through cross-scalar governance support, especially under conditions of increasing water stress when tensions rise over access (Few et al., 2018; Few & Tebboth, 2018).
Harnessing agrobiodiversity in Koutiala, Mali	In Koutiala, cotton production plays a central role in rural livelihoods. Key issues in the area are difficulties in obtaining farm inputs, inadequate social safety nets, gender inequality, poverty, degraded natural resources, herder-farmer conflicts, and poorly functioning governance structures. Climate change is exacerbating these challenges, making farm households vulnerable to multiple risks.	<i>Reduced vulnerability/increased adaptive capacity:</i> Agricultural management practices that make use of biodiversity and ecosystem services have reduced farm household vulnerability. Households with a high number of agrobiodiversity-based adaptation practices were more likely to have a low vulnerability (Segnon, 2019). <i>Improved resilience:</i> Exploiting agricultural biodiversity enhanced resilience of smallholder household farm and livelihood systems to climatic and non-climatic shocks (Segnon, 2019; Segnon et al., 2020). <i>Material wellbeing:</i> Diverse farming practices improved household food security and material wellbeing (N'Danikou et al., 2017; Segnon, 2019).

The assessments of adaptation outcomes are based on empirical evidence and cite literature where the results are reported in more detail.

semi-arid regions in seven countries across Africa (Mali and Ghana in West Africa; Ethiopia and Kenya in East Africa, and Botswana and Namibia in Southern Africa) and India in South Asia, ASSAR investigated regionally-relevant, socio-ecological risks and dynamics that relate to livelihood transitions, and the access, use and management of land and water resources in water-stressed environments. By doing so, ASSAR generated stakeholder-driven knowledge on vulnerability and adaptation to climate change in semi-arid regions.

From the ASSAR project, we chose five examples of ongoing adaptation across four countries (Kenya, Namibia, Mali, India), showing different adaptation types, operational at different scales, and implemented by different actors. In India, we discuss rural-urban migration as an autonomous adaptation strategy that individuals and families are undertaking, moving from drought-prone and water-scarce rural areas in Karnataka to informal settlements in towns and cities. This case examined the outcomes of migration at intra-household and household scales, as well as broader implications on the social-ecological system families moved within. The second example from India draws on evidence of outcomes of a planned adaptation action; sub-national policy in Maharashtra that incentivises farmers to invest in rainwater harvesting structures (in this case, farm ponds); to climate-proof agrarian households from erratic rainfall.

In Namibia, we discuss state-driven drought management interventions as well as autonomous adaptation strategies (e.g. water-saving techniques, changed sowing dates) by smallholder farmers in Onesi constituency. For Kenya, we consider recent initiatives fostered by a range of organizations, including community-based civil society actors, to re-establish communal systems of pastoral land zonation in the drylands around Isiolo and neighbouring counties. The hope in these planned adaptation responses is that this will reduce current and future pressure on water and pasture resources for livestock. In Mali, we examine experiences of smallholder farmers in harnessing agrobiodiversity to prepare for and respond to drought risks and impacts in Koutiala, southwest Mali. The case examined the outcomes and implications of such autonomous adaptation strategies, on household vulnerability.

We applied the eleven frames of EA to examine adaptation outcomes in each case and highlight the key frames for each case in Table 1. This exercise showcased how, when viewed from different frames, the evaluation of adaptation progress changed. For example, farm ponds in Maharashtra, India have positive impacts when seen through an EbA frame (captured through metrics of increased rainwater harvesting and storage) but do not get assessed as effective when seen through a justice/equity frame (because of uneven access to farm pond subsidies by different farmers).

This application of the frames to empirical cases illustrates how definitions of EA and their associated metrics shape what we assess as effective and calls for using combinations of EA frames when tracking adaptation outcomes. These combinations will depend on the scale of intervention and it's intended goals but recognizing biases in certain frames can be a first step in pluralizing how we operationalize EA.

In Table 1, we detail particular frames for each case to showcase how the research team used combinations of EA

frames to construct a fuller picture of how effective each adaptation was. We find that different conceptualizations of adaptation outcomes (column 3) privilege different aspects of the outcomes of the same adaptation strategy.

For example, land and water management based adaptation interventions in Kenya have involved amendments to pastoral land zonation rules. When assessed through an equity and justice lens, these interventions can effectively enable distributive, procedural, and recognitional justice. When assessed through an adaptive governance framing, the need for cross-scalar governance support to mediate conflict over finite becomes a critical mediator of EA (Few et al., 2018; Few & Tebboth, 2018).

Another example of how different EA frames lead to varied understandings of adaptation outcomes is seen in Maharashtra, India. A scheme promoted by the subnational government for digging and lining farm ponds is aimed at incentivizing rainwater harvesting and drought-proofing smallholder agriculture. Through subsidies, farmer groups are incentivized to store rainwater runoff, thereby providing protective irrigation during dry spells, and recharging local groundwater through percolation. A purely economic assessment of adaptation effectiveness finds that farm ponds have positive net returns in terms of farmer incomes under current 50% subsidies on initial investment (Kumar et al., 2016). Net returns tended to be higher when the stored water was used for high value crops. However, when seen from a sustainable adaptation frame, which highlights system-level trade-offs, it was seen that farmers tended to use the farm ponds to extract groundwater and fill the ponds, exacerbating water extraction. While this higher groundwater use is linked to water-intensive agriculture and higher incomes, overall, it led to competitive groundwater extraction, exacerbating water scarcity (Kale, 2017; Thomas & Duraisamy, 2018).

Overall, applying the eleven frames of adaptation effectiveness to the empirical evidence demonstrates that different entry points to assessing effectiveness can capture certain aspects of effectiveness and a combination of different framings can help conduct more holistic analyses of monitoring and enabling effective adaptation that is sustainable and inclusive.

5. Principles for effective adaptation: a tentative way forward

In this paper, we review the adaptation literature and identify eleven frames used to conceptualize EA (Figure 1 and Table 2). Table 2 synthesizes eleven principles of effective adaptation based on these frames, suggesting them not as a longlist of essential targets to meet but as different considerations to reflect on when designing new adaptation interventions and developing metrics to track adaptation progress. These eleven frames of EA are put forth as a contribution to the growing 'adaptation science' literature (Nalau & Verrall, 2021; Preston et al., 2013; Vincent et al., 2021) that is critically examining how heuristics and metrics used to conceptualize and measure adaptation effectiveness have real-world implications on adaptation outcomes (e.g. Eriksen et al., 2021). We argue that different principles, rooted in specific epistemologies and

methodologies to assess EA, privilege certain aspects of adaptation while potentially leaving out others.

The EA frames discussed in this review range from being normative (e.g. a wellbeing frame, which aspires to adaptation that improves material, subjective, and relational human wellbeing) to more process-based (e.g. CbA which might have normative goals of inclusion and empowerment but focusses on procedural change, here, community participation, as a vehicle to do so). Notably, the frames fall along a continuum and frames can simultaneously be process- and outcome-based. For example, the maladaptation frame aims to pre-empt undesirable and unintended adaptation outcomes while also paying attention to the trade-offs at different spatial and temporal scales during and after the intervention.

Critically, the differences between frames mean that they are informed by different underlying assumptions, thereby lending themselves to different metrics of assessing progress. Thus, an EbA frame centralizes the importance of restoring ecosystems to achieve EA, operates at landscape or watershed scales, and uses metrics such as green cover, water availability, or health of particular ecosystem services. The assumptions and biases underpinning particular frames become most noticeable when examining the metrics used to assess adaptation outcomes. As an illustration, efficiency and wellbeing framings assess adaptation outcomes by asking, ‘do costs of the adaptation strategy outweigh its benefits’ or ‘does the intervention increase multi-dimensional wellbeing’? In contrast, the transformational adaptation and equity framings focus on *processes and pathways* of change and adaptation action, explicitly asking ‘who wins or loses in a particular pathway’, seeking to address vulnerability beyond the realm of climate impacts alone.

As expected, there are overlaps between frames: e.g. the EA as transformation frame draws on ideas of sustainability and equity while both the adaptive governance and CbA frames have participation and decentralization as foundational tenets. In our view, these overlaps signal how different disciplinary

and normative entry points converge on similar conceptualizations of EA. Further, these overlaps reinforce that different combinations of the eleven principles can cover different facets of adaptation outcomes and it is not necessary to adhere to each one individually to assess adaptation effectiveness. Operationally, it is important to understand gaps and strengths of each principle and supplement it with others to have robust metrics to assess effectiveness.

This paper unpacks these frames and their implications for EA, in a bid to motivate adaptation researchers and practitioners to consider the pros and cons of a particular lens before applying it. As we show through empirical examples from Kenya, Mali, Namibia, and India (Table 1), assessing EA through a particular frame leads to variable evidence on adaptation outcomes. Operationally, what this suggests is that choosing one frame over another can privilege or silence certain types of outcomes, with direct implications on tracking adaptation progress and building adaptive capacities of the most vulnerable. Furthermore, how EA is framed will significantly impact adaptation implementation and outcomes. Thus, we argue that the selection of a frame or frames to inform the implementation and evaluation of EA should rightly be understood as a wielding of power (Gear & Dehm, 2020).

Clearly, adherence to all eleven principles of effective adaptation may not be feasible or even desirable. Because they reflect different prioritizations and approaches, inherent trade-offs exist between many of them (e.g. maximizing economic benefits might not necessarily meet social or ecological goals of sustainable adaptation). However, we argue that the discomfort these trade-offs highlight is crucial for the adaptation community to acknowledge and in fact, these trade-offs are only rendered visible when we look across the eleven principles and consider their implications. This would enable explorations, in ways more pragmatic than conceptual, of, for instance, the focus, conflicts, and outcomes of CbA versus EbA.

Indeed, the delineation of eleven principles of effective adaptation is not meant as an academic exercise alone. In practice, recognizing the strengths and blind spots of each frame could mean funders and implementing agencies use *combinations of frames* when tracking adaptation progress. For example, when assessing adaptation outcomes, supplementing a cost-benefit analysis (underpinned by a utilitarian frame) with tracking equity outcomes of an intervention over time (equity/justice frame) can provide a more complete picture of adaptation progress (as shown in the Maharashtra example in Table 1). Another example can be complementing an EbA approach, which focusses on measuring benefits to ecosystem services, with a maladaptation framing that also considers adaptation outcomes over space and time, and for different user groups.

The list of principles is thus presented as a way to acknowledge that different frames use different entry points and metrics to operationalize effectiveness and how choosing certain frames for defining and tracking adaptation outcomes can lead to different results. As critical engagement with adaptation effectiveness increases, we believe that this identification of different frames and their associated principles can both inform and pluralize guidance in international processes such as the 2021–2023 Global Stocktake as well as national

Table 2. Eleven principles for effective adaptation.

Adaptation should

- (1) minimize costs, and maximize benefits
- (2) support achievement of material, subjective, and relational wellbeing goals
- (3) reduce vulnerability and/or increase adaptive capacity, especially of the most vulnerable and those most at risk to climate change
- (4) increase resilience by building functional persistence over long timescales so that systems have the ability to bounce back from climatic shocks
- (5) be economically, ecologically, and socially sustainable, explicitly looking at longer-term, cross-generational viability of adaptation actions
- (6) take into account unintended negative consequences and explicitly look at the cross-scalar, long-term impacts of adaptation actions
- (7) invest in ecosystem conservation, management and restoration to enhance ecosystem services, and hence reduce impacts of climate change on human systems
- (8) be co-produced with communities to ensure inclusive and sustainable adaptation
- (9) be oriented towards achieving transparency, accountability and representation in governance through multi-scalar, participatory, and inclusive processes
- (10) be oriented toward socially just and equitable processes and outcomes
- (11) be a process that fundamentally changes human thinking and practices in the face of climate change and overtly challenge the power structures that generate vulnerability to its impacts

and sub-national exercises on tracking and monitoring adaptation progress.

In conclusion, we present the eleven principles to the adaptation community as a way to open up the conversation on adaptation effectiveness metrics, complement existing exercises that summarize ways to assess effectiveness, and illuminate frames that need more operationalization (e.g. maladaptation and transformation pathways).

Notes

1. Preston et al. (2013, p. 470) define heuristics as 'a common sense, rule of thumb guiding the conceptual framing of adaptation, the prioritization of adaptation policies and measures, and/or the pathways by which they are implemented'.
2. Effective adaptation as efficient; as enhanced resilience; as reduced vulnerability and enhanced adaptive capacity; as good governance; as just and equitable action; as sustainable; as avoided maladaptation.
3. There remain caveats to the choice of the eleven principles. Our approach was an iterative process of reviewing the literature, combining or separating emerging themes, and testing them against empirical evidence. The list is in no way exhaustive and we acknowledge that others might arrange the principles in a different way, dividing some and combining others.
4. Conceptually, vulnerability has evolved from having two dimensions (an external dimension – exposure – which includes risks, shocks, and stress; and an internal dimension – adaptive capacity – which refers to lack of means to cope without damaging loss (Robert, 1989)), to the IPCC's Fourth Assessment Report framing of vulnerability as a function of exposure (the character, magnitude, and rate of change and variation in the climate), its sensitivity (determined by the natural and/or physical environment), and its adaptive capacity (the ability of a system to adjust to, take advantage of opportunities, or to cope with the consequences of climate change, climate variability and extremes) (IPCC, 2007). More recently, a risk-based framing has gained prominence with vulnerability conceptualised as one of three components of risk, which is defined as the potential for consequences (i.e. impacts) where something of value is at stake and where the outcome is uncertain (IPCC, 2014).
5. A full discussion on the differences between vulnerability and resilience framings is beyond the scope of this paper but those interested can read (Gallopín, 2006; Cannon & Müller-Mahn, 2010; Miller, 2010; Béné et al., 2012).
6. Sustainable adaptation has been defined as 'measures that reduce vulnerability and promote long-term resilience in a changing climate' (Leichenko and O'Brien, 2008, p. 31) and focuses on addressing vulnerability and poverty (Taylor, 2013) as well as meeting goals of social justice (Santhia et al., 2018).

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